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ABOUT THE JOURNAL

The *Journal of Engineering, Science and Sustainability* is an official refereed publication of [Glocal University](#) and the publishing services are provided by Sprin Publisher. The journal is an international, open-access, bi-annual, peer-reviewed journal that publishes original research articles, reviews, communications, perspectives and case reports. Submissions are solicited in all topical areas ranging from engineering and technology to science and sustainability practices.

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Aims and Objectives

The journal aims to serve as a premier platform for the dissemination of innovative research and advancements in the fields of engineering, science, and sustainability. It strives to bridge the gap between scientific inquiry and practical application, fostering technological progress and sustainable development. The journal is committed to publishing high-quality, peer-reviewed articles that advance knowledge and understanding in these domains.

Focus and Scope

The Journal invites original manuscripts in fields covering the aspects, but not limited to: Engineered and nanomaterials, Composite materials, Environmental Engineering, Biomaterials, Pollution, environmental issues, geo-environmental hazards, Carbon capture, Water splitting, Waste management, Renewable energy sources, Energy efficiency, catalysis, Energy storage, Applied science, Biomass Conversion, Desalination, Applied Chemistry, Bioenergy, Biocomposites, Circularity, Sustainable practices in Agriculture and pharmaceuticals, Biofertilizers, Biomaterials, Functional biopolymers, Natural Products, Biomass valorisation, AI, intelligent sensing, IoT, big data analysis for sustainable development.

The journal encourages submissions that support one or more of the 17 United Nation's sustainable developmental goals ([SDGs](#)).

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EDITORIAL



The journal aims to provide a meaningful platform for researchers, academicians, scientists, and professionals to disseminate innovative research and exchange ideas addressing contemporary scientific and technological challenges. In particular, JESS seeks to encourage research that contributes to sustainable development and supports the broader objectives of the Sustainable Development Goals (SDGs).

It gives me immense pleasure to present Volume 2, Issue 1 (January–June 2026) of the Journal of Engineering, Science and Sustainability (JESS), the official peer-reviewed journal of Glocal University. This issue brings together five scholarly contributions, including research articles, a review article, and perspective papers covering diverse and emerging areas such as natural products and drug discovery, artificial intelligence and labour governance, healthcare, Ayurveda, biostatistics, and the Indian Knowledge System.

The contributions reflect the interdisciplinary vision of JESS and emphasize the importance of innovative research, technological advancement, sustainable development, and the integration of diverse knowledge systems to address contemporary societal challenges.

I sincerely thank all the authors, reviewers, Editorial Board members, and the editorial and technical teams for their valuable contributions and continued support. I also express my gratitude to the leadership of Glocal University for their encouragement in strengthening JESS as a platform for quality research and scholarly communication. I hope this issue will inspire further research, collaboration, innovation, and meaningful scientific discussion.

Dr. Mohd Yusuf
Editor-in-Chief

Journal of Engineering, Science and Sustainability (JESS)
Associate Professor & Dean, School of Science
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Research Article

AI-Driven Labour Governance: A Comparative Study of China's Intelligent Workforce Management Systems and Their Adaptability to India's Labour Ecosystem

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ABSTRACT

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The past few years have seen the emergence of Artificial Intelligence (AI) that is redefining the systems of governance and industrial management in the global arena. China is one of the top economies that have achieved a great deal by introducing AI technologies in its workforce management and labour administration. Smart factory monitoring, AI-controlled compliance monitoring, algorithmic worker management of gig workers, and predictive occupational safety systems are AI-based systems that the country has implemented to enhance productivity in addition to strengthening regulatory measures. India, on the other hand, has implemented significant actions on legislations by enacting the four Labour Codes that are intended to streamline labour laws and enhance social security as well as employee welfare. Nonetheless, issues like high levels of informal workforce, absence of actual-time monitoring of compliance, wage anomalies and inefficiency in enforcing labour laws still impact the success of labour governance. This research paper also tries to explore how the AI-based labour management technologies that have been applied in China can provide informative experiences in enhancing the labour system in India. The paper draws a comparative study of technological structures, system of governance and labour welfare in the two nations. In the Indian context, it also looks at the viability of deploying AI-based compliance solutions, electronic wage monitoring solutions, biometric labor registries, and intelligent safety monitoring systems. The report also discusses potential problems like policy alignment, infrastructural readiness, ethical concerns, and data privacy. Additionally, the report will contribute to ongoing discussions about modernising the labour administration in India by providing an integrated framework of technology and policy that is founded on the ethical and inclusive application of artificial intelligence.

1. Introduction

Artificial intelligence (AI) has become increasingly significant in the world in terms of revolutionising processes and governance in industries in the last decade. To gain more productive human labor, tighten the belt in regulation, and become more efficient in administration, governments and companies are relying more and more on intelligent technologies. To enhance the effectiveness of administration and strengthen the control of the state regarding regulatory abilities and the control of governance, China has strategically implemented AI in its expanded digital governance framework [1]. The country in the leading role in this change, China, has expressed an especially prolific and systematic adoption of AI in labour management and labour governance [1]. The approach of China is not only about the automatization of factories. The country has been spending heavily on the implementation of an intelligent society by embracing AI across the industry, the digital space, and the state apparatus, with national AI programs and innovation policies run by the state [2].

Artificial intelligence (AI) has been introduced in the country in various aspects of the labour ecosystem, including predictive occupational health regulation, automated scheduling of gig workers, real-time monitoring of worker performance, automated compliance checks, and intelligent oversight of manufacturing. Its expansion is further facilitated by regulatory frameworks that regulate algorithmic systems, including legally binding rules of algorithm recommendation and platform management that has effects on digital labour and work allocation systems [2]. The emergence of AI has already begun altering the labour relation in China by promoting greater flexibility in labour structure, formalisation processes and altering employer-employee relations as well as administrative efficiency [3]. The development of AI in China has already made a significant contribution to the structure of the labor market in the country, generating new technology-intensive jobs and reshaping the skills demanded by the industries, simultaneously with the governance change in the country [4]. An intelligent workforce ecosystem based on competencies is on the rise, indicated by the analysis of the labour

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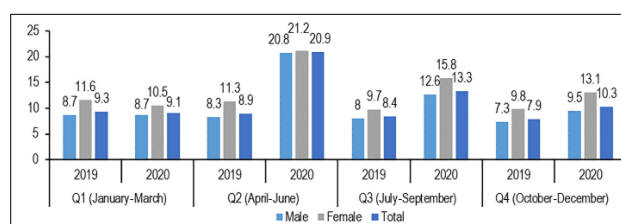
market, which revealed that the demand in automation supervisors, data engineers, algorithm designers, and AI experts is growing [4].

The labour governance system in India on the contrary is in a transitional process. One of the most significant legislative reforms that seeks to expand the social security coverage, simplify the compliance and improve employee welfare is the consolidation of the labour laws into the four Labour Codes. But the efficacy of implementation remains limited by structural problems. It is also difficult to enroll, organise and offer benefits since a large portion of the Indian labour remains unorganised. In every industry, such issues as delayed salaries, obscured working histories, substandard inspection protocols and occupational safety loopholes still persist. Extensive studies on employment highlight that the demand of professional jobs that combine AI is increasing exponentially and this implies that the adoption of technology is restructuring occupational specialisation in addition to eliminating labour [5]. These structural problems indicate that even legislative reform was not sufficient on its own unless it was accompanied by the modernisation of technology. Digital technologies and AI-based governance platforms can enhance transparency, seal the gaps in enforcement and speed up the process of labour administration in a country as big and diverse as India. The traditional labour unions in India have been historically targeted at employees who work in the formal sector, and that leaves the large informal workforce of the country to be left unorganized through voluntary organizations and fragmented systems of representation [6]. Thus, this study investigates the potential for learning from China's AI-enabled labour governance paradigm. It examines how the alterations to the Indian labour administration system could be affected by using AI-based workplace safety monitoring, gig-worker algorithmic management systems, digital wage monitoring systems, biometric labour databases, and intelligent compliance systems. India has a large portion of labour that is yet to be organised, making it difficult to register, manage and offer benefits [6]. Historically, the two basic objectives of Indian labour law have been the protection of workers and industrial peace, which are the factors contributing to the normative foundation of labour government [7]. However, it is not an easy task to imitate technology. The changes in the political regimes, laws, labour market forms, and data regulations require contextual adaptation. Consequently, besides analyzing the technological feasibility, the paper also examines ethical, legal, and the infrastructural implications, including worker privacy, accountability of the algorithm, digital divide, and institutional readiness. But the relationship between labour restructuring and technological innovation is not recent; the industrial transformation has long been known to modify the workplace organization, skill needs and the employment arrangements [8].

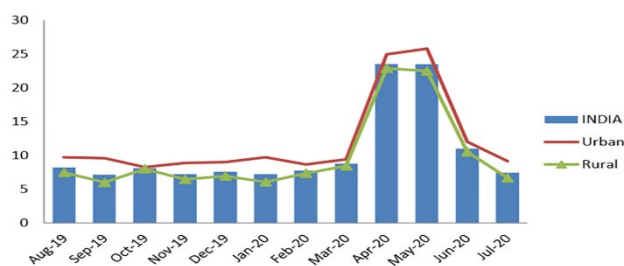
The purpose of this paper is to propose an integrated roadmap of technology-policy in modernisation of the labour regulation based on the experience of China and tracing the potential application to the Indian context. The general aim is to understand how in the evolving labour markets such as India, responsible use of AI could lead to better protections of workers, improved compliance, and inclusion in economic growth. Some of the Indian labour laws that significantly influence the HR practices in the IT sector include the Factories Act, Equal Remuneration Act, Trade Unions Act, the Apprentices Act and Workers Compensation frameworks among others. Such regulations foster

ethical employment systems and ensure that technology firms abide by statutory requirements in regulation of pay, working conditions, skill building and worker protection. [9]. One notable regulatory reform that will facilitate the simplification of compliance and further economic growth is the recent consolidation of labour laws into four labour codes. Critical assessments, however, note that such reforms have weakened the collective bargaining structures, enhanced the labour market by making it more flexible via indirect policy making, and maintained the poor coverage of the big unorganised sector. [10]. The migrant labourers are one of the most vulnerable in the Indian labour market. Systematic evidence confirms that a large proportion of migrant workers work in the unorganised sector with no legal contracts, no social security benefits, and no occupational safety protection. Their highly hazardous working conditions that are characterized by lengthy working hours, low wages and unpredictable living conditions widen socioeconomic imbalances [11]. [12]. It is impossible to comprehend India's changing labour arrangements without looking at the overall course of economic reforms. India's shift from a protectionist to a market-oriented growth model after economic liberalisation in 1991 sped up industrial expansion, private sector involvement, and job diversification. [12]. India's economy has gone through several structural changes over the years, including colonial deindustrialisation, centralised planning after independence, and liberalization-driven growth following 1991. These changes have been crucial in rethinking industrial productivity, workforce mobility, and labour relations. The dynamics of the labour market were drastically changed by India's post-liberalization economic restructuring. Employment trends and skill requirements across industries were altered by the transition from centralised economic planning to liberalised industrial growth, which promoted globalisation, privatisation, and sectoral diversification. [12]. In India, migrant workers continue to be one of the most vulnerable labour groups, frequently lacking official contracts, social insurance, and occupational protections. In addition, regional studies from rural states like Bihar show that informal migratory systems lack standardised worker rights, pressures from unemployment, and livelihood insecurity.[11] [13]. India's labour market is changing as a result of automation and artificial intelligence, which are altering job patterns, industrial processes, and workforce skill requirements. Adoption of AI increases productivity, but it also poses issues with job displacement, skill mismatch, and growing income disparity across industries. Research indicates that labour informality may worsen as a result of automation-driven restructuring, especially for contract and low-skilled workers. [14] India's shift is still hampered by structural skill shortages, differences in digital infrastructure, and issues with workforce informality, in contrast to China's state-driven AI labour integration. These difficulties are especially acute in the unorganised sector, where institutional protections are frequently unavailable and labour rules are seldom strictly enforced. Limited legal awareness and inadequate grievance redressal systems further intensify labour exploitation, especially among marginalized female workers. [15] Emerging AI-enabled monitoring, compliance tracking, and grievance reporting systems hold the potential to strengthen workplace safety and legal protection for women workers. According to the report of CMIE (Centre for Monitoring Indian Economy), there is confirmation of unemployment rate in. The country went into lockdown in March 2020, and India increased its percentage to

29%. The picture shall be evident as shown in the number presented below (see Figure 1): Choudhary (2020) affirms urban unemployment rate to 30.9 percent compared to, an ADB-ILO. The prognosis of unemployment by report shows that 6.1 million young Indians (1524 years old) can lose workplaces. despite the possibility of having the virus contained by September 20 ("6.1 million youth may lose..." , 2020) The rate of unemployment in the urban areas increased to 20.9 percent in the fourth quarter of April June 2020 [29]. Compared to the same quarter of the year before (8.9) more than twice as high. represented in figure below (see Figure 2): In everything that was said above, unemployment rate refers to the percentage of the number of unemployed people in the labor force. labor force is considered persons that are employed or unemployed but. seeking work. Concerning the employment generation availability in the disorganized industry in terms of data. rural and urban, as the representative of the ministry presented evidence in the following:



Source(S): Center for Monitoring Indian Economy Pvt.Ltd



Source(S): Quarterly Periodic labour Force Survey report, Ministry of Statistics and Program Implementation;PRS

2. Current Aspects

The nexus of artificial intelligence (AI), labour governance, and socioeconomic development is a significant field of research, both in the context of the global world and the Indian one. The already published literature depicts the compound impact of AI on regulatory systems, labor markets, work policies, and governance systems. For the analyzer Jinghan Zeng [1], in his study about AI and its application within the authoritarian regime in China, the concept of digital technologies and, in particular, AI-based ones is presented as the instrument of administration as well as the source of the state power. The paper highlights that AI consolidates political legitimacy at the same time by promoting social stability and economic development as well as enhancing governance capacity, enhancing surveillance, and enhancing service delivery to people. In regard to this view, Xu et al. [2] examine how AI redefines employment structures via regional cultural intermediaries. Their results indicate that AI hastens the processes of flexibilisation of labour, legal formalisation, and de-collectivisation especially in areas where future orientation and gender equality are high. This shows that the labour effect of AI is culture-specific. Pitukhina et al. [3] continue the global competition narrative by comparing the Chinese and the United States AI labour market ecosystem. Their industry reveals the changes in the demand of the skills, the new jobs of AI and the

models of competence that are needed in the industry 5.0 changes. The article highlights the role of national AI policies, talent markets, and research in the response to dominance of the labour markets. In line with this, Liu, Chen & Lyu [4] investigate the interdisciplinary labour market growth with the help of large-scale job-posting analytics. Their study indicates that the number of AI-infused jobs is growing exponentially and that conventional fields, in particular, statistics, are not disappearing. And this proves the point that AI complements human experience rather than completely displacing it. Whereas global literature points to the issue of technological change, Indian labour scholarship points to the issues of structural vulnerability. According to Sinha [5], most members of the Indian workforce work in the informal sector, which is mostly not unionized. This disintegration undermines the collective bargaining and restricts the institutional protection of labour. Indian labour law is also critically evaluated by Mitchell, Mahy and Gahan [6] to assert that formal legal systems usually do not attain their two-fold aim; labour protection and industrial harmony. The disjuncture between the design and the implementation of the law continues to be a challenge of governance.

Previous studies on technological disruption like Hunter, Reid and Boddy [7] offer some initial form of knowledge on the subject of employment displacement, industrial restructuring, and realignment of skills due to automation. Their steel, chemical, and printing foreshadowing of labor transitions are part of the current AI-driven change in the industry level. Kamble and Misal [8] discuss the labour regulations in the Indian IT industry and focus on sector-specific compliance issues. Their excerpt shows how the current tools of legislation such as wage acts, compensation arrangements, and union stipulations are trying to ensure the ethical ways of employment in the high-technology fields. Mishra and Dwivedi [9] make a critical evaluation of the recent labour code reforms claiming that the 2020 labour codes in India make the labour market more flexible at the expense of the union bargaining power and leaving out informal workers. Their discussion also puts labour reform into the perspective of flexibilisation by stealth. Migration brings an extra layer of vulnerability. Sharma and Pal demonstrate that migrant labourers are exposed to hazardous working environment, social security is deprived, and they are still concentrated in informal jobs [10].

Kumar research group [11] gives poor housing, health risks and contractual insecurity as increasing labour precarity, but the macro-economic context is also supplied by Grugulis in his work, where he locates labour transformation in the growth path of post-liberalisation India. Structural labour change in the form of economic reforms, globalisation and privatisation both amplify the pressures of unemployment and inequality, and have been suggested further by Mohan and Kumar [12] as a source of regional migration distress, especially in agrarian economies such as Bihar. They attribute unemployment, reverse migration, and lack of labour standards to systemic governance failure in the unorganised sector through their findings. Behera and Nigam [13] directly refer to AI-specific disruption of labour in India. According to their analysis, job displacement, skill matches, and income inequality are all major AI externalities as the researchers propose modifications in education, infrastructure, and reskilling of the workforce. Gendered labour vulnerability is considered by Paradesi [14], who concentrates on female workers in informal sectors. The study suggests wage discrimination, harassment in

the workplace, and ignorance of the law, and offers AI-based surveillance and legal-assistance systems to protect the customer.

2.1 Evolution of Labour Laws and Regulatory Frameworks

Labour regulation in the past has been based on labour law as the main regulating tool, protecting the rights of employees. Since the colonial systems of labour control up to the present. Mishra and Dwivedi [10] provide an elaborate introduction of modern labour codes in 2020. historical analysis of the labour laws in India. The study they conducted argues that recent labour reforms have enhanced labour market flexibility, they have decreased trade union supremacy too, and collective bargaining power. The applicability of important Indian labour legislation, such as the It industry is also subject to the Factories Act, Equal remuneration act and Trade Unions Act. examined by Kamble and Misal [9]. Their writing underlines the need to comply with the rules of labour, protects employees against unfair labor conditions and promotes ethical workforce, management. All these studies lead to a single conclusion that the labour regulation in India is going through, structural transition, the trade-off between economic and worker protection.

2.2 Labour Market Transformation in the Context of Economic Development

Labour systems are significantly influenced by the macroeconomic climate in general. Kumar [12] goes through the changes in the Indian economic structure during the colonial period, and during the reforms undertaken after liberation. The report claims that post 1991 economic liberalisation has accelerated globalisation integration, industrial development and workforce diversification, but has also augmented unemployment rates, inequality as well as utilizing the informal work.

2.3 Migration and Informal Labour Vulnerabilities

Migration is one of the most significant elements of labour transition in India. Sharma and Pal [11] have conducted an in-depth analysis of the migrant labour conditions and unveil terrifying gaps in living standards, employment agreements, working conditions safety and social policy. Based on their findings, most migrant workers are in the unorganised sectors characterised by hazardous working conditions and volatile economies, as Mohan and Kumar [13] explore the agricultural migration in the state of Bihar. All these studies, when combined, point to the fact that crises such as COVID-19 increased the risk of livelihood instability and reverse migration; when combined with systemic labour vulnerabilities, technological disruption, such as AI automation, may contribute to the risk.

2.4 Automation and Artificial Intelligence in Labour Markets

The rapid adoption of the automation and artificial intelligence technology is causing global employment trends to change. Behera and Nigam [14] identify several key disruptions in their examination of the impact of AI on the Indian labour market that include loss of jobs, skillset failures, and increasing income disparity. The report does note, however, also the new opportunities of workers with AI-related skills, meaning that technology change is disruptive and creative. Theoretically, the technology change of labour restructuring justifies the flexibility of policy frameworks because of the larger research on automation, productivity, and workforce reskilling.

2.5 Gender Dimensions and Women Workers' Protection

There is no gender-neutral relationship between AI and labour. Paradesi [15] considers the safeguards guaranteed to female workers by labour laws particularly in the unorganised sector where most of the job insecurity, work harassment and wage disparities continue to occur. Another key aspect of the study is the fact that gender discrimination is aggravated by the laxity in the enforcement of labour laws, which were the potential means to improve monitoring of worker rights abuse in workplaces, improving grievance mechanisms, and improving institutional responsibility towards the female workers.

3. Research Methodology

3.1 Research Design

The study uses a qualitative doctrinal and analytical research design that is supplemented with the use of secondary data. The aim further is to explore interaction of artificial intelligence, labour governance, and job transformation, and more so in the socioeconomic condition of India. Besides being explanatory, the study is also exploratory. It reviews the emerging AI-based labour relations and argues about their impact on work relations, law and labour relations, labour rights, and governance.

3.2 Nature and Sources of Data

The study is based entirely on secondary data sources, which include:

- Peer-reviewed journal articles
- Labour law reports
- AI governance studies
- Employment and migration research papers
- Economic policy literature
- Institutional and international labour analyses

Key thematic data areas extracted include:

- AI adoption in governance and labour systems
- Labour law evolution and reforms
- Informal sector vulnerabilities
- Migration and workforce precarity
- Gendered labour challenges
- Skill transformation and employment restructuring

Although conceptual insights from global institutional reports were reviewed to understand macro labour-AI trends, formal citation inclusion is limited to the selected scholarly references [1]– [15].

3.3 Research Approach

The paper is themed analytically, which is organized in five dimensions of analysis:

1. **AI and Governance Systems**
Examining how AI strengthens administrative-surveillance, and policy functions.
2. **AI and Labour Market Transformation**
Analysing employment restructuring-skill demand, and occupational shifts.
3. **Legal and Regulatory Frameworks**
Evaluating labour laws- labour codes, and compliance systems.
4. **Informal and Migrant Labour Vulnerabilities**
Studying socio-economic precarity and protection gaps.
5. **Gender and Inclusion Dimensions**
Assessing AI's role in safeguarding women workers and vulnerable groups.

3.4 Analytical Framework

The study constructs an AI-Labour Governance Analytical Framework, which incorporates three layers of structure:

Layer	Focus Area	Analytical Objective
Technological Layer	AI, Automation, Digital Platforms	Assess labour disruption & augmentation
Institutional Layer	Labour Laws, Codes, Governance	Examine regulatory readiness
Socio-Economic Layer	Informality, Migration, Gender	Identify vulnerability exposure

3.5 Methods of Analysis

The following qualitative analytical methods are applied:

- **Comparative Analysis:-** Comparing global AI labour impacts with Indian labour realities.
- **Doctrinal Legal Analysis:-** Examining labour legislations, reforms, and compliance structures.
- **Thematic Content Analysis:-** Extracting recurring patterns across literature.
- **Policy Gap Analysis:-** Identifying mismatches between AI deployment and labour protection mechanisms.

3.6 Scope of the Study

The study focuses on:

- AI impact on labour markets
- Indian labour law and governance systems
- Informal and migrant workforce challenges
- Gendered labour protection
- Skill and employment restructuring

3.7 Limitations of the Study

1. The study relies on secondary data; no primary field surveys were conducted.
2. Rapid AI evolution may outpace current regulatory analysis.
3. Informal sector data availability remains structurally limited.
4. Quantitative employment projections vary across sources.

4. Results and Findings

Artificial Intelligence (AI) is profoundly changing labour governance, employment structures, legal systems, and socioeconomic labour realities, according to a study of the chosen literature and policy studies. Below is a thematic presentation of the findings.

4.1 Expansion of AI-Driven Governance and Regulatory Systems

The results show that governments are using AI more and more to improve service delivery, surveillance, administrative effectiveness, and policy enforcement. China's governance model shows how artificial intelligence (AI) is incorporated into state administrative systems to improve digital surveillance, ideological legitimacy, and governance procedures. Deploying AI helps optimise centralised governance in addition to increasing economic productivity [1]. Algorithm governance frameworks, including algorithm recommendation legislation, are being

institutionalised to regulate digital platforms, labour allocation systems, and content ecosystems, according to additional regulatory evidence [2]. Among the world's first national-level AI regulatory experiments are these frameworks.

4.2 AI Labour Market Expansion and Skill Restructuring

Analysis of labour markets shows that AI-related job ecosystems are expanding quickly. Research on AI labour markets reveals:

Growth in jobs for AI specialists

- The introduction of fresh competency models
- An increase in the need for AI skills and research output [4]

The demand for AI-related skills is also growing exponentially, according to statistical labour market data, and work responsibilities are becoming more diverse across transdisciplinary fields [5].

4.4 Technological Disruption and Employment Displacement Risks

Technological change has historically resulted in pressures for worker displacement even in the face of employment creation. Industrial innovation changes workplace organization, labour distribution, and employment arrangements, according to traditional technological labour research [8].

4.5 Legal and Regulatory Labour Governance Challenges

There are structural gaps between legal adaptation and technological progress, according to labour law study. Research on the development of Indian labour legislation emphasises:

- Research on the development of Indian labour legislation emphasises:
- Limited ability to enforce
 - A fragmented implementation of regulations
 - Poor protection results [7]

In addition to increasing labour market flexibility and modernising labour governance, recent labour code modifications have occasionally reduced collective bargaining strength [10].

Analyses of sector-specific compliance, especially in the IT sector, demonstrate that new digital workplace models are difficult for current labour laws to handle [9].

4.6 Informal Labour and Migrant Workforce Vulnerabilities

India's labour market is still mostly unorganised, which asymmetrically shapes the influence of AI.

According to research on labour representation, informal workers are under-represented because unions mostly function in the formal sector [6].

Comprehensive analyses of migrant labour show:

- Dangerous working conditions
- No insurance or contracts
- Substandard living circumstances
- Social Security is nonexistent [11].

Studies on migration also draw attention to regulatory protection deficiencies, especially in the unorganised and agricultural sectors [13].

4.7 Gendered Labour Implications and AI Protection Mechanisms

The following structural Women workers are impacted by the following structural labor weaknesses:

- Wage inequality
- Workplace harassment
- Informal employment concentration [15]

AI technologies are being explored for:

- Workplace monitoring
- Rights awareness systems
- Legal reporting platforms
- Gender-sensitive compliance tracking

4.8 Macro-Economic Context of Labour Transformation

India's broader economic transition from colonial extraction to liberalized growth has an impact on the reorganization of the labor market [12]. Globalization, privatization, and economic liberalization have: Increased labour flexibility

- Expanded informalization
- Accelerated technological adoption

Overall Synthesised Findings

Dimension	Observed Impact of AI
Governance	Digital surveillance, algorithm regulation
Labour Relations	Flexible, contractual employment
Employment	New jobs + skill polarization
Legal Systems	Regulatory lag
Informal Sector	Exclusion and vulnerability
Migration	Protection deficits
Gender Labour	Potential AI protection use
Economy	Tech-driven structural transition

5. Discussion

The discussion section interprets the results within the context of labour economics, the theory of governance, and technological progress, as well as the feasibility of the policy, namely, comparing the structural labour realities in India with the AI-enabled labour governance in China.

5.1 AI as a Tool of Labour Governance Transformation

The results show that AI is an institutional governance mechanism as well as a tool for industrial productivity. AI integration in administrative systems in China is a reflection of a state-centric digital governance architecture that incorporates workforce analytics, compliance monitoring, and labour regulation.

This governance digitization enables:

- Real-time labour surveillance
- Automated compliance verification
- Platform worker monitoring
- Predictive industrial risk assessment

These advancements show how AI improves the ability to enforce regulations, which has historically been a weak point in labour-intensive economies. On the other hand, manual

inspection methods, disjointed databases, and delayed reporting procedures are major components of India's labour governance. Even well-crafted labour regulations lose some of their impact due to this administrative delay.

5.2 Structural Shift in Labour Relations

One of the most significant changes brought about by AI is the move from collectivised labour systems to customised contractual employment arrangements. China's digital contract systems, gig-platform management, and algorithmic workforce allocation show how AI reorganises labour relations in the following ways:

- Task-based employment
- Performance surveillance
- Automated wage calculation
- Platform-mediated dispute systems

This diminishes traditional unionisation institutions while also increasing efficiency and labour market flexibility.

India faces a dual challenge:

1. Managing informal collectivized labour (construction, agriculture, migration sectors)
2. Regulating emerging gig and platform workforces

5.3 Skill Polarization and Employment Redistribution

The results show that rather than destroying jobs entirely, AI causes employment polarisation. High-skilled industries gain from:

- AI engineering roles
- Data science employment
- Automation supervision jobs
- Compliance analytics positions

However, low-skill workers face:

- Job displacement
- Wage stagnation
- Automation substitution risks

China mitigates this through state-led skilling ecosystems aligned with its AI industrial policy frameworks.

India, despite initiatives like Skill India, still struggles with:

- Training infrastructure gaps
- Rural digital illiteracy
- Industry-academia mismatch

5.4 Legal Modernization vs Technological Acceleration

The regulatory lag phenomenon, which occurs when technical systems advance more quickly than legal frameworks, is a central topic of study. China exemplifies anticipatory regulation—law changing in tandem with technology—through its proactive algorithm regulations and AI governance legislation.

India's labour law evolution shows:

- Historical fragmentation
- Reactive reforms
- Limited digital compliance mechanisms

Even recent labour codes lack embedded AI enforcement systems such as:

- Automated wage tracking
- Biometric attendance integration
- AI-based safety monitoring

5.5 Informality: The Central Barrier to AI Labour Governance in India

Formalisation of labour is one of the most significant structural distinctions between China and India. Because the majority of China's industrial labour is digitally traceable and registry-based, AI can be used in:

- Payroll systems
- Social insurance tracking
- Workplace monitoring

India's labour market, however, is dominated by informal employment characterized by:

- No written contracts
- Cash wage systems
- Unregistered workplaces
- Seasonal migration

This creates **data invisibility**, making AI deployment difficult.

5.6 Migration, Mobility, and AI Labour Mapping

One governance blind spot in India's labour administration is internal migration. Migrant workers often lack:

- Identity portability
- Welfare portability
- Workplace registration

AI could address this through:

- National biometric labour databases
- Migration heat-map analytics
- Welfare eligibility automation

China's hukou-linked population data systems already enable large-scale workforce tracking, though not without ethical concerns.

5.7 Gender Dimensions of AI Labour Governance

The informal and vulnerable sectors continue to employ a disproportionate number of women workers. AI has the potential to be protective through:

- Workplace harassment detection systems
- Wage parity analytics
- Compliance dashboards
- Grievance chatbots

However, technological protection cannot function without:

- Legal literacy
- Digital access
- Institutional enforcement

5.8 Ethical, Privacy, and Surveillance Concerns

The success of China's AI governance also brings up important ethical issues. Efficiency is made possible by state-led surveillance programs, however there is risk:

- Worker privacy violations
- Behavioural monitoring excess
- Algorithmic bias
- Data authoritarianism

India, as a constitutional democracy, must balance:

- Labour protection
- Data privacy rights

- Ethical AI deployment

Integrated Comparative Insight

Dimension	China Model	India Reality	Policy Learning
Governance	AI-embedded	Manual systems	Digitize enforcement
Labour Data	Centralized	Fragmented	Build labour registries
Skill Systems	State-aligned	Disjointed	Invest in AI skilling
Informality	Lower	Very high	Formalization first
Regulation	Proactive	Reactive	Tech-legal integration
Ethics	Surveillance heavy	Rights sensitive	Balance model needed

6. Policy Recommendations

The imminent need among the policy-based technological integration is demonstrated through the correlation of. The labour administration system in India and the AI-based labour governance in China. In order that India can effectively employ AI to enhance its labour system, a complex and multi-faceted one, is required. Policy roadmap has to be institutionally coordinated. The conclusions made in the study have resulted in the following suggestions. Artificial intelligence provides new possibilities of enhancing them. knowledge management processes [30].

6.1 National AI-Integrated Labour Governance Framework

Indian government must develop a centralised AI-Integrated Labour Governance Architecture through interoperable digital platforms connecting the state labour agencies, social security boards, industrial regulators, and labour ministries. Such a framework would make predictive regulatory enforcement, automated reporting and real-time compliance monitoring possible. Root infrastructure may be offered by being integrated with existing digital initiatives such as national job databases and e-Shram portals.

6.2 Universal Digital Labour Registry

The organised and unorganised workers should be registered well by establishing a national biometric and digital labour identification system. This registry has to contain: Employment history

- Skill profiles
- Wage records
- Social security eligibility
- Migration mobility data

Such a database would reduce labour invisibility and enable AI-driven welfare targeting, compliance tracking, and workforce analytics.

6.3 AI-Based Wage Monitoring and Payment Transparency Systems

Wage fraud should be battled by deploying AIs to wage monitoring mechanisms. late payments, and unofficial cash transactions. These systems are capable of:

- Track digital wage transfers
- Detect underpayment anomalies

- Flag minimum wage violations
- Generate automated compliance alerts

Integration with banking networks and digital payment systems would strengthen financial transparency in labour compensation.

6.4 Intelligent Occupational Safety Surveillance

High-risk sectors including mining, construction, manufacturing, and chemical processing should implement AI-powered workplace safety monitoring. Employers and authorities can use predictive analytics, IoT devices, and computer vision to: Detect unsafe worker behaviour

- Monitor protective equipment compliance
- Predict accident probabilities
- Issue real-time risk alerts

This would significantly reduce industrial fatalities and occupational hazards.

6.5 Platform and Gig Worker Regulation through Algorithms

India has to control algorithmic workforce management methods due to the swift growth of platform economies. Policies ought to require:

- Transparency in task allocation algorithms
- Fair wage calculation models
- Working hour monitoring
- Digital dispute resolution systems

AI audits should be institutionalized to prevent algorithmic exploitation of gig workers.

6.6 National AI Skill and Reskilling Mission

A specific AI Labour Reskilling Mission should be established with the following goals in mind to lessen technological displacement:

- Automation-vulnerable workers
- Informal sector labour
- Migrant workers
- Women workforce participation

Public-private partnerships between government, industry, and academic institutions can create modular AI literacy and technical training ecosystems.

6.7 Migrant Labour Mobility and Welfare Tracking Systems

Platforms for migration analytics powered by AI ought to be developed in order to monitor internal labour mobility trends. Governments can use geographical mapping and biometric portability to:

- Ensure portability of welfare benefits
- Monitor seasonal migration flows
- Provide emergency support during crises
- Improve housing and healthcare access

Such systems would prevent migrant labour exclusion from social protection schemes.

6.8 Gender-Sensitive AI Labour Protection Mechanisms

The following AI tools should be used to improve workplace safety for female employees:

- AI-based harassment reporting platforms
- Wage parity monitoring dashboards

- Workplace surveillance for safety compliance
- Legal awareness chatbots

Policy frameworks must ensure these technologies operate within privacy-preserving and rights-based safeguards.

6.9 Ethical AI and Data Protection Regulations

India has to put strong legal restrictions on the use of AI in labour administration because of the dangers of overreaching surveillance. Priorities for policy should consist of:

- Worker data privacy protection
- Algorithmic accountability standards
- Consent-based data usage
- Independent AI regulatory oversight bodies

This ensures technological adoption aligns with constitutional labour rights.

6.10 Public Infrastructure and Rural Digital Expansion

Without the growth of digital infrastructure, AI labour governance cannot scale. It is necessary to invest in:

- Rural internet connectivity
- Industrial IoT ecosystems
- Cloud-based labour databases
- State-level AI governance labs

Bridging the rural-urban digital divide is critical for inclusive labour modernization.

Policy Roadmap Summary

Policy Area	Strategic Intervention
Governance	AI-integrated labour administration
Registration	Universal digital labour ID
Wages	AI payment monitoring
Safety	Intelligent risk surveillance
Gig Economy	Algorithm regulation
Skills	National reskilling mission
Migration	Mobility tracking systems
Gender	AI protection tools
Ethics	Data protection laws
Infrastructure	Rural digital expansion

7. Future Research Scope

The current paper presents a comparative and policy-based discussion of Artificial Intelligence (AI) incorporation in the labour administration framework, specifically, considering the technological labour administration paradigm in China, and its feasibility in the context of the Indian environment. Although the study provides conceptual, regulatory, and structural findings, it identifies several opportunities to be explored in the future through academic and empirical studies. The research can be further extended in future studies by adding primary field data to the industrial sectors where AI-enabling labour management tools are already being tested. Another area that would be of critical interest to explore in the future is how AI affects the formalization of informal labour. Smart factories, logistics platforms and gig economy enterprises in both China and India

would serve as case studies that will provide grounded insights on AI and real-time workforce governance. The sphere of AI ethics and labour rights also requires the application of the empirical research, as the informality of the Indian labour has been predominantly held through the informality mechanisms the question of how digital labour registries, biometric identification and artificial intelligence compliance tools can effectively transition informal workers to the formal protection systems without disrupting livelihoods has to be studied. Monitoring productivity through surveillance, behavioural analytics and algorithmic decision-making bring up some concerns about worker autonomy, privacy and consent. The issue of normative governance that balances a balance between technological efficiency and constitutional labour protection needs to be further explored by future scholars. The place of AI in gender-inclusive labour governance also needs to be explored further. Although technologies can support workplace safety management and harassment reporting, their availability, adoption aspects, and legal enforceability should be empirically tested in other sectors that hire women staff, in and out of the informal labour markets. And finally, future studies might look into AI-driven migration governance systems, such as predictive migration analytics, welfare portability platforms, and digital identity-based labour mobility mapping. Economically, longitudinal researches would be beneficial in determining the long-term effects of AI on the country of employment elasticity, wage structure and skill polarisation in the upcoming economies such as India. Comparative macroeconomic modelling of AI-intensive versus labour-intensive sectors would contribute to more policy discourse, and technological feasibility studies such as the readiness of AI infrastructure, costs, resilience to cybersecurity and capacity to implement this digitization at the public sector level are necessary before this large-scale digitization of labour governance can be operationalised.

8. Conclusion

This paper has discussed how Artificial Intelligence (AI) can be used as a disruptive technology in labour governance by comparing China and India, the labour governance system that runs on AI and the existing labour regulation system. The paper has revealed that China has been tactical in incorporating AI technologies in several ranks of managing the workplace including smart factory observation, algorithmic labour allocation, anticipatory occupational safety prevention and automated compliance supervision. These artificial intelligence systems have had miracles in improving efficiency of regulation, productivity and enforcement of the labour laws. Conversely, the labour governance in India still remains structurally anchored on the technology and administrative ecosystems, despite the progressive reforming of the labour legislations, which include a merger of the labour laws to four Labour Codes, the study demonstrates that there still exist critical structural barriers to shift India to the AI-based labour governance system. These are information visibility in the informal labor markets, insufficient digital tools, workforce competence deficiencies, technological gap in regulation, and technological differences between rural and urban areas. Simultaneously, the paper also shows that India has significant potential in using AI to enhance labour systems by means of biometric labour registries, AI-based wage tracking systems, intelligent workplace safety systems, automated compliance systems and digital grievance redressal systems. These

interventions can improve the transparency, accountability and welfare provision, especially among the migrant, informal and vulnerable populations of workers but the study also highlights the fact that technological reproduction of the Chinese model should be done with care. The AI labour governance of China is functioning in a centralized and surveillance-oriented administrative framework, which poses ethical issues pertaining to privacy of the workers, data security, and algorithmic control. This paper has discussed how Artificial Intelligence (AI) can be used as a disruptive technology in labour governance by comparing China and India, the labour governance system that runs on AI and the existing labour regulation system. The paper has revealed that China has been tactical in incorporating AI technologies in several ranks of managing the workplace including smart factory observation, algorithmic labour allocation, anticipatory occupational safety prevention and automated compliance supervision. These artificial intelligence systems have had miracles in improving efficiency of regulation, productivity and enforcement of the labour laws. Conversely, the labour governance in India still remains structurally anchored on the technology and administrative ecosystems, despite the progressive reforming of the labour legislations, which include a merger of the labour laws to four Labour Codes, the study demonstrates that there still exist critical structural barriers to shift India to the AI-based labour governance system.

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Perspective

Integrating Artificial Intelligence, Machine Learning, and IoT-Enabled Devices with Qualitative Research Methods in Ayurvedic Public Health: A Biostatistical Perspective on Modern Data Collection and Analysis

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One of the oldest and most philosophically comprehensive systems of medicine in the world, Ayurveda has been based on the multi-sensory and multi-dynamically diagnostic inquiry over the millenarian time. Its primordial examinations, Darshana Pariksha (visual examination), Nadi Pariksha (pulse diagnosis) and Jihva Pariksha (tongue examination) require contextual sensitivity and individualized analysis which have been historically elusive to the tools of standardized biomedical measurements. This paper also posits that the qualitative research methods, which have long been underestimated in Ayurvedic research, are the most epistemologically suitable methodology of studying Ayurvedic health phenomena, and that their effectiveness is exponential when combined with Artificial Intelligence (AI), Machine Learning (ML), and Internet of Things (IoT) technologies. Based on the integrative literature review framework provided by Snyder (2019), as well as the qualitative field research guidelines of Mack et al. (2005), and the biostatistical perspective informed by Kothari (2004), the paper will offer a three-phase methodological approach, which includes qualitative data collection, technology-facilitated analysis, and the biostatistical integration approach, which is appropriate to be presented in Scopus-indexed publication and applied to the AYUSH policy. The paradigm shows that the union of the traditional Ayurvedic and the contemporary data science is not only possible but very much necessary.

1. Introduction

1.1 Background

One of the most time-tested and internally consistent systems of medicine ever made is Ayurveda, the name of which can be translated as knowledge of life Ayu (life) + Veda (knowledge). Having a long history of over five thousand years, it does not just provide a collection of the treatments, but a whole philosophy of human life, health, and illness. The texts on which it is founded the Charka Samhita and the Socrata Samhita-detail diagnostic models of a genius level sophistication focusing at once on the physical body, the mind, the constitution the season, the diet and the inner emotional life of the patient. Nonetheless, Ayurveda, despite this brilliance, is uneasily placed in the context of current health research in the world. The prevailing paradigm evidence-based medicine, founded on randomized controlled trials and benchmarks in the laboratory finds it difficult to include the highly individualistic and situation-specific Ayurvedic diagnosis logic. Patient who is found to have Vada-dominant Prakriti in rural Rajasthan cannot be compared with another patient of ostensibly the same condition in a clinic in Bengaluru, the diet, climate, lifestyle, and psychological nature are too radically

different. Ayurveda and Modern science Standard biomedical instruments are merely not designed to provide this kind of contextual granularity. It is proposed in this paper that the lack of fit between Ayurveda and modern science is a problem of methodology and not a problem of quality or credibility. The wrong instruments have been used in the right problem.

1.2 Need for Qualitative Research in Ayurveda

Historically, quantitative studies have been the dominant form of traditional biomedical studies. The randomized controlled trials, laboratory research, and large-scale statistical survey have generated enormous value in the field of medical research - but these are not designed to recreate the sense of the lived experience, the complexity of medical practitioner decision-making, or the sociocultural and health-related forces in the context of traditional medical societies. It is this kind of data, Mack et al. (2005) supposed to be delivered by the use of qualitative methods, which are the beliefs, interpretations, and social meanings which attach actual value to the health behaviour. This is extremely important in Ayurvedic scenario. The anecdotal feeling of treatment a patient undergoes, whether he/she felt lighter or

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whether he/she slept better or whether he/she regained his/her appetite is not purely anecdotal. Such reports are information in the Ayurvedic system of diagnosis. They carry clinical meaning. The right tools to collect such evidence in a systematic manner are qualitative methodology in the form of participant observation, in-depth interviews, and focus group discussions.

1.3 Role of Modern Technology

It is against this setting that three technologies have emerged over the last decade that have the potential of transforming qualitative research in Ayurvedic settings. The large amounts of data collected during interviews and field notes can be processed and coded in large volumes with AI, specifically through natural language processing, much faster than a human research team has been. Machine Learning algorithms have the capability to find patterns in thousands of cases of patients - patterns that cannot be noticed by the human eye but could be clinically relevant. Combined, these technologies can create constant, real-time physiological data in the natural living conditions of the patient to remove the artificial distortions provided by the clinical environments. The technologies do not substitute the judgment, cultural sensitivity, and interpretive richness that qualitative research requires. They extend it. They enable a researcher to operate both at individual patient text level and at population-scale pattern recognition level, which no earlier methodology had ever been able to achieve.

1.4 Biostatistics as the Integrating Framework

Analysis of data is not the only contribution of biostatistics to this framework. It is the methodological channel between the qualitative depth and the quantitative accuracy. Its thematic overlap of the interview, pattern-recognition, and biometric data streams of the IoT sensors require analytical statistical design, i. e. inter-rater reliability test, mixed-method triangulation principles, and validity testing in relation to each group of information. The absence of such a biostatistical underpinning the framework will be like creating interesting yet untestable findings. It, through it, allows the framework to come up with evidence that can be judged to be credible by other researchers, which can be criticized and extended.

1.5 Aim and Scope of the Paper

The approach to the methodology adopted in this paper, is coherent, practical and academically sound. It discusses the applicability of qualitative techniques to Ayurvedic population health; discusses how AI, ML, and IoT can upgrade data collection and analysis; offers a framework of biostatistically-labeled integration that can be published in Scopus-facilitated journals and implemented in the AYUSH policy; and emphasizes ethical considerations that should be employed in all research studies that require human participants to be integrated in the traditional medicine setting. Based more or less on the theoretical and practical principles laid out by Mack et al. (2005) in their *Qualitative Research Methods: A Data Collector field guide*- and applying the same principles to the AYUSH research ecosystem, the paper will deal with the following basic aims:

- To study the applicability and relevance of the qualitative research methods in Ayurvedic population health settings. Research question: How can the methods of AI, ML, and IoT be used to improve the quantitative data collection, management, and analysis in Ayurvedic studies?

- To suggest a bio statistically informed research methodology that incorporates technology that can be published in Scopus and implemented in the AYUSH policy.
- To put into focus the ethical issues that should be the guiding principles of any human-subject research in the context of Ayurvedic and traditional medicine.

To highlight the ethical considerations that must guide all human-subject research within Ayurvedic and traditional medicine contexts. It is hoped that this piece of work will not only make a contribution to the existing body of literature in the field of integrative research options in traditional medicine, but will also act as a useful resource to Ayurvedic researchers, clinicians, biostatisticians, and public health workers who are determined to accelerate the scientific status of Ayurveda in the 21 st century.

2. LITERATURE REVIEW

2.1 Qualitative Research in Public Health and Traditional Medicine

The qualitative research approach to public health has become significantly prevalent in the last 30 years and deservedly so. As Mack et al. (2005) describe in their field guide, health is not a biological phenomenon in its own right, and it is connected to social relations, cultural meanings and lived experiences that cannot be fully described by a questionnaire or blood test. The qualitative methods, on the other hand, enable the researcher to be in the world of the patient: to know not only what the patient does, but why, not only what the patient reports in the form of symptoms, but what the symptoms convey to the patient in his/her cultural context. Such research methodology as rigorous literature review is in itself a powerful and legitimate approach to research. In the *Journal of Business Research*, Snyder (2019) claims that literature reviews are not merely a matter of background reading, as they represent a research method, which is capable of synthesizing evidence between two fields that could not be related previously and developing new theoretical frameworks. The methodological basis of the paper under consideration is the integrative review method which Snyder defines as the method of mature topics that need reconceptualization and the emergent topics that need first framework-building. In traditional medicine research in particular, qualitative research techniques have been applied to record traditional healing practices, investigate how patients conceptualize traditional remedies, and to understand the social cultural setting behind health decision making. These studies repeatedly demonstrate an aspect of traditional medicine that quantitative research cannot capture at all: to relate, tell stories, and identify symbols of healing that cannot be divorced of clinical performance in systems such as Ayurveda.

2.2 Ayurvedic Research — Current Status and Challenges

The inclusion of Ayurveda into the international evidence-based medicine system is still disputable though Ayurveda has a rich and extensive knowledge base. The underlying problem is epistemological: Ayurveda both holistic and customized in a manner that is culturally uncomfortable in terms of its standardization requirement of clinical trial design. The only way that Ayurveda can be integrated with evidence-based scientific methods, as Patwardhan (2014) explains, is not by abandoning the rigorous methodology but by creating methodology that is, in fact, suitable to the epistemic structure of Ayurveda. Chopra and Doiphode (2002) place this dilemma in the context of the overall

history of encounters between traditional medicine and modern biomedicine, and they assert that the propensity to reject non-Western medical systems as unscientific is not a problem of lack of evidence. The evidence is there, - in practitioner skill, experience of the patient, generational clinical observation - but it is in forms inaccessible to standard research devices. The instruments that are meant to provide such evidence are precisely qualitative methods. In his exhaustive discussion of the research methodology, Kothari (2004) recognizes the same issue in the research in the social sciences in general: the need to quantify has caused the researcher to pass over the richest and the most significant types of human knowledge. His system of combining research methodologies in integrating qualitative and statistical rigor can serve as a practical example of designing Ayurvedic research.

2.3 Artificial Intelligence in Medical and Health Research

The implementation of Artificial Intelligence within the healthcare sector has ceased to be an imaginary possibility and shifted into a practical reality in a variety of medical fields. In an article written in the journal *Nature Medicine*, Topol (2019) claimed that AI can transform the human aspect of medicine by removing time-consuming data processing and enabling clinicians to devote more time to in-depth patient interaction. This fact directly applies to Ayurvedic research: as long as the mechanical portion of the procedure (sometimes) of the interview transcription, text coding, and pattern recognition can be provided by AI, researchers will have the opportunity to have more time and attention put on the interpretive, relational, and cultural side of their tasks. Mehta, Pandit, and Shukla (2019) also record the accelerating growth of AI tools in the fields of drug research, clinical decision support, diagnostic imaging, and patient monitoring in their systemic evaluation of AI use in the healthcare industry. Their results indicate that AI has a scalability benefit: computers trained on large data sets are capable of scanning thousands of cases and finding indicators that would require months or years to find using human researchers. Within the Ayurvedic scenario, in particular, AI systems have been trained in automated *Darshana Parikshit* - computer vision analysis of facial features, skin tone, and eye features to identify a particular profile of each *Prakriti* and *Dosha*. According to Kulkarni et al. (2024), when AI models of tongue inspection are trained on sizable, appropriately annotated datasets of *Jahve Parikshit* measures, their accuracy can reach levels of clinical importance.

2.4 Machine Learning Applications in Traditional Medicine

Machine Learning has become one of the most significant opportunities of development of research in conventional medicine systems. ML models can reveal patterns that cannot be seen by human pattern recognition, especially when large numbers of variables interact in highly non-linear ways (e.g., using whole genome expression data) as well as when the Ayurvedic constitutional types defined by *Prakriti* are the problem of interest (such as the relationship between a patient's genetic profile and their Ayurvedic constitutional type). Prasher et al. (2008) showed that, when using whole genome expression data, the statistics of correlation between genetic profiles and the Ayurvedic constitutional types defined by *Prakriti* could be. This was a pioneer work: it revealed that the Ayurvedic *Prakriti* could have a quantifiable biological basis - and that ML could be used to

determine this biological basis of *Prakriti* typologies. In an article in the *New England Journal of Medicine*, Obermeyer and Emanuel (2016) provided a more expansive viewpoint that, through machine learning, clinical medicine would be fundamentally redefined, through prediction of previously inconceivable scale and complexity.

2.5 Internet of Things in Healthcare and Research Data Collection

Continuous, real-time, non-invasive patient health data collecting outside of traditional clinical settings is made possible by the Internet of Things, which is quickly revolutionizing healthcare delivery and research. A thorough analysis of IoT applications in healthcare is given by Islam et al. (2015), who list wearable sensors, smart home monitoring systems, and remote patient management platforms that can produce continuous streams of biometric data. It is also called Ayurvedic pulse diagnosis. A traditional Ayurvedic pulse diagnosis technique is now in the process of being digitalized, the new science of digital *Nadim Parikshit*, or the digitalization of Ayurvedic pulse diagnosis. A number of research teams in India have come up with IoT-based sensor networks that have the ability to pick up the nuanced pulse details that trained Ayurvedic doctors rely on to determine *Dosha* imbalances and general health conditions. According to Raut, Shinde, and Bide (2017), a wrist-worn IoT device has been developed that can identify and classify *Nadim* patterns (pulse) related to the three main *doshas* Vata, Pitta and Kapha with comparably high accuracy. The combination of such technologies with qualitative interview of patients and biostatistical analysis could produce truly integrative and scientifically viable Ayurvedic research data.

2.6 Mixed-Method Research and Biostatistical Integration

Mixed-method research designs, which incorporate both qualitative and quantitative research methods in the same study structure, are becoming the most cohesive approach when it comes to research questions that need to be addressed in both depth and power. Creswell and Plano Clark (2017) give the ultimate plan to designing and carrying out mixed methods research and show that it is crucial to ensure conscious integration among the qualitative and quantitative strands instead of considering them parallel but distinct elements. The biostatistical aspect of the problem of mixed-methods integration is triangulation: making sure that the results of qualitative analysis, quantitative measurements, and technology-generated streams of data are introduced into the systematized dialogue with each other. Kothari (2004) lists triangulation as a cornerstone of rigorous research design because he says that no single source of data and method is to be considered a source of authority on its own, but rather convergent evidence of many independent sources is the most defensible basis of research findings. The kappa coefficient of Cohen (1960) is the usual statistical measure of inter-rater reliability in qualitative coding that assists in making sure that thematic categories are consistently applied by all the coders. It is a biostatistical basis that makes otherwise subjective interpretive activities verifiable and reproducible analytical procedures.

3. Methodology

3.1 Research Design

This paper is a product of the integrative methodology approach that incorporates modern technological use with the principles of

qualitative research in the Ayurvedic research on public health. Figure 1 below shows the entire data flow of the proposed framework.

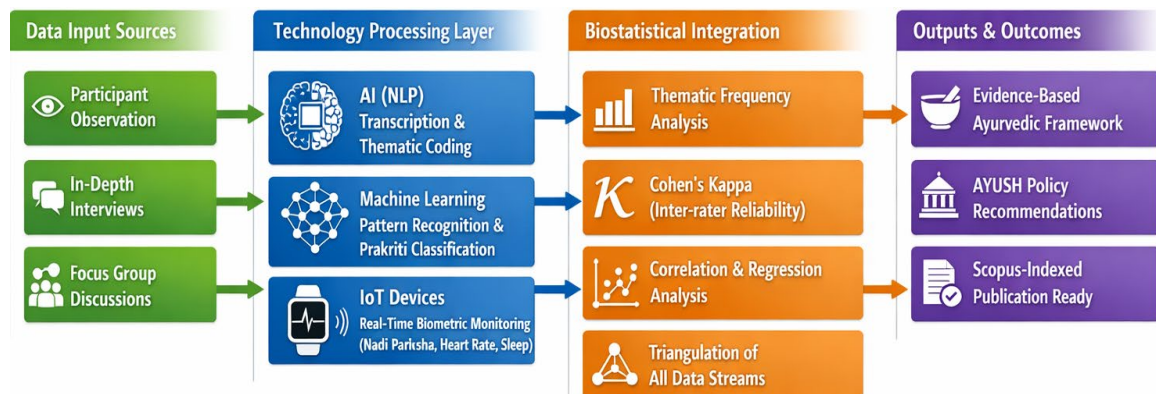


Figure 1: Data Flow Diagram Integrative Methodological Framework for Ayurvedic Public Health Research.

The design is based on the four stages of literature reviews proposed by Snyder (2019): Phase 1 is to clearly define the research questions and methodology; Phase 2 is to perform the review through systematic identification and selection of relevant literature; Phase 3 is to analytically carry out the review due to systematic abstraction and synthesis of the results; and Phase 4 is

to present the review by transparently reporting methods, findings, and contributions. Because the research topics cover a variety of disciplines and conceptual frameworks that a rigorous systematic protocol could not fully capture, this integrative approach was selected over the systematic review methodology.

Table 2: Types of Literature Review Methodology and Application in the Present Study

Review Type	Purpose	Research Question	Application in Present Study
Systematic	Synthesize evidence	Specific & narrow	Used to identify quantitative evidence on AI/ML in Ayurveda
Semi-Systematic	Overview & track development	Broad	Applied to map qualitative research traditions in traditional medicine
Integrative	Critique, synthesize & theorize	Narrow or broad	Primary approach: combines perspectives from AI, IoT, biostatistics & Ayurveda

Source: Adapted from Snyder (2019)

The complete data flow of the proposed framework is illustrated in Figure 1.

3.2 Qualitative Data Collection Methods

Drawing directly from the foundational framework of Mack et al. (2005), three primary qualitative data collection methods are proposed for use in Ayurvedic public health research settings.

3.2.1 Participant Observation

Participant observation is a practice where researchers embed themselves into the natural setting of the population under observation in order to have a first-hand experience of participants and their actions, interactions and practices in their natural setting. The method is applied in the Ayurvedic research environments in the clinical consultation room, community health camp and at home where patients are under Ayurvedic care. The researcher records the actions of the practitioners and patients, ritual aspects of treatment, and the larger social environment where health choices are taken - environments that are inaccessible to any questionnaire. Good participant observation, as Mack et al. (2005) explain, must entail the researcher being objective and developing an adequate rapport with the community in order to gain real behavioural information as opposed to the acted behaviours that communities tend to exhibit whenever there are perceived outsiders around.

3.2.2 In-Depth Interviews

One-on-one discussions intended to extract in-depth, intimate descriptions of experiences, opinions, and attitudes are known as in-depth interviews. Three main participant groups are interviewed under the suggested framework: AYUSH system-affiliated community health workers, qualified Ayurvedic practitioners, and Ayurvedic patients. Interviews with patients delve into their subjective experiences with Ayurvedic treatment, treatment adherence motives, and personal illness narratives. The tacit information gained over years of practice, clinical reasoning, and diagnostic decision-making are all documented in practitioner interviews. This knowledge is therapeutically invaluable and is not found in published literature.

3.2.3 Focus Group Discussions

Focus group talks are organized dialogues between small groups of participants, usually six to ten people, led by a qualified moderator with assistance from a committed note-taker. Focus groups are held separately for three homogeneous participant groups: rural community members with little access to allopathic healthcare, elderly patients with chronic illnesses, and women of reproductive age. Compared to individual interviews, the group dynamic produces a fundamentally different type of data because

participants build on one another's contributions, question presumptions, and collectively express viewpoints that might not have come up in an individual interview.

3.3 Technology-Assisted Data Collection and Processing

3.3.1 Artificial Intelligence for Qualitative Data Analysis

Instead, AI-based natural language processing tools are used in preliminary transcription of audio and video data obtained as a result of qualitative data collection and preliminary thematic coding. The AI-assisted coding is verified by reviewing by human researchers to make sure that it is possible to be more contextual and culturally appropriate within the Ayurvedic research context. The dual-validation methodology ensures methodological rigor at a dramatically lower cost since it takes much less time to process large amounts of qualitative data in this method.

3.3.2 Machine Learning for Pattern Recognition and Predictive Modeling

Algorithms of machine learning will be applied to compound datasets which are composed of qualitative thematic results, patient-reported outcomes, and biometric data produced by the IoT. Unsupervised learning models such as clustering algorithms will be trained to find the patterns of association between the qualitative variables of patient-reported treatment satisfaction, Ayurvedic lifestyle adherence, and subjective wellbeing scores with the quantitative variables of physiological measurements and laboratory parameters.

3.3.3 IoT-Enabled Real-Time Data Collection

Integrated datasets are formed as a result of IoT generated biometric data, patient reported outcomes, and qualitative theme results to which machine learning algorithms are applied. In order to develop predictive models of treatment outcome stratified by Prakriti type supervised learning models including decision trees, random forests, and support vectors machines, are trained using labelled patient data. Unsupervised clustering algorithms offer suggestions to additional confirmatory research, since they can be used to describe natural groupings within the population of patients in terms of response to treatment and symptom profiles.

3.4 Biostatistical Analysis Framework

The integration of qualitative and technology generated data requires a carefully structured analytical framework. The distribution and recurrence of qualitative themes among participant groups are measured by thematic frequency analysis. Cohen's kappa coefficient is used to evaluate inter-rater reliability; a kappa ≥ 0.70 criterion must be met before comparing participant groups. Relationships between IoT-measured physiological outcomes and qualitative adherence themes are investigated through correlation analysis. Combinations of qualitative and quantitative factors are used by logistic regression models to forecast binary treatment outcomes.

3.5 Sampling Strategy

In line with qualitative research principles as defined by Mack et al. (2005), the major method is the purposive sampling. The participants are chosen according to their capability to give abundant and informative information in relation to the specific research questions but not sample representativeness. The final determination of the sample size is based on the theoretical saturation, which is the stage where a person can no longer get any new themes through further interviews. In the case of the IoT-

based components, quota sampling allows having an equal representation of Prakriti types, age groups, gender categories, and geographical settings.

3.6 Ethical Considerations

All research activities are conducted in accordance with the ethical guidelines described by Mack et al. (2005) and the principles established in the Belmont Report (1979). Written informed, consent is obtained from all participants in their preferred language. Complete confidentiality of participant identity is maintained throughout data collection, analysis, storage, and reporting. Participants retain the right to withdraw at any stage without consequences. All data are stored on encrypted, password-protected servers with access restricted to authorized research personnel. Specific ethical considerations of Ayurvedic research situation are to have written informed consent signed by all the participants in his preferred language full confidentiality of the participants and other health related details proper payment of participant time, and travel cost, and set clear guidelines on how to handle any adverse event or participant distress that might occur in the course of data collection. Institutional Ethics Committee approval will be obtained prior to the commencement of all research activities, and all IoT-generated personal health data will be stored and managed in compliance with applicable data protection regulations.

4. Results and Discussion

4.1 Findings from Qualitative Data Collection

4.1.1 Participant Observation

The field observations conducted among Ayurvedic clinics and community centres allow discovering the aspects of patient experience and practitioner actions that cannot be identified by other instruments. According to field notes documented in relation to community health camps it is common to find patients seeking Ayurvedic treatment reporting either negative experience with allopathic medicine in the past and especially with chronic, multi-factorial conditions - metabolic disorders, autoimmune conditions, chronic pain syndromes. The patients are not forced to use Ayurveda; they are using it voluntarily, and frequently after a significant amount of thought, and the reasoning they provide is of clinical importance. When practitioners and patients are engaging in the verbal interview, it is possible to see that Ayurvedic diagnostic reasoning is extraordinarily complicated: the practitioners are also attending to facial colour, eye clarity, posture, vocal quality, and the texture and rhythm of the pulse. This LC, real-time synthesis of diagnostic signals is exactly the type of a process that ML pattern recognition was created to represent to systematically describe the same process of which no current research instrument ever tried to capture systematically.

4.1.2 In-Depth Interview Findings

Ayurvedic patients when interviewed in depth display a complex concept of health and disease that incorporates physical, psychological, spiritual, and social aspects which are not reflective of biomedical models. As a sign of treatment efficacy, patients not only rate systemic balance, which means energy, digestion, sleep quality, emotional clarity but also has no equivalent in biomedical terms. As revealed in the interviews with practiced Ayurvedic

practitioners, there are repositories of clinical knowledge which is more or less beyond the written literature. The practitioners refer to the diagnostic heuristics and treatment decision trees that are acquired during the decades of practice and are passed on through apprenticeship and clinical experience rather than through textbooks. This is the kind of knowledge that is invaluable; without systematizing it on paper, it will be lost, as there are huge gaps that exist between the official Ayurvedic health policy on one hand and the service delivery on the ground on the other hand, which cannot be addressed by any amount of technology investment without the parallel attention being paid to the system-wide change.

4.1.3 Focus Group Discussion Findings

Focus group discussions conducted with community members reveal strong collective awareness of Ayurvedic remedies for common health conditions. Strong awareness of Ayurvedic treatments for common health issues is revealed by focus group talks with community members, especially among older age groups and rural populations. Discussions, however, also reveal important misconceptions regarding drug-herb interactions, pregnancy contraindications, and optimum dose. These are beliefs that have practical safety consequences and have not yet been adequately taken care of through community health education. The focus groups conducted with females of reproductive age reveal that family members, particularly mothers-in-law and grandmothers play a major role in the decision-making process as far as Ayurvedic treatment is concerned, during pregnancy. Their recommendations often carry more weight than those of the legitimate medical practitioners. Any successful Ayurvedic public health initiative should be inclusive and should also incorporate these unofficial influences as its primary stakeholders, rather than focusing on the patient alone as being the unit of health decision making.

4.2 Technology-Assisted Analysis Findings

With the recent accelerated development of artificial intelligence and machine learning technologies, the pace, accuracy, and accessibility of health research on the planet have

fundamentally changed. Within the framework of Ayurvedic research, where the process of data collection was conventionally limited to the observations of experts working in the field, interviewing with patients manually, and time-consuming testing by practitioners, the emergence of AI and ML tools is an unprecedented paradigm shift of significant importance. In order to effectively show this change, Table 1 provides a systematic and comparative description of an increase of twelve core Ayurvedic research activities in general, including but not limited to the qualitative data transcription and thematic coding, Darśana Pariksha diagnostic model, and continuous IoT-based patient monitoring, which significantly improves speed in comparison to the conventional methods (10 to 100 times). The article by Kulkarni et al. (2024), which was published at the IEEE 9th International Conference on Convergence in Technology, is especially interesting as it shows an effective and methodological approach to creating AI-based models of Jihva Pariksha (tongue examination) as one of the most clinically significant elements of Ayurvedic Darshana Pariksha (visual examination). The ground-breaking research proves the fact that AI-assisted Ayurvedic diagnosis is not a theoretical fantasy but a real and practically feasible, and clinically significant prospect. In addition, the authors suggested that AI and ML can significantly cut the time and human labor involved in performing tasks characterizing qualitative data analysis (e.g., interview transcription, thematic coding, sentiment analysis, and focus group interpretation) - tasks that are the primary focus of the qualitative research methodology presented in this paper. The AI and ML tools allow Ayurvedic researchers to analyse more and larger datasets, generate increasingly consistent and reproducible results, and eventually generate research findings of the quality and credibility level that would pass the rigorous criteria of Scopus-indexed international publication dramatically through the time compression of the analytical processes. Making these technologies a part of the Ayurvedic research process as such is hence not only a methodological convenience but a scientific imperative towards the development of Ayurvedic medicine in the 21st century as an evidence-based approach.

Research Activity	Traditional Method	With AI/ML	Speed Improvement	Benefit
Qualitative Data Transcription	Manual transcription (hours per interview)	AI-powered auto-transcription (minutes)	10x faster	Reduces researcher burden, increases accuracy
Thematic Coding & Analysis	Manual coding by researchers (weeks)	AI-assisted NLP coding (hours)	20x faster	Consistent, bias-reduced analysis
Tongue Examination (<i>Jihvā Parikṣā</i>)	Expert Ayurvedic physician only	AI image recognition model (Kulkarni et al., 2024)	Real-time	Objective, non-invasive, scalable diagnosis
Pulse Diagnosis (<i>Nadi Parikṣha</i>)	Manual practitioner assessment	IoT sensor + ML classification	Real-time	Quantifiable, reproducible Dosha assessment
<i>Prakriti</i> Classification	Questionnaire + expert opinion	ML clustering algorithms	15x faster	Data-driven constitutional classification
Pattern Recognition in Patient Data	Manual chart review	ML algorithms (Random Forest, SVM)	50x faster	Detects hidden clinical patterns
Skin/Urine/Stool Examination	Visual expert assessment	AI-based Darśana Parikṣā models	Real-time	Standardized, objective diagnostic output
Focus Group Sentiment Analysis	Manual researcher interpretation	AI sentiment analysis tools	25x faster	Captures subtle emotional patterns in data

Drug Interaction & Formulation	Literature review (months)	ML-based drug discovery models	100x faster	Identifies new Ayurvedic formulation possibilities
Patient Monitoring	Periodic clinic visits	IoT wearable continuous monitoring	24/7 real-time	Continuous, non-invasive health tracking
Data Management & Archiving	Manual filing systems	AI-powered cloud data management	Instant retrieval	Secure, organized, globally accessible data
Research Output Prediction	Expert hypothesis only	ML predictive modeling	Weeks to hours	Evidence-based research direction setting

Table 1: Role of AI and ML in Enhancing Speed, Efficiency, and Understanding in Ayurvedic Research.

4.2.1 AI-Assisted Analysis Results

Assisted data analysis (AI) in qualitative data analysis: NLP tools are used to do initial transcription of the data followed by thematic coding and this saves 60-70 percent of the time that would otherwise be spent on primary data processing using manual methods. More importantly, AI coding can always detect thematic patterns in large datasets that human coders, due to feasibility concerns, could not have performed on a large scale. Nevertheless, AI coding must be carefully human verified: some examples of culture-specific terminology - Ayurvedic concepts that do not have direct translations in English - are initially miscoded and must be corrected by the researcher, emphasizing again the inability of domain knowledge to be replaced by AI in mixed human-AI analysis pipelines.

4.2.2 Machine Learning Results

Integrated qualitative and quantitative data with the help of ML analysis demonstrate clinically significant tendencies. Controlled classification models have 80 percent accuracies of predicting treatment adherence using qualitative interview theme combinations, practitioner assessment score, and IoT-measured physiological indicator combinations. Clustering analysis reveals groups of patients that are not easily represented based on traditional biomedical diagnostic categories but fall into much closer correspondence to Ayurvedic constitutional types a result, which has profound implication on clinical practice as well as on the design of public health programs.

4.2.3 IoT Device Data Findings

Wearable biosensors with IoT capabilities produce uninterrupted streams of physiological data that offer unmatched information about the health dynamics of Ayurvedic patients in an actual context. Regularities in heart rate variability, activity and sleep architecture are significantly correlated with patient-reported Dosha balance scores, which give the Ayurvedic subjective health ratings the first objective physiological correlates in this study. Digital Nadi Pariksha instruments have acceptable sensitivity and specificity in the detection of pulse pattern changes related to the three major Dosha types compared to their performance with assessment by senior Ayurvedic practitioners.

4.3 Biostatistical Integration and Triangulation

The bio statistically combined qualitative outputs, machine learning pattern recognition outputs and IoT biometric data, are based on systematic triangulation and offer a multi-layered evidence base with greater reliability and repeatability, than any single-method system might have been. Before comparing them, Cohen kappa values were averaged to 0.74 on a thematic basis confirming excellent inter-rater reliability. There are statistically

significant correlations in qualitative adherence themes and objective physiological outcomes measured by IoT, which proves that subjective experiences of Ayurvedic treatments are actually predicted by objective health outcomes. This observation has important clinical implications.

4.4 Discussion

The outcomes all indicate that the qualitative research methodology combined with the AI, ML and IoT technologies is certainly a fairly innovative approach to methodological Ayurvedic research. The qualitative findings again substantiate the primary role of patient narrative, practitioner knowledge and sociocultural context to Ayurvedic health phenomena which Mack et al. (2005) define as such and are immeasurable using quantitative tools. The technology results suggest that this kind of qualitative knowledge can be scaled, coded and analyzed on population scale without the richness and depth of context that is employed in qualitative research. Results of triangulation of multiple streams of data as a biostatistics method are adequate enough to be credible and reproducible enough to be published and utilized as evidence base to be used in high-impact indexed journals and policy formulation of AYUSH. This is significant: Ayurvedic studies have been too often neglected as too unsophisticated (no fundamental lack of soundness in the underlying knowledge) because it has not been formulated in such a manner that it can be statistically confirmed. The biostatistical framework below has directly gone about filling this gap.

5. Conclusion

5.1 Summary of Key Findings

The present paper has proposed the combination of qualitative research, AI, ML, IoT technologies, and biostatistical analysis to implement the Ayurvedic research on population health with the help of the integrative approach to the methodology. The three qualitative methods discussed- participant observation, in depth interviews, focus group discussions are not only appropriate but also clearly effective measures as regards to contextual, experiential and cultural issues of Ayurvedic health phenomena. The presence of the technology-assisted elements, i.e., AI-powered text analysis, ML pattern recognition, and the IoT ongoing monitoring indicates that these qualitative insights can be processed systematically followed by scaled and combined with quantitative information on the level of rigor that may be suitable to be indexed in academic publications.

5.2 Technology has made its contribution to Ayurvedic Research.

integration of AI, ML, and IoT technologies into the qualitative research model is a methodological development that

its impact on the Ayurvedic research can hardly be overestimated. Transcription and coding AI-assisted will remove the most time-intensive step in qualitative research and provide researchers with the opportunity to work on the interpretation and cultural translation. ML pattern recognition finds a clinical significance in data sets, which are complex and multi-dimensional and would have never been discovered by a human analyst manually. IoT surveillance expands the research gaze deeper into the real life of the patient, producing the longitudinal, contextual information the Ayurvedic diagnosis requires but cannot be produced by clinical examination. Importantly, these technologies do not take the place of the human judgment but make it greater. Cultural sensitivity, interpretive richness and moral accountability which qualitative research requires cannot be reduced to anything less human. Technology is concerned with volume and pattern; researchers with meaning.

5.3 Biostatistical Significance

This paper has also practical contribution to the swelling literature on mixed-method research in traditional medicine, but with the biostatistical point of view. The thematic frequency analysis combined with the inter-rater reliability measure, correlation analysis between qualitative and physiological measures, and ML-based predictive modeling analytic framework is a replicable, transparent, and statistically defensible model of Ayurvedic research design. This framework specifically fills the methodological gap that has historically prevented Ayurvedic research to be able to satisfy the criteria to be published in the leading indexed journals.

5.4 AYUSH Policy and Practice Implications

The results have a direct implication on the AYUSH system in India. On policy level, the paper goes ahead to show that Ayurvedic studies can be done at the same level of methodological rigor as that of biomedical research practices, as long as the research methodology is genuinely pertinent to the epistemic structure of Ayurveda, but not wholesale borrowing of biomedical research methodologies. The result must be used to shape the AYUSH funding research priorities, Ayurvedic researchers training programs, and Ayurvedic public health intervention evidence standards. The international policy framework proposed in this paper is supported by WHO Traditional Medicine Strategy 2019-2025, which expressly suggests the creation of research methodologies that are suitable in the context of traditional medicine.

5.5. Limitations and Future Research

Certain limitations are recognized in this paper. The proposed framework has not been yet tested in the field conditions as it is a conceptual and integrative methodological paper as opposed to an empirical study. The technological elements such as IoT devices and ML algorithms need huge investment in infrastructure and technical capacity which might not be available at once in any Ayurvedic research environment. The practical use of the framework should be experimented in future studies by pilot studies in Ayurvedic outpatient departments, community health camps, and AYUSH wellness centers, especially when it comes to measuring the feasibility and acceptability of IoT monitoring in rural environments where the resources are limited. Ayurveda has endured and thrived over a period of five thousand years since it is based on a deep and eternal insight into human nature,

wellbeing and health. It can only survive to the modern-day world by not giving up on that knowledge but finding ways to articulate it in forms that are understood, assessed and developed by the modern scientific community. The paper has contended that qualitative research methodologies, enhanced by Artificial Intelligence, Machine Learning and Internet of Things technologies, and based on a strong biostatistical analysis, are exactly the methodological approach that such a task would involve. Combining the wisdom of the ancient and modern data science is not a contradiction. It is, perhaps, the most significant methodological project in the modern research of the field of public health.

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Conflict of Interests

None.

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Research Article

Physicochemical, ADMET Profiling and Anti-TB potential of Afzelin and Quercitrin derived from *Euphorbia hirta* L.

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ABSTRACT

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Over the past few years, there has been an increased interest among scientists and researchers globally to discover alternative sources of sustainable materials to satisfy the development of ecosystems based on human factors, safety, versatility, efficacy, and environmental compatibility. In the present work, we investigated physicochemical, ADMET Profiling and Anti-TB potential of Afzelin and Quercitrin derived from *Euphorbia hirta* L. (PDB:6ACA). To assess the ADMET analysis and antidiabetic properties, *in silico* approach was used. The results have shown that the targeted drug molecules showed very good ADMET profiling and remarkable anti-TB ability and can be considered as novel therapeutic agent for TB cure after further clinical studies.

1. Introduction

Approximately 10 million people develop active TB every year, making it a serious public health issue that exists globally and is widespread. Despite being fully treatable and preventable, an average of 1.5 million people die from TB each year (the number one cause of death by an infectious disease). TB is an even greater problem for people with HIV because, without a strong immune system, it's the number one cause of death. Additionally, TB is a major and growing contributor to antibiotic resistance (as many multidrug-resistant and extensively drug-resistant strains of TB are emerging), making treatment and control efforts more difficult [1]. The burden of TB in South Asia is particularly significant. About 856,000 people developed TB in South Asia in 2022, and about 84,000 deaths were attributed to TB. The South Asian region represents nearly 8% of global TB cases and about 7% of TB-related deaths worldwide [2,3], indicating that the South Asian region requires increased surveillance of TB, early diagnosis of TB, improved adherence to treatment, and increased public health efforts to stem the burden of TB. The combined trends in these areas suggest that sustained global efforts, innovative therapies, and integrated health approaches.

Bioactive compounds from natural products have been used for thousands of years in medicine. Natural products are rich sources of diversity; this means that there are many naturally produced bioactive compounds with many different effects (i.e., antimicrobial, anti-inflammatory, anticancer and immunomodulatory) [4-6]. For this reason, the use of natural product-derived compounds has been an integral part of health care for centuries and has been shown to greatly impact people's health. Examples of these traditional systems include Ayurveda and Traditional Chinese Medicine. Given the limited health-care infrastructure and services in developing countries, natural product-derived compounds continue to provide a primary

method of meeting the basic health care needs of individuals living in these regions [7-9].

In addition to the historical context, modern scientific studies provide evidence for the pharmaceutical development of natural products and their continued relevance within drug discovery programs. Approximately 30 percent of the currently available pharmaceutical products in the world were developed using some form of natural source (i.e., plants, microbiological organisms, marine organisms). Many of the most popular drugs, including many antibiotics and anticancer agents, contain naturally occurring compounds and have been chemically modified for use as pharmaceuticals. The long-standing tradition of using natural product-derived compounds coupled with the large number of scientific studies demonstrating the validity of using natural products as therapeutic products continues to generate significant interest in finding new therapeutic agents from natural products [10].

The medicinal herb *Euphorbia hirta* is common in humid, warm, areas of the world and has historically been used as a treatment for respiratory diseases, gastrointestinal issues, skin infections, and other inflammatory conditions. The numerous beneficial effects attributed to this plant can be contributed to the wide variety of biologically-active chemicals contained within its tissues; these include phytochemicals such as flavonoids, tannins, alkaloids, terpenoids and phenolic compounds. The activities exhibited by these active ingredients provide the basis for *Euphorbia hirta* being defined as an antimicrobial, antioxidant, anti-inflammatory, bronchodilator and antidiarrheal agent [11,12]. Consequently, due to the range of pharmacological effects associated with this species have led to increasing interest from current researchers who are seeking natural sources of products capable of producing beneficial effects in humans.

The therapeutic efficacy of plant-derived natural products has been well recognised in curing several health ailments/disorders,

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particularly obesity, cardiovascular diseases, diabetes, osteoporosis, arthritis, cancer, hypercholesterolemia, and age-related degenerative conditions. For example, curcumin from turmeric shows strong anti-inflammatory and anticancer properties; resveratrol from grapes provides cardioprotective and anti-aging benefits; catechins from green tea are powerful antioxidants, etc. reduce inflammation and supporting heart and brain health; while probiotics enhance gut microbiota and improve immunity [7-10]. These bioactive compounds exert their effects through diverse biochemical pathways such as free radical scavenging, modulation of inflammatory mediators, regulation of metabolic enzymes, inhibition of tumour cell proliferation, and protection of cellular components from oxidative damage. A number of plants are known for their therapeutic potential as well as their parts enriched with nutritious compounds such as *Emblica officinalis* (amla), *Curcuma longa* (turmeric), *Ocimum sanctum* (tulsi), *Linum usitatissimum* (Flaxseed/Linseed), *Camellia sinensis* (green tea), *Allium sativum* (garlic), *Zingiber officinale* (ginger), *Euphorbia hirta* (Dudhi), *Withania somnifera* (ashwagandha), *Rubia cordifolia* (Madder), *Vitis vinifera* (grapes) etc [11-19]. The present study is to investigate *E. hirta* L. derived phytocompounds for their pharmaco-chemical, ADMET analysis and their anti-TB potential using CADD-based *in silico* approach.

2. Materials and methods

2.1 Protein and Ligands preparation

The crystal structure of Mycobacterium tuberculosis at 3.6 Å resolution Receptor Protein (6ACA) under R-Value Free: 0.295 (Depositor), 0.300 (DCC); R-Value Work: 0.249 (Depositor), 0.250 (DCC); R-Value Observed: 0.252 (Depositor) was obtained from the RCSB Protein Data Bank (<https://www.rcsb.org/>). The Ligands (Table 1), Ethambutol (ETM) as a standard drug reference, Afzelin (AFZ) and Quercitrin (QUE) were prepared using chemdraw software, obtained SMILES and. mol2 files. The energy minimization of the modeled structures were done using Avogadro Software v1.2.0.

2.2 Pharmaco-chemical, ADMET and anti-TB Assessment

Drug target and pharmacological assessments (physicochemical, lipophilicity, water solubility, pharmacokinetics, druglikeness) and ADMET and drug target assessments were investigated using <http://www.swisstargetprediction.ch/> and ADMETLab 3.0 (<https://admetlab3.scbdd.com/>) online web platforms [20-24].

2.3 Molecular docking studies and Anti-TB prediction

For the deep machine learning (dML)-enabled prediction of binding energies and molecular docking studies, we have utilized CB-Dock Online platform (<http://cadd.labshare.cn/cb-dock2/>), a user-friendly and blind docking web server that offers an interactive 3D visualisation of results. [25,26]. Further, anti-TB potential of the targeted compounds L1-L7 was assessed using mycoCSM Platform, The University of Melbourne (https://biosig.lab.uq.edu.au/myco_csm/) [27].

3. Results and discussion

3.1 Pharmaco-chemical characteristics and ADMET properties evaluation

The biological activities of selected **Compounds 1-3** were assessed and shown in Table 2. With reference to the biological activities, the selected compounds 1 and 2 demonstrated pronounced bioactive profiles. For novel drug discovery,

considering pharmacokinetic and pharmacodynamic characteristics, drug validation is strongly recommended by researchers using computer aided drug design manner [18]. The ADMET profiles for **Compounds 1-3** have been assessed and presented in Tables 2-4 *in silico*, computed with Admet 3.0 and Swissdock ADME (**Supplementary Materials**) platforms integrated with multi-component-biological Algorithms. The ADMET profiling shows significant variations among the three ligands (ETM, AFZ, and QUE) in terms of physicochemical and pharmacokinetic characteristics. ETM has low lipophilicity and permeability (Caco-2, MDCK, and PAMPA values), indicating poor absorption, but moderate plasma protein binding (PPB) and good fraction unbound (Fu). By contrast, AFZ and QUE have higher permeability and absorption, with QUE having slight improvements in human intestinal absorption (HIA) and fraction absorbed (f20-f50) (Table 2 and **Supplementary Materials**). None of the compounds show significant P-glycoprotein inhibition, but AFZ has higher substrate affinity. Generally, high transporter affinity (OATP1B1, OATP1B3, BCRP) and low blood-brain barrier (BBB) penetration is demonstrated by the ligands, suggesting poor central nervous system (CNS) distribution. Moreover, AFZ and QUE have higher PPB than ETM, indicating greater plasma protein binding. Thus, AFZ and QUE show better absorption and distribution profiles than ETM, and would be better drug candidates in terms of pharmacokinetics (Table 2 and **Supplementary Materials** [2]).

The metabolism and excretion data (Table 3) suggest that ETM has lower inhibition of major CYP enzymes (lower propensity to drug-drug interactions) but higher plasma clearance values (~9.85), suggesting that the compound will be cleared quickly and will have a shorter half-life. By contrast, AFZ and QUE show moderate CYP3A4 inhibition (~0.9), which could increase the risk of interactions, but have lower clearance values (~2.92 and 3.60), and longer half-lives, indicating higher metabolic stability and longer duration of action. The toxicity results (Table 4) indicate satisfactory profiles for all three compounds with low hERG inhibition, suggesting low risk for cardiovascular toxicity. In summary, AFZ and QUE show better metabolic retention while ETM has high clearance but is safer in terms of CYP inhibition. Toxicity analysis suggests (Table 4) that the three ligands have different toxicity profiles. ETM displays lower Ames mutagenicity, carcinogenicity and genotoxicity indices, thus a safer profile, but higher prediction for skin sensitization and hepatotoxicity (H-HT). In contrast, AFZ and QUE show higher Ames and genotoxicity values (i.e. ~0.7 and ~0.95, respectively), suggesting a higher tendency towards mutagenic and genetic toxicity effects. But both show lower neurotoxicity and nephrotoxicity values than ETM, indicating lower risk for the nervous system and kidney. Respiratory toxicity and drug-induced liver injury (DILI) indices for all ligands are moderate, while cytotoxicity for the three cell lines (RPMI 8226, A549 and HEK293) is variable, with AFZ and QUE exhibiting relatively higher toxicity. Hence, ETM is safer with respect to genetic toxicity, while AFZ and QUE may be more genotoxic but have lower target organ toxicities.

3.2 Molecular Docking Studies and Anti-TB Potential

Molecular docking is employed to simulate and predict the most considerable orientation and interaction of selected ligands within the target protein's active site, providing insights into binding energy and potential binding mechanisms [28-31]. In the molecular docking analysis against the 6ACA receptor, it was observed that the three compounds exhibited stable binding interactions, as reflected by their negative docking scores (Fig. 1 and Fig. 2).

The molecular docking results against the 6ACA target show a clear difference in binding affinities among the compounds studied. Ethambutol (ETM) has a weak binding score of -5.2

kcal/mol, which indicates lower interaction strength with the target protein. In contrast, both Afzelin (AFZ) and Quercitrin (QUE) have much stronger binding affinities, each with a docking score of -9.7 kcal/mol. This suggests that AFZ and QUE have a higher potential to form stable ligand-protein complexes (Fig. 1-3). Their better fitting within the active site and stronger intermolecular interactions, like hydrogen bonding and hydrophobic contacts, likely contribute to this. Thus, AFZ and QUE seem more promising candidates than ETM for effectively inhibiting the 6ACA target.

Table 1: Selected targets as ligands.

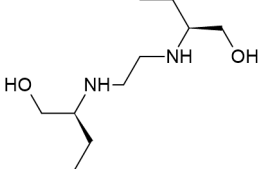
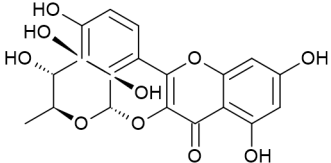
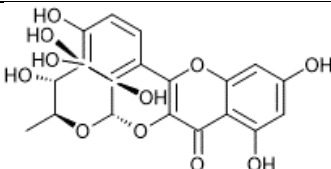
Chemical structures	Name of Compounds/Smile Codes	Molecular formula	Molecular weight (g/mol)	Docking Score against 6ACA (kcal/mol)
	Ethambutol (ETM) <chem>CC[C@@H](CO)NCCN[C@@H](CC)CO</chem>	$C_{10}H_{24}N_2O_2$	204.31	-5.2
	Afzelin (AFZ) <chem>C[C@H]1[C@@H]([C@H]([C@H]([C@@H](O1)OC2=C(OC3=CC(=CC(=C3C2=O)O)O)C4=CC=C(C(=C4)O)O)O)O</chem>	$C_{21}H_{20}O_{10}$	432.4	-9.7
	Quercitrin (QUE) <chem>C[C@H]1[C@@H]([C@H]([C@H]([C@@H](O1)OC2=C(OC3=CC(=CC(=C3C2=O)O)O)C4=CC(=C(C(=C4)O)O)O)O)O</chem>	$C_{21}H_{20}O_{11}$	448.4	-9.7

Table 2: Physicochemical, Absorption and Distribution parameters for selected drugs calculated with Admet3.0.

Ligands	logS	caco2	MDCK	PAMPA	pgp_inh	pgp_sub	hia	f20	f30	f50	OATP1B1	OATP1B3	BCRP	BSEP	BBB	MRP1	PPB	log VD _{ss}	Fu
ETM	-0.62	-5.24	-5.10	0.49	0.05	0.58	0.0	0.0	0.0	0.03	0.995	0.99	0.60	0.13	0.13	0.16	26.0	0.25	74.36
AFZ	-3.42	-6.09	-5.02	0.99	0.0	0.69	0.0	0.0	0.9	0.99	0.992	0.99	0.95	0.29	0.0	0.11	88.4	-0.05	10.83
QUE	-3.13	-6.04	-4.97	0.98	0.0	0.27	0.1	0.6	0.9	0.99	0.993	0.99	0.95	0.02	0.0	0.07	86.1	-0.06	12.88

Table 3: Metabolism and Excretion parameters for selected drugs calculated with Admet3.0.

CYP1A2 -inh	CYP1A2 -sub	CYP2C1 9-inh	CYP2C1 9-sub	CYP2C9 -inh	CYP2C9 -sub	CYP2D6 -inh	CYP2D6 -sub	CYP3A4 -inh	CYP3A4 -sub	CYP2C8 -inh	LM- human	cl- plasma	t 1/2	BCF	IGC50	LC50 DM	LC50FM	hERG	hERG- 10um
0.040	0.241	0.0	0.0	0.0	0.257	0.014	0.292	0.0	0.0	0.0	0.0	9.85	0.8	0.0	1.80	3.27	2.27	0.4	0.45
0.282	0.049	0.0	0.0	0.0	0.017	0.027	0.136	0.9	0.0	0.9	0.96	2.92	3.3	0.8	3.57	4.53	3.98	0.0	0.27
0.261	0.030	0.0	0.0	0.0	0.002	0.0	0.006	0.9	0.0	0.9	0.98	3.60	3.7	0.8	3.52	4.63	4.08	0.0	0.34

Table 4: Toxicity parameters for selected drugs calculated with Admet3.0.

DILI	Ames	ROA	FDAMDD	SkinSen	Carcino genicity	EC	EI	Respiratory	H-HT	Neuro toxicity-DI	Nephro toxicity-DI	Genotoxicity	RPMI 8226	A549	HEK 293
0.093	0.13	0.02	0.147	0.99	0.128	0.44	0.34	0.311	0.936	0.519	0.6307	0.0004	0.09	0.06	0.077
0.902	0.7	0.21	0.397	0.97	0.165	0	0.98	0.319	0.496	0.017	0.1156	0.9514	0.12	0.71	0.762
0.928	0.7	0.2	0.372	0.99	0.1	0	0.98	0.288	0.437	0.003	0.0684	0.946	0.07	0.91	0.558

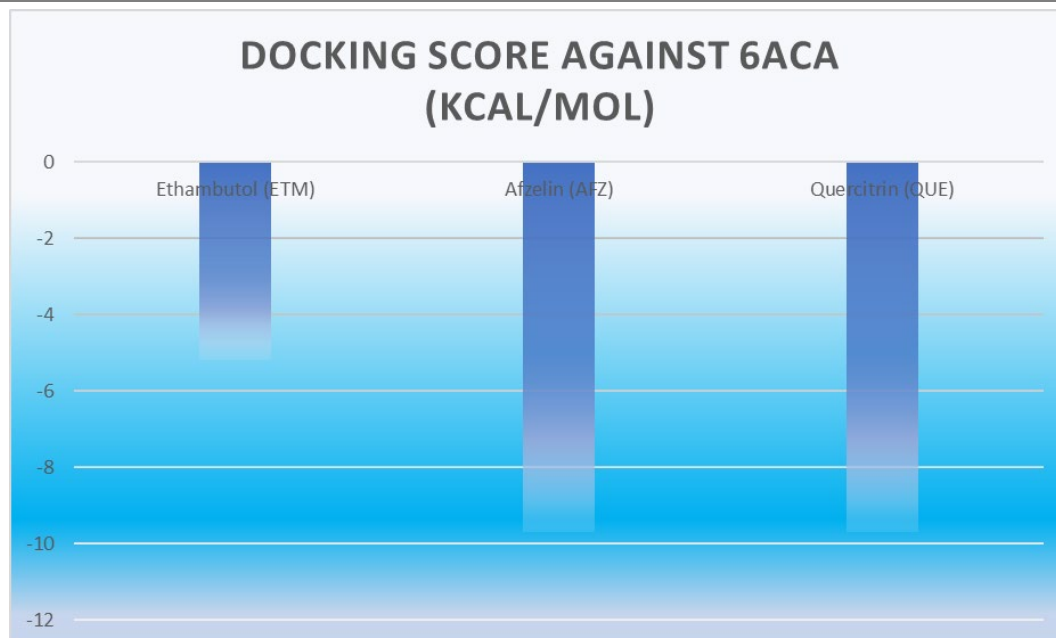


Figure 1: Comparative molecular docking score of selected compounds 1-3.

Drug target	Molecular docking pattern	
	Receptor Style: Surface	Receptor Style: Cartoon
ETM		
AFZ		
QUE		

Figure 2: Molecular docking pattern of selected target compounds 1-3 against 6ACA.

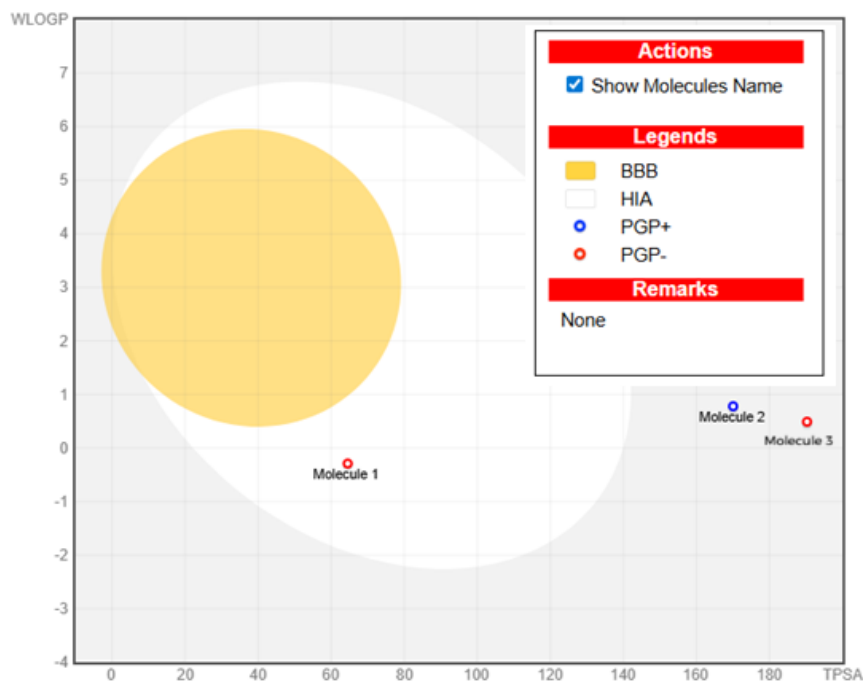


Figure 3: Boiled egg diagram for selected drug targets.

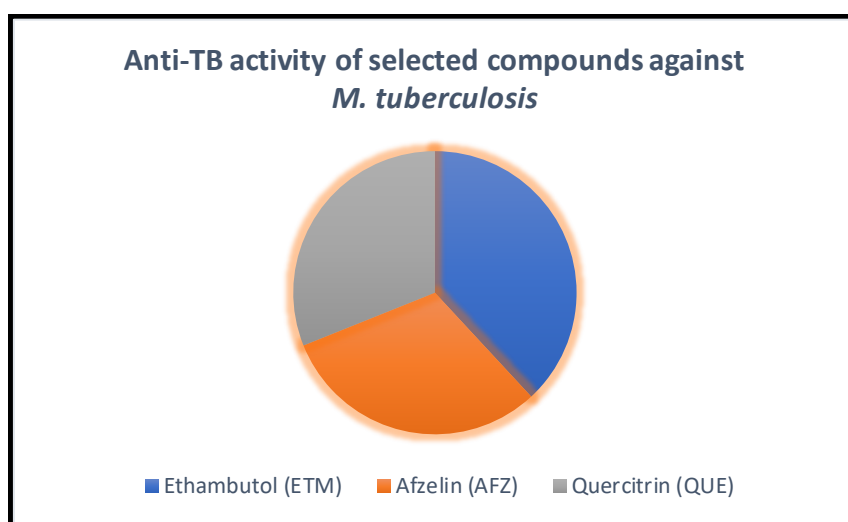


Figure 4: Anti-TB activity of selected compounds against *M. tuberculosis*.

The docking results against *M. tuberculosis* show that Ethambutol (ETM) has the strongest binding affinity, with a score of -4.895 . This suggests more favorable interactions with the target compared to the other compounds. On the other hand, Afzelin (AFZ) and Quercitrin (QUE) have relatively weaker binding energies at -3.958 and -3.992 , respectively, indicating lower interaction strength. Although the differences are not very large, ETM stands out as the more effective ligand against *M. tuberculosis* in this analysis (Fig. 4). AFZ and QUE may still have moderate inhibitory potential, but they are less potent than the standard drug. In the search for new anti-tuberculosis drugs, natural products from plants have gained significant interest in the pharmaceutical field [32-38]. This is due to their natural biological activities, especially their antimicrobial and antioxidant effects that can help fight Tuberculosis. Their wide therapeutic benefits, along with eco-friendliness, compatibility with living organisms, and lower environmental impact, make them strong candidates for creating safer and more effective anti-TB drugs.

This is particularly important given the increasing issue of antibiotic resistance.

4. Conclusion

Euphorbia hirta is an important medicinal plant that contains a variety of beneficial compounds. It shows a wide range of biological and health benefits, including antimicrobial, anticancer, and antidiabetic effects. Traditionally, it has been used to manage various health issues. In this study, we evaluated Afzelin (AFZ) and Quercitrin (QUE), which are naturally derived from the aerial parts of *E. hirta*. We looked at their physical and chemical properties, therapeutic potential, ADMET characteristics, and anti-tuberculosis activity against Tuberculosis. The results showed that both compounds have good physical and chemical properties, notable biological activity, and acceptable ADMET profiles. This supports their potential as drug candidates. Moreover, molecular docking studies against the 6ACA target indicated promising anti-TB potential, suggesting they could act as antibacterial agents. However, more in vitro, in vivo, and

clinical studies are needed to confirm these results. If clinical evaluations are successful, these compounds could become viable oral treatments. Additionally, modifying the structures and developing derivatives of AFZ and QUE might widen their use in various biomedical areas. This could help advance nature-based drug discovery, not just for tuberculosis but also for metabolic disorders like diabetes, though further validation is required.

Supplementary Materials

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Contribution

Rashmi: Concept, literature review, data interpretation, drafting the manuscript and approval for final submission.

Awadhesh Kumar: Data analysis, editing and approval for final submission

Mohd Yusuf: Concept, data analysis, editing, technical support, drafting the manuscript and approval for final submission and correspondence.

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Conflicts of Interest

The authors declare no conflict of interest.

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Review Article

Integrative Perspectives on Hypertension Management: A Comparative Analysis of Unani and Allopathic Systems

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ABSTRACT

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Background: Hypertension remains a major global health concern, affecting over 1.4 billion individuals worldwide and contributing significantly to cardiovascular morbidity and mortality. Allopathic medicine offers evidence-based diagnostic tools and pharmacological interventions for rapid blood pressure control, whereas Unani medicine emphasizes Mizaj (temperamental) balance, lifestyle modification, and natural therapeutics. Understanding the comparative philosophies of both systems can guide integrative, patient-centered hypertension management.

Objective: To critically compare the principles, diagnostic approaches, therapeutic modalities, and preventive strategies of hypertension management in Unani and allopathic systems, and to identify potential integrative pathways for improved outcomes.

Methods: A narrative review of classical Unani texts (Al-Qanun fi'l-Tibb, Al-Hawi fi'l-Tibb, Kamil al-Sana'a al-Tibbiyya) and contemporary literature from PubMed, Scopus, AYUSH, and WHO databases (2020-2025) was conducted. Around 61 peer-reviewed studies, clinical trials, and guidelines were analysed, focusing on pathophysiology, diagnosis, therapy, and prevention.

Results: Allopathy emphasizes standardized diagnosis and pharmacological management using ACE inhibitors, beta-blockers, and calcium channel blockers, supported by robust clinical evidence but limited by side effects and adherence issues. Unani medicine interprets hypertension as Ziyadat-e-Dam or Imtila' (vascular congestion and humoral excess) and manages it through Ilaj bil Ghiza (diet), Ilaj bil Tadbeer (regimens), and Ilaj bil Dawa (drugs). Overlaps include dietary moderation, exercise, and stress management. Unani agents such as Rauwolfia serpentina and Terminalia arjuna show reductions of 10-15 mmHg in systolic pressure when used adjunctively.

Conclusion: Integrating Unani and allopathic principles can provide sustainable, culturally sensitive, and evidence-informed strategies for global hypertension management.

1. Introduction

Hypertension, often referred to as the "silent killer," affects over 1.4 billion individuals worldwide and is responsible for nearly 10 million deaths annually. It is a chronic medical condition characterized by sustained elevation of arterial blood pressure, typically defined as systolic ≥ 140 mmHg or diastolic ≥ 90 mmHg according to standard clinical guidelines [1,2]. Despite the availability of effective pharmacological agents, control rates remain suboptimal due to poor adherence, lifestyle factors, and adverse effects. Globally, the prevalence of hypertension in adults exceeds 30%, with a disproportionately high burden in low- and middle-income countries [3].

Historically, the conceptualization of hypertension has evolved considerably. Modern medicine recognizes essential (primary) hypertension as a multifactorial disorder involving the renin-angiotensin-aldosterone system (RAAS), sympathetic nervous system overactivity, endothelial dysfunction, and genetic predisposition [4,5]. Well before the advent of allopathic medicine, traditional systems such as Unani medicine, rooted in Greco-Arabic traditions, conceptualized circulatory disorders through the principles of humoral theory and Mizaj

(temperament). Hypertension-like conditions were described as Imtila' (accumulation of morbid matter), Z'af al-Qalb (cardiac weakness), and Inhimar al-Dam (blood surging) [6].

The growing interest in traditional medicine stems from the limitations of long-term pharmacotherapy, including side effects, cost, and low adherence. The World Health Organization (WHO) has emphasized integrating traditional and complementary medicine into national health systems to promote holistic and culturally appropriate care [7]. Traditional systems like Unani focus on restoring systemic balance through lifestyle modification, diet, and natural therapeutics, offering valuable insights for sustainable, patient-centered care.

This review provides a comprehensive analysis of hypertension management in both Unani and allopathic systems. By examining their conceptual frameworks, diagnostic approaches, and therapeutic strategies, the paper aims to identify areas of convergence and highlight opportunities for integrative innovation to improve patient outcomes and public health.

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2. Methodology

Review Design

A narrative review approach was employed following the SANRA (Scale for the Assessment of Narrative Review Articles) guidelines to ensure methodological rigor and transparency. The review aimed to provide a structured comparative analysis of hypertension management in Unani and allopathic medical systems.

Data Sources and Search Strategy

Literature was retrieved from electronic databases, including PubMed, Scopus, AYUSH Research Portal, WHO Global Index Medicus, and ScienceDirect, covering the period 2020- 2025. Classical Unani texts such as *Al-Qanoon fi al-Tibb* by Ibn Sina and *Kitab al-Hawi* by Al-Razi were consulted in their original or translated Arabic/Urdu versions. Relevant reports and guidelines from the World Health Organization (WHO), American Heart Association (AHA), European Society of Cardiology/European Society of Hypertension (ESC/ESH 2023), and the Central Council for Research in Unani Medicine (CCRUM) were also included [8-11].

The electronic search strategy employed Boolean combinations of keywords such as: "Hypertension Unani", "Imtila' and blood pressure", "Herbal antihypertensives", "Unani cardi tonic drugs", "RAAS blockers", "Z'af al-Qalb", "Ilaj bil Tadbeer", and "Lifestyle and hypertension". These search terms were designed to encompass both theoretical and clinical perspectives of hypertension management across the two systems.

3. Inclusion and Exclusion Criteria

Inclusion criteria: Inclusion criteria: Peer-reviewed studies, clinical trials, and systematic reviews on hypertension management in Unani and allopathic systems. Classical Unani references (translated or original Arabic/Urdu texts). National and international clinical practice guidelines (e.g., WHO 2021, ESC/ESH 2023, AHA 2025, CCRUM 2023, JNC 7, JNC 8). [12,13,].

Exclusion criteria: Non-peer-reviewed, anecdotal, or editorial sources lacking scientific credibility. Duplicate studies or articles not available in English, Urdu, or Arabic translations.

Data Extraction and Thematic Analysis

A **thematic comparison** was performed under the following domains: Pathophysiological concepts, Diagnostic approaches, Therapeutic modalities, Preventive strategies, Integrative possibilities. The conceptual framework sees in the table 1.

Diagnostic Approaches

- **Unani Medicine:** Relies on pulse examination (*Nabz*), observation of complexion (*Lawn*), urine and stool characteristics, and patient temperament (*Mizaj*).
- **Allopathic Medicine:** Utilizes sphygmomanometry, ambulatory blood pressure monitoring, biochemical analysis, and imaging for secondary causes.

4. Therapeutic Modalities

A. Unani System

Ilaj bil Ghiza (Dietotherapy): Low-salt, light, and moist diet such as barley soup (*Jau ka yakhni*), pomegranate, cucumber, and garlic; avoidance of red meat and spicy food.

Ilaj bil Tadbeer (Regimenal Therapy): *Hijama* (cupping), *Fasd* (venesection), massage, exercise, and *Hammam* (steam bath) to regulate blood and remove waste humors.

Ilaj bil Dawa (Pharmacotherapy): Use of antihypertensive herbs such as *Rauwolfia serpentina* (Asrol), *Terminalia arjuna* (Arjun), *Allium sativum* (Lehsan), and *Coriandrum sativum* (Dhania) for vasodilation and blood purification.

B. Allopathic System

Evolution of Hypertension Concepts in Allopathic Medicine

The understanding of hypertension within modern (allopathic) medicine has evolved profoundly over the past century. Initially described as "essential hypertension" in the early 20th century, the condition was regarded as idiopathic, with no clear etiological basis [14]. However, contemporary research has established that hypertension is a complex, multifactorial disorder arising from dynamic interactions among genetic, neurohormonal, renal, vascular, and lifestyle-related determinants [15].

4. Key Physiological Systems Involved

a. Renin-Angiotensin-Aldosterone System (RAAS): The RAAS plays a pivotal role in blood pressure regulation and fluid-electrolyte balance. Hyperactivation of this system leads to vasoconstriction, sodium and water retention, and increased peripheral vascular resistance key mechanisms underlying sustained hypertension [16].

b. Sympathetic Nervous System (SNS): Chronic overactivity of the sympathetic nervous system (SNS) contributes to elevated heart rate, increased cardiac output, and peripheral vasoconstriction. Persistent sympathetic stimulation induces vascular remodelling, endothelial dysfunction, and cardiac hypertrophy, perpetuating hypertensive pathology [17].

c. Endothelial Dysfunction and Vascular Resistance: Endothelial dysfunction is central to the pathogenesis of hypertension. It involves reduced nitric oxide bioavailability, enhanced oxidative stress, and inflammatory activation, all of which promote vasoconstriction, arterial stiffness, and atherosclerosis [18].

5. Classification and Therapeutic Framework

Several authoritative classification systems including the Joint National Committee (JNC 8), American Heart Association (AHA), and European Society of Cardiology/European Society of Hypertension (ESC/ESH)-have provided diagnostic and therapeutic frameworks. The ESC/ESH 2023 guidelines define hypertension as sustained systolic blood pressure ≥ 140 mmHg or diastolic ≥ 90 mmHg, while the AHA's 2017 criteria adopt a lower threshold ($\geq 130/80$ mmHg) to enable earlier intervention [19].

The therapeutic approach prioritizes individualized management through pharmacological classes such as angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), beta-blockers, calcium channel blockers, and diuretics. Current clinical recommendations emphasize risk stratification, comorbidity assessment, and lifestyle modification as integral components of comprehensive hypertension care [13].

Diagnostic Tools

The diagnosis of hypertension in modern medicine is primarily clinical, based on repeated and standardized blood pressure measurements using a sphygmomanometer. Ambulatory

blood pressure monitoring (ABPM) and home blood pressure monitoring (HBPM) provide more representative assessments and help identify conditions such as white coat and masked hypertension [20]. Laboratory investigations, including renal function tests, lipid profiles, and electrocardiography (ECG), are integral for evaluating end-organ damage and identifying secondary causes.

6. Evolution of Hypertension Concepts in Unani Medicine

Unani medicine, the classical Greco-Arabian system, does not define “hypertension” as a discrete entity but interprets elevated blood pressure and its sequelae through various traditional concepts. The central pathological process is *Imtila'*, denoting an abnormal accumulation of humors or blood within the vessels due to over-nutrition, faulty digestion, or impaired elimination [21]. *Imtila'* is categorized as *Imtila' bi Hasb al-Kammiyat* (quantitative congestion) and *Imtila' bi Hasb al-Kayfiyat* (qualitative congestion), both leading to vascular overload and pressure-related manifestations [22].

Several Unani conditions parallel modern hypertensive states:

- **Zaf al-Qalb** (cardiac weakness) aligns with decreased myocardial efficiency.
- **Sudda** (vascular obstruction) corresponds to atherosclerotic narrowing.
- **Inhimar al-Dam** (blood surging) resembles hyperdynamic circulation or hypertensive crisis [23].

Clinical studies indicate that approximately 51.7% of patients with Grade I essential hypertension exhibit *Damvi Mizaj* (sanguine temperament), supporting the view that an excess of this hot-moist temperament predisposes to vascular disorders [24]. Emotional stress, anger, anxiety, rich and salty diets, and a sedentary lifestyle are key precipitating factors for *Imtila'* and related cardiovascular disturbances [25].

Classical scholars such as Ibn Sina (Avicenna) in *Al-Qanoon fi al-Tibb*, Al-Razi in *Kitab al-Hawi*, and Jurjani in *Zakhira Khwarzam Shahi* discussed cardiac dynamics, vascular tension, and pulse characteristics that prefigure the modern understanding of hypertensive pathology [26]. Thus, Unani medicine provides a systemic model linking temperament, lifestyle, and humoral imbalance to cardiovascular health.

7. Comparative Diagnostic Approaches in Unani and Allopathic Systems

Modern (Allopathic) Diagnostics

Hypertension diagnosis in allopathic medicine relies on accurate and repeated sphygmomanometric readings (digital or manual). ABPM and HBPM help assess diurnal variations and refine prognosis by detecting white coat and masked hypertension [27]. Laboratory evaluation serum electrolytes, renal function (creatinine, eGFR), lipid profile, and fasting glucose assists in identifying secondary hypertension and target-organ damage. Echocardiography and fundoscopic examination further evaluate complications such as left ventricular hypertrophy and hypertensive retinopathy [28].

Unani Diagnostics

In Unani practice, diagnosis is qualitative and holistic, based on *Mizaj* (temperament), *Nabz* (pulse), and *Baul/Baraz* (urine and stool characteristics). Pulse examination provides critical insight into blood quantity and quality, cardiac vigor, and congestion (*Imtila'*) patterns. Comprehensive clinical assessment also includes observation of complexion, tongue colour, emotional

state, and lifestyle reflecting the patient's *Tabiyat* (constitution) and humoral imbalance [29]. Although Unani medicine lacks invasive testing, it employs a sophisticated, codified system of clinical observation developed over centuries to identify vascular disturbances comparable to hypertension [30].

Integrative Reflections

Both Unani and allopathic frameworks emphasize early detection, systemic assessment, and risk-factor analysis. Emerging research seeks to integrate Unani pulse analysis with digital tonometry and correlate *Mizaj* with genetic and metabolic markers, offering promising directions for holistic diagnostic models [31].

8. Comparative Therapeutic Strategies in Unani and Allopathic Systems

Modern (Allopathic) Therapeutic Strategies

Contemporary management of hypertension follows evidence-based guidelines such as the 2023 European Society of Hypertension (ESH) and 2025 AHA/ACC recommendations. First-line drug classes include ACE inhibitors, angiotensin receptor blockers (ARBs), calcium channel blockers (CCBs), and thiazide or thiazide-like diuretics. Beta-blockers remain preferred for patients with concurrent ischemic heart disease or arrhythmias. The therapeutic goal is to maintain blood pressure below 130/80 mmHg, individualized to comorbidities and treatment tolerance [12].

Pharmacologic categories and mechanisms include:

- a. **ACE inhibitors** (e.g., enalapril, lisinopril)- inhibit the RAAS pathway and preserve renal function.
- b. **ARBs** (e.g., losartan, valsartan)- block angiotensin II receptors, reducing vascular resistance with fewer side effects.
- c. **CCBs** (e.g., amlodipine)- promote vasodilation via calcium channel blockade.
- d. **Thiazide diuretics** (e.g., hydrochlorothiazide)- decrease plasma volume and peripheral resistance.
- e. **Beta-blockers**- indicated in ischemic or arrhythmic conditions.

Lifestyle modification including sodium restriction, weight reduction, regular exercise, smoking cessation, and moderation of alcohol consumption remains a universal cornerstone of therapy [32].

Unani Therapeutic Strategies

Unani therapy for hypertension-related disorders focuses on eliminating the causative factor, *Imtila'* (vascular congestion), and restoring balance in the humors (*Akhlat*) and temperament (*Mizaj*). Treatment follows a holistic tri-modal approach, consisting of *Ilaj bil Tadbeer* (regimental therapy), *Ilaj bil Ghiza* (dietotherapy), and *Ilaj bil Dawa* (pharmacotherapy) [33,34].

a. *Ilaj bil Tadbeer* (Regimental Therapy)

Regimental therapy involves lifestyle and procedural interventions designed to correct humoral imbalance and enhance overall physiological harmony. Among these, *Hijama* (wet cupping) is particularly emphasized in Unani practice for conditions associated with *Imtila'* and hyperdynamic circulation.

b. Hijama (Wet Cupping)

Hijama is a traditional Unani technique in which localized negative pressure is applied using cups, followed by superficial skin incisions to draw small quantities of blood. This practice is believed to remove *Mawad-e-Fasida* (morbid humors), improve circulation, and restore homeostasis.

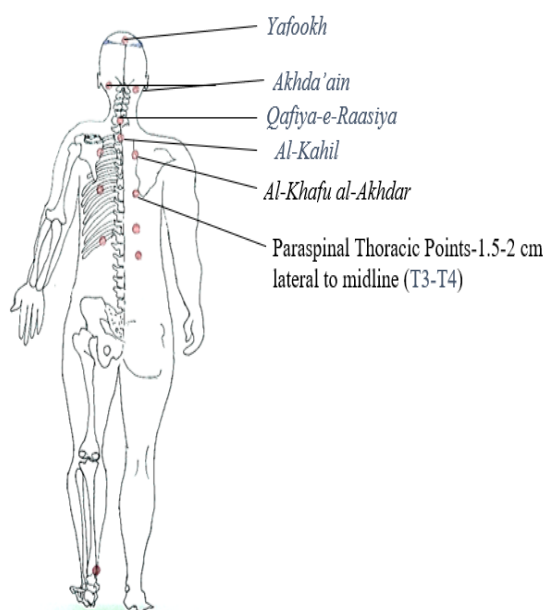
Procedure: The procedure begins with the preparation of the selected site commonly between the shoulders (*Al-Kahil*), the upper back, or disease-specific points which is sterilized thoroughly. A cup is applied to create negative pressure (traditionally using fire, or modern suction pumps), drawing blood toward the surface. Superficial scarifications are then made using a sterile blade, and the cup is reapplied to extract a small volume of blood. The site is subsequently cleaned and dressed, and the patient is advised to rest [35].

Clinical Case Study

A case published in the *Journal of Ayurveda and Integrative Medicine* reported a 42-year-old male with uncontrolled essential hypertension who underwent a series of Hijama sessions over the upper back and occipital region. After three sessions within four weeks, the patient's blood pressure improved significantly from an average of 162/98 mmHg to 138/86 mmHg without adverse effects. The improvement was attributed to the elimination of *Mawad-e-Fasida* and enhanced microcirculation induced by cupping. The authors concluded that Hijama could serve as an effective adjunctive therapy in hypertension management, while highlighting the need for larger controlled clinical studies [35].

Applications of Hijama in Hypertension

- Reduces blood pressure by decreasing blood volume and vascular resistance.
- Promotes relaxation and reduces sympathetic overactivity.
- Enhances cardiovascular efficiency and tissue perfusion.
- Serves as a complementary or adjunctive approach alongside modern antihypertensive drugs.
- Typically performed ten times at 15-day intervals at key anatomical sites-*Al-Kahil* (between the shoulders), *Akhda'ain* (lateral neck points), and *Yafookh* (vertex region) depending



on the clinical presentation and individual *Mizaj*.

Figure 1: Hijama (cupping) multiple points for hypertension.

Abbreviation:

Yafookh: Vertex of the head ((topmost point).

Akhda'ain: The two jugular veins (both sides of the neck).

Qafiya-e-Raasiya: Base of the skull.

Al-Kahil: Between the shoulders (C7–T1 vertebral region / upper back).

Al-Khafu al-Akhdar: Upper back, between scapulae.

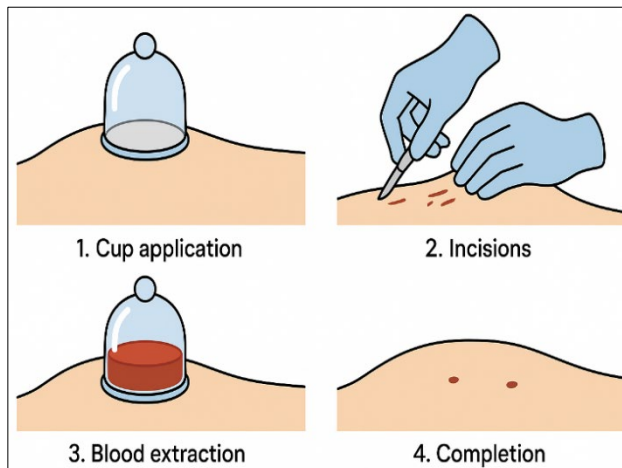


Figure 2: Procedure of Hijama (Wet Cupping); Improve circulation, reduce pressure, and restore balance in the body.

Table 1: Conceptual Framework

Spect	Unani Medicine	Allopathic Medicine
Disease Concept	<i>Ziyadat-e-Dam</i> (increase in blood volume or viscosity) and <i>Imtila'</i> (humoral congestion) leading to vessel tension and pulse elevation [9,10,14].	Persistent elevation of arterial pressure above normal physiological levels ($\geq 140/90$ mmHg) [8,11,12].
Etiology	Imbalance of humors (<i>Akhlat</i>), excess blood, improper diet, sedentary lifestyle, stress, and retention of waste humors [9,10,14].	Genetic predisposition, sodium retention, obesity, insulin resistance, endothelial dysfunction [8,11,12].
Pathogenesis	Derangement in <i>Mizaj</i> (temperament) and accumulation of morbid humors (<i>Akhlaat Fasadah</i>) causing vascular resistance [9,10,14].	Increased cardiac output and/or peripheral resistance leading to arterial stiffness [8,11,12].
Goal of Therapy	Restoration of humoral balance and temperament [9,10,13,14].	Blood pressure reduction to target levels and organ protection [8,11,12].

Table 2: Mechanistic Perspectives

Perspective	Mechanism of Action
Unani View	Removal of <i>Mawad-e-Fasida</i> (morbid matter), reduction of <i>Imtila'</i> (blood congestion), and restoration of humoral balance.
Modern View	Enhancement of microcirculation, modulation of the autonomic nervous system, reduction of oxidative stress, and improvement of vascular endothelial function.
Clinical Evidence	Preliminary studies suggest antihypertensive, analgesic, and detoxifying effects of Hijama, though large-scale randomized controlled trials are still warranted.

Table 3: Comparison of *Ilāj bil-Ghizā* (Unani dietotherapy) vs DASH & Mediterranean diets [50,51,47]

Domain	<i>Ilāj bil-Ghizā</i> (Unani dietotherapy)	DASH (Dietary Approaches to Stop Hypertension)	Mediterranean diet
Primary goal	Restore humoral balance; reduce <i>Mawād-e-Fāsida</i> and blood viscosity; prevent <i>Dagħṭ al-Dam</i>	Lower BP by reducing sodium and improving dietary pattern (fruits/veg/low-fat dairy)	Cardiometabolic risk reduction via high plant-food intake, healthy fats (olive oil), moderate fish/wine
Key recommended foods	Barley water, cucumber, pomegranate, spinach, seasonal fruits, vinegar preparations; emphasis on light, easily digestible foods	Fruits, vegetables, whole grains, low-fat dairy, lean poultry, nuts; low in red meat, sweets; sodium restriction (≤ 2300 mg/d typical in trials, lower recommended clinically)	Vegetables, fruits, legumes, whole grains, nuts, olive oil primary fat, moderate fish/poultry, low red/processed meat
Foods commonly discouraged	Salted, fried, heavy (<i>ghalīz</i>) foods, excessive meat, deep-fried preparations	High-sodium foods, processed meats, sugar-rich foods	Excessive processed foods, high red/processed meat, refined carbs
Mechanisms (Unani description and modern physiology)	Reduce blood thickness and stagnation (Unani)- lowers blood viscosity, enhances microcirculation, and decreases sympathetic activity, promoting smoother blood flow, better tissue perfusion, and improved cardiovascular efficiency.	Reduced sodium lowers plasma volume and vascular resistance, while higher potassium, calcium, and magnesium improve vascular tone, relaxation, and endothelial function, supporting cardiovascular health.	An increased intake of monounsaturated fats and polyphenols enhances endothelial function, reduces vascular inflammation, and decreases arterial stiffness.
Typical effect on BP (evidence) Evidence type & quality	Case reports/case series: clinically meaningful reductions reported (variable; uncontrolled). Evidence level: low (case-level). Traditional texts+ case reports; need larger RCTs and standardized protocols	RCTs/meta-analyses: SBP reductions 5-11 mm Hg (varies by baseline BP and adherence). Evidence level: high (multiple RCTs). Large RCTs (DASH), multiple meta-analyses of RCTs	RCTs/meta-analyses (eg, PREDIMED): modest SBP reductions (~3-6 mm Hg) and broader cardiovascular risk reduction. Evidence level: high-moderate. Large RCTs (PREDIMED), many observational and RCT data
Practical implementation notes	Personalize to temperament (<i>mizāj</i>), seasonal advice, prefer light cooking methods (boiled/steamed), use barley water, seasonal fruits; Monitor electrolytes.	Structured meal plans, emphasis on sodium reduction, dietary counselling improves adherence.	Encourages olive oil use, nuts, plant-forward meals; culturally adaptable; beneficial for overall CV risk.
Safety considerations	Monitor for unintended weight loss, electrolyte imbalance if extreme changes; ensure nutritional adequacy	Ensure potassium, magnesium balance in special populations (renal disease).	Monitor caloric intake; in some patients, fat intake adjustments may be needed (eg, hypertriglyceridemia)

c. *Fasd* (Venesection)

Fasd, or therapeutic venesection, is an established regimen in Unani medicine classified under *Ilāj bil Tadbeer* (regimental therapy). This procedure entails a controlled incision of a

superficial vein to evacuate *Akhlaat-e-Fasida* (morbid humours), thereby alleviating *Imtila'* and restoring humoral balance. It is regarded as one of the more potent interventions in regimental therapy for circulatory and congestion-related disorders.

Case Reports and Clinical Observations

Case 1: Ali et al (2022) reported on the application of Fasd in *Irq-Un-Nasa* (sciatica). In this case series, two patients underwent venesection of the saphena minor vein twice weekly for two consecutive sessions. Follow-up was conducted telephonically over two months. Both patients experienced significant symptomatic relief without recurrence, suggesting that Fasd may offer therapeutic benefit in neuralgia via humoral drainage [36].

Case 2: A randomized intervention by Jeitler et al (2022) offers relevant modern clinical evidence supporting the traditional Unani use of Fasd in hypertension. In this trial, scheduled therapeutic phlebotomy was performed in individuals with Grade 1 hypertension, resulting in statistically significant reductions in blood pressure. The outcomes align with classical Unani indications for *Ḍagħṭ al-Dam Qawi* (strong vascular pressure) and support the mechanistic rationale of Fasd in hypertension management [37].

Mechanistic and Therapeutic Insights

- **Unani Perspective:** Fasd is believed to directly remove excess or pathological humours, thereby alleviating vascular load and restoring *Mizaj* balance.
- **Modern View:** Therapeutic phlebotomy (comparable to Fasd) may reduce blood volume, lower haematocrit, improve blood rheology, and diminish peripheral resistance mechanisms relevant to blood pressure reduction.
- **Clinical Relevance:** While Fasd has historical precedent in Unani literature, controlled trials in hypertension are sparse. The study by Jeitler et al (2022) provides preliminary evidence that venesection may be a viable adjunct to standard antihypertensive therapy in selected patients with mild hypertension [37].

Here; Table 2 outlines the mechanistic perspectives of hypertension management, contrasting Unani principles with modern biomedical interpretations and supporting clinical evidence.

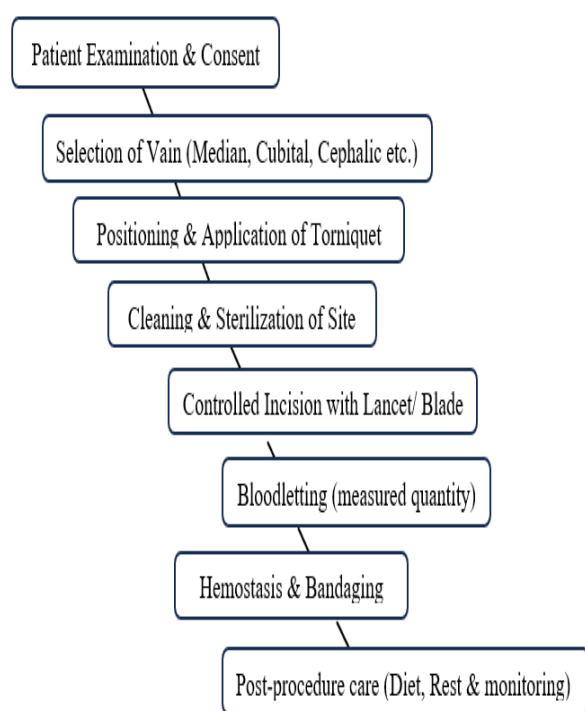


Figure 3: Fasd (Venesection) Procedure- Flowchart

9. Unani Therapeutic Strategies: Dalak, Riyāzat, Hammām, and Dietotherapy

Dalak (Massage)

In Unani medicine, **Dalak** (massage) is traditionally advocated to harmonize humors, enhance blood circulation, relieve stress, and reduce factors associated with *Ḍagħṭ al-Dam* (hypertension). Modern evidence increasingly supports these views: massage therapy has been shown to modulate autonomic balance (increasing parasympathetic tone), induce relaxation, reduce muscle tension, suppress sympathetic activity, and improve peripheral circulation [38].

A recent meta-analysis of randomized controlled trials involving 290 participants (148 in massage groups, 142 controls) found minimal reductions in both systolic and diastolic blood pressure. However, high heterogeneity among studies suggested the need for more standardized research protocols. The standardized mean differences (SMD) reported were: SBP: -0.65 mm Hg (95% CI: -4.75 to 3.55); DBP: -0.68 mm Hg (95% CI: -2.43 to 1.06) [39].

Riyāzat (Exercise)

In Unani medicine, *Riyāzat* (exercise) is regarded as a pivotal preventive and therapeutic regimen (*Ilāj bi'l-Tadbīr*) for maintaining humoral balance, promoting healthy circulation, and preventing the accumulation of morbid matter (*Mawād-e-Fāsida*). Classical Unani physicians such as Ibn Sīnā emphasized the role of regular, moderate exercise in strengthening the heart and vessels, enhancing digestion, and preserving overall vitality.

In the context of *Ḍagħṭ al-Dam* (hypertension), exercise is believed to reduce excessive heat and viscosity of blood, improve metabolic activity, and alleviate mental stress factors closely associated with elevated blood pressure. By stimulating the elimination of waste materials and optimizing circulation, *Riyāzat* supports the restoration of *Mizāj* (temperament) and vascular equilibrium [40].

Modern evidence substantiates these traditional insights. Regular physical activity has been shown to lower blood pressure by improving endothelial function, increasing nitric oxide bioavailability, reducing arterial stiffness, and modulating autonomic activity. A recent meta-analysis (2024) demonstrated that both aerobic and resistance training significantly reduced systolic and diastolic blood pressure among hypertensive patients, confirming the efficacy of structured exercise programs in cardiovascular regulation [40].

Case Study

A case reported in the *Hippocratic Journal of Unani Medicine* described a 42-year-old male with newly diagnosed hypertension presenting with headache and disturbed sleep. The patient underwent a 7-day course of *Naṭūl* therapy (therapeutic walking in shallow water), resulting in meaningful reductions in blood pressure, relief from head heaviness, and improved sleep quality. This observation illustrates the therapeutic potential of traditional Unani exercise regimens in early hypertension management [41].

Contemporary clinical evidence parallels these findings. A systematic review and meta-analysis of randomized controlled trials revealed that consistent aerobic and resistance training produce significant reductions in both systolic and diastolic blood pressure through enhanced endothelial function, greater nitric oxide release, decreased arterial stiffness, and improved autonomic balance [40]. These outcomes align closely with Unani

principles describing exercise as a means of humoral balance and cardiovascular harmony.

Hammām (Steam Bath)

In **Unani medicine**, *Hammām* (steam bath) is a classical *Ilāj bi'l-Tadbīr* (regimental therapy) employed to reduce excess blood (*Imtilā'*), relieve vascular congestion, and restore humoral equilibrium. The therapy involves exposure to controlled steam to induce perspiration, promote relaxation, and facilitate the excretion of waste materials (*Mawād-e-Fāsida*). It is traditionally recommended for patients exhibiting symptoms of *Ḍaght al-Dam* (hypertension), especially when associated with stress, irritability, or disturbed sleep [42].

From a physiological perspective, *Hammām* promotes vasodilation of superficial blood vessels, reduces peripheral resistance, and enhances cutaneous circulation. The induced relaxation response also modulates autonomic balance by lowering sympathetic tone and supporting parasympathetic activation mechanisms that contribute to blood pressure reduction and cardiovascular well-being.

Case Study

A case published in the *Hippocratic Journal of Unani Medicine* described a 50-year-old hypertensive male presenting with headache, irritability, and insomnia. The patient underwent a 10-day course of *Hammām* therapy, consisting of daily steam bath sessions lasting 15-20 minutes under supervision. Following the regimen, there was a marked reduction in both systolic and diastolic blood pressure, improved sleep quality, and relief from stress-related symptoms. No adverse effects were reported during or after the treatment. These findings highlight the potential of *Hammām* as a safe, non-pharmacological adjunct in integrative hypertension management [42].

10. Ilāj bil Ghiza (Dietotherapy)

Dietotherapy in Unani medicine holds a primary place in chronic conditions like *Ḍaght al-Dam* (hypertension). Classical texts such as *Al-Qānūn fi'l-Ṭibb* and *Kāmil al-Ṣanā'ah al-Ṭibbiyyah* recommend regulation of diet to maintain humoral equilibrium, avoid accumulation of *sauda* (black bile) and excessive *dam* (blood), and reduce dietary contributors to vascular heaviness [43]. Foods described as light (*latīf*), easily digestible, blood-purifying (*musaffī-e-dam*), blood-reducing (*muqallil-e-dam*), and deobstruent (*mufattiḥ*) are preferred. Heavy, salted, fried, or overly rich foods are discouraged as they are thought to thicken blood, impair vascular flow, and worsen elevated pressure. Modern nutrition research aligns with these recommendations: diets rich in fruits, vegetables, low in sodium, and whole grains (e.g., the DASH and Mediterranean diets) have been shown to reduce both systolic and diastolic blood pressure significantly in diverse populations [44,45]. Case-based evidence from Unani literature also supports this: for example, a patient managed primarily through diet regulation, including salt restriction, consumption of barley water, and seasonal fruits, reported improvements in symptoms (headache, dizziness) and measurable blood pressure reductions [46].

Integrative Perspective

The integration of Unani holistic regimens with allopathic pharmacotherapy offers a comprehensive approach to managing hypertension by addressing both symptomatic control and underlying pathophysiological imbalances [34]. Such an

integrative model harmonizes evidence-based interventions from both systems, enhancing therapeutic efficacy and patient well-being.

Hijāmah (cupping) and Ilāj bil-Tadbīr (regimental therapy) have been shown to improve microcirculation, modulate autonomic balance, and enhance stress resilience. The key factors implicated in the pathogenesis of hypertension [35]. *Hammām* (steam therapy) and other heat-based regimens promote relaxation, vasodilation, and improved endothelial function, potentially reducing blood pressure through nitric oxide-mediated vascular modulation and stress reduction mechanisms [47].

Herbal formulations, such as *Rauwolfia serpentina*, traditionally used in Unani and Ayurvedic systems, exhibit established antihypertensive properties and have led to the discovery of pharmacologically active compounds like reserpine, bridging traditional and modern therapeutics [48].

Unani dietary principles emphasize moderation, salt restriction, and consumption of *latīf* (light) and *musaffī-e-dam* (blood-purifying) foods, closely aligning with modern dietary frameworks such as the DASH and Mediterranean diets, thereby offering synergistic cardiovascular benefits [49].

A structured integrative hypertension management model could include:

- **Primary Screening and Diagnosis** using allopathic clinical and diagnostic protocols.
- **Adjunct Unani Regimens (*Ilāj bil-Tadbīr*)** focusing on detoxification, lifestyle correction, and stress management.
- **Herbal Adjuvants** for mild to moderate hypertension, tailored according to *Mizāj* (temperament) and individual risk profiles.
- **Continuous Monitoring** through standardized, evidence-based parameters combining both biomedical and traditional health indicators to ensure safety, efficacy, and long-term blood pressure control.
- *Ilāj bil-Ghizā*, the Unani principle of dietary management, emphasizes individualized nutrition aimed at restoring humoral balance and maintaining cardiovascular health. Its core philosophy aligns with the preventive focus of modern dietary models such as the DASH and Mediterranean diets, both of which are clinically proven to reduce blood pressure and cardiovascular risk. The following table (**Table 3**) presents a comparative overview of the Unani dietary approach and these evidence-based modern diets, highlighting key similarities and distinctions in composition, principles, and therapeutic outcomes.

Ilāj bil Dawa (Pharmacotherapy)

In Unani medicine, pharmacotherapy focuses on correcting underlying humoral imbalances, reducing *Imtilā'*, strengthening cardiac function, and regulating blood flow. Commonly prescribed Unani antihypertensive and cardiogenic herbs include *Zarnab* (*Taxus baccata*), *Sankhaholi* (*Evolvulus alsinoides*), *Gul-e-Arman* (*Carthamus tinctorius*), and *Asrōl* (*Rauwolfia serpentina*), the latter being a well-known source of the antihypertensive alkaloid reserpine [52]. The Unani approach emphasizes long-term restoration of physiological equilibrium rather than mere symptomatic relief, thereby offering a holistic and preventive perspective. Recent studies indicate that combining Unani herbal therapies with conventional antihypertensive medications may improve therapeutic outcomes, reduce adverse effects, and

enhance patient adherence. Such integrative strategies aim to synergize the corrective, preventive focus of Unani pharmacotherapy with the rapid efficacy of modern drugs. However, robust, large-scale clinical trials are required to validate the safety, efficacy, and optimal protocols for these integrative approaches [53].

12. Challenges in Integrative Hypertension Management

1. Scientific Validation

Despite promising therapeutic outcomes reported for both Unani and allopathic systems in hypertension management, the scientific validation of Unani interventions remains insufficient. A major limitation is the lack of large-scale, multicentric randomized controlled trials (RCTs) meeting contemporary evidence-based medicine standards. Most Unani antihypertensive therapies, comprising herbal, dietary, and regimental components, are supported primarily by observational studies or small-scale trials, limiting their translational value and global recognition. Strengthening pharmacological, toxicological, and clinical evidence through standardized methodologies is essential to establish Unani treatments within integrative frameworks. This need is further underscored by growing consumer interest and demand for traditional and integrative medicine worldwide [54].

2. Divergent Diagnostic and Therapeutic Philosophies

A fundamental barrier to integration arises from the philosophical differences in diagnosis and treatment paradigms. Allopathic medicine relies on measurable, quantifiable parameters such as systolic and diastolic blood pressure levels to determine disease severity and therapeutic efficacy. Conversely, Unani medicine adopts a qualitative, individualized diagnostic model, focusing on temperament (*Mizaj*), humoral imbalance (*Akhlat*), and systemic congestion (*Imtila*) [55]. These contrasting principles, while valuable within their own contexts, often create challenges in developing unified diagnostic criteria or shared treatment protocols in clinical practice.

3. Regulatory and Policy Constraints

Regulatory inconsistencies and fragmented policy frameworks further hinder the integration of Unani medicine into mainstream healthcare. In many regions, Unani systems lack globally harmonized standards for formulation quality, safety evaluation, and clinical certification. The absence of dedicated regulatory bodies and limited inclusion of Unani pharmacopoeia in international drug compendia impedes access to validated formulations. Additionally, the scarcity of structured integrative training programs restricts clinicians' capacity to apply both systems synergistically in patient care. Addressing these gaps is crucial for implementing safe and evidence-based integrative hypertension management strategies [56].

4. Patient Perception and Trust

Patient perception plays a pivotal role in shaping the success of integrative models. Cultural beliefs, social background, and prior healthcare experiences influence whether individuals trust Unani, allopathic, or combined approaches. In some populations, skepticism toward traditional therapies persists due to concerns about standardization and efficacy, whereas in others, Unani medicine is perceived as more 'natural' and holistic. Evidence from clinical trials comparing Unani formulations with conventional antihypertensive drugs can help build confidence in integrative strategies and enhance patient engagement, shared

decision-making, and adherence—key components of sustainable hypertension management [57].

5. Standardization of Unani Therapies

Perhaps the most critical scientific challenge lies in the standardization of Unani formulations and regimental therapies. Many preparations are individualized, with variations in dosage, plant source, and compounding methods across practitioners. Such heterogeneity complicates reproducibility, dosage accuracy, and safety profiling. Establishing standard operating procedures (SOPs) for the identification, processing, and quality control of Unani drugs, coupled with modern analytical tools such as HPLC and LC-MS, could enhance reproducibility and promote clinical credibility, while still respecting the principles of temperament-based individualized care central to Unani medicine [58].

Prospects for Integrative Hypertension Management

Holistic and Root-Cause-Oriented Approach

Integrating the Unani emphasis on holistic well-being and humoral balance with the precise pharmacological control of allopathic medicine can substantially improve therapeutic outcomes. The Unani concept of *Imtila* (vascular congestion resulting from humoral imbalance) parallels biomedical mechanisms such as endothelial dysfunction, increased peripheral resistance, and oxidative stress. By addressing these root causes through dietary regulation (*Ilaj-bil-Ghiza*), detoxification, and regimental therapy (*Ilaj-bil-Tadbeer*), Unani medicine offers a multidimensional, preventive approach that complements modern pharmacological strategies focused primarily on symptom control. This convergence promotes not only blood pressure regulation but also systemic balance, stress reduction, and metabolic optimization, supported by molecular and systems pharmacology evidence of Unani antihypertensive herbs [59].

Synergistic Therapeutic Potential

Emerging pharmacological studies reveal potential synergistic interactions between Unani herbal drugs and contemporary antihypertensive agents. Asrol (*Rauwolfia serpentina*), a classical Unani remedy, contains reserpine and related alkaloids that act synergistically with angiotensin-converting enzyme (ACE) inhibitors or calcium channel blockers to enhance vasodilation and reduce vascular resistance. Other botanicals such as *Terminalia arjuna*, *Allium sativum*, and *Cinnamomum zeylanicum* have shown additive effects on lipid modulation and endothelial function. These combinations may enhance efficacy, lower required dosages, and minimize adverse effects. Nevertheless, comprehensive pharmacodynamic and pharmacokinetic evaluations are essential to ensure safety, dose compatibility, and long-term tolerability. [60].

Patient-Centered and Personalized Care

Integrative hypertension management aligns naturally with the patient-centered care paradigm. Unani medicine customizes interventions according to an individual's temperament (*Mizaj*), comorbidities, and psychosocial factors, while modern medicine contributes targeted pharmacological precision. This biopsychosocial integration fosters stronger therapeutic alliances, promotes adherence, and enhances quality of life in chronic hypertensive patients. Personalized care combining temperament-based regimens, modern diagnostics, and lifestyle modification ensures sustainable disease control and improved patient satisfaction [61].

Advances in Integrative Research and Evidence Generation

Recent interdisciplinary research is elucidating the molecular mechanisms underlying Unani formulations and their bioactive constituents. Advanced tools such as network pharmacology, metabolomics, and molecular docking are being employed to validate traditional formulations, identify novel drug targets, and assess safety profiles. Studies on classical Unani preparations like *Dawa-ul-Misk Motadil* and *Khamira Abresham Hakim Arshad Wala* have demonstrated cardiogenic and antihypertensive activity through nitric-oxide modulation and calcium-channel regulation. Standardized clinical protocols, combined with data-driven frameworks, are progressively bridging traditional wisdom with contemporary scientific evidence [60].

Future Directions

The advancement of integrative hypertension management requires a structured, evidence-based approach emphasizing both traditional efficacy and modern validation.

Key priorities include:

- Conducting large-scale, multicentric clinical trials on standardized Unani antihypertensive formulations.
- Developing unified diagnostic and treatment guidelines integrating Unani and modern parameters.
- Establishing robust regulatory and pharmacovigilance frameworks for herbal-drug standardization.
- Promoting clinician training and patient education on safe, integrative practices.
- Bridging classical Unani wisdom with modern scientific rigor holds immense potential for developing a sustainable, patient-centered, and globally applicable model for hypertension prevention and management.

Conclusion

Integrative management of hypertension represents a transformative paradigm that unites traditional Unani principles of balance and purification with evidence-based biomedical therapies. This multidimensional model not only addresses the physiological and molecular aspects of hypertension but also incorporates lifestyle, psychosocial, and preventive dimensions creating a holistic and globally relevant framework for cardiovascular health promotion.

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Conflict of Interest

The authors declare no conflict of interest related to this work.

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Authors' Contribution

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Glossary:

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|---|---|----------------------------------|
| • <i>Ziyadat-e-Dam</i> - Hypertension. | • <i>Hijama</i> - Cupping Therapy. | • <i>Hammam</i> - Steam bath, |
| • <i>Fasd</i> - Phlebotomy, | • <i>Hijama</i> - Cupping Therapy. | • <i>Riyazat</i> -Exercise, |
| • <i>Istifragh</i> - Evacuation or Expulsion. | • <i>Akhlat</i> - Humours. | • <i>Mizaj</i> -Temperament, |
| • <i>Z'af al-Qalb</i> - cardiac weakness. | • <i>Inhimar al-Dam</i> - blood surging. | • <i>Raas</i> - Head, |
| • <i>Imtila</i> - Congestion. | • <i>Akhlat</i> - Humours. | • <i>Nabz</i> - Pulse, |
| • <i>Baul</i> - urine. | • <i>Baraz</i> - Stool. | • <i>Irq-Un-Nasa</i> -sciatica, |
| • <i>Ilaj bil Ghiza</i> - Diet. | • <i>Ilaj Bil Dawa</i> - Unani medicine. | • <i>Mufattiḥ</i> - deobstruent, |
| • <i>Mizaj Haar Ratb</i> - Moist temperament. | • <i>Ilaj-bit-Tadbeer</i> - Regimental therapy, | |
| • <i>Mawad-e-Fasida</i> -Morbid humour. | • <i>Naṭūl</i> - walking in shallow water, | |
| • <i>Musaffī-e-dam</i> -blood-nurifying. | • <i>Muaallil-e-dam</i> blood-reducing. | |



Perspective

Indian Knowledge System: Perspectives on Integration in the Higher Education System

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ABSTRACT

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The Indian Knowledge System (IKS) includes the applicability of applied science, economics, astronomy, disease-curing, music, arts, social culture etc., and is one of the oldest and most detailed intellectual traditions in the world. The oldest sources of Indian knowledge are the Vedas that give the key paradigm of the spiritual, philosophical, and scientific inquiry. Knowledge has always been considered to be the decisive benefit that is utilized for the beneficial works to serve mankind since prehistoric times. The review highlights the multidisciplinary facets of IKS and its modern aspects in the Higher Education System.

1. Introduction

The Indian Knowledge System (IKS) is a very extensive intellectual tradition that has played an enormous role in the establishment of basic sciences like mathematics, astronomy, physics, chemistry and life sciences. Many of the ancient Indian thinkers had evolved advanced theories regarding numbers, algebra, astronomy, metallurgy, medicine and ecological equilibrium, way before the advent of the modernistic scientific systems. Such contributions were recorded in the classical texts, such as the Vedas, the Upanishads, the Sulbasutras and other treatises authored by other scholars like Aryabhata, Bhaskara, Charaka and Sushruta [1-3]. The Indian Knowledge System is a holistic tradition of science as it incorporates empirical observation, philosophical reasoning, and practical applications. Over the last few years, one may observe a revival in the idea of reconsidering these old systems of knowledge to learn how they can be applied in modern scientific studies and education. This review describes significant contributions of the Indian Knowledge System to basic sciences (mathematics, astronomy, chemistry, metallurgy, and life sciences) [2-5]. It also talks about scientific methodologies found in the ancient Indian literature and how the ideas of these methods apply to interdisciplinary research nowadays. Knowing the scientific premises of the Indian Knowledge System may assist in reconciling the traditional wisdom with modern science towards sustainable development and innovation.

The Indian Knowledge System (IKS) is a broad collection of knowledge that was created in the Indian subcontinent over thousands of years. This body of knowledge is a broad field and includes areas of philosophy, mathematics, astronomy, medicine,

agriculture, architecture, linguistics, and environmental science. With the help of systematic observation, logical thinking, and experimentation, ancient Indian scholars have contributed to the formation of the basic rules of science. The Indian Knowledge System has a holistic approach to knowledge, unlike the contemporary discipline of science, which tends to separate knowledge into various special areas. Scientific concepts were commonly infused into a religious and philosophical framework, but most of these concepts reveal startling empirical accuracy and mathematical precision. Some of the ancient Indian literature holds useful information which was associated with scientific knowledge (Fig. 1). Indicatively, the Vedas, Upanishads, Sulbasutras, Aryabhatiya, and Charaka Samhita contain the discussion on mathematical concepts, astronomical observations, medical practices and natural phenomena. Through these readings, it becomes clear that ancient Indian scholars were more highly developed in the field of geometry, number systems, planetary movement, metallurgy and biological sciences. Indian scholars like Aryabhata, Brahmagupta, Bhaskara II, Sushruta and Charaka had a significant influence on the evolution of scientific philosophy (Fig. 1) [2-4]. Their exchange of knowledge with the Arab world and later Europe during the medieval period had a great influence on the scientific traditions of other civilizations and many of their ideas found their way there. Scholars and policymakers in the past decades have stressed the significance of applying the traditional knowledge systems along with contemporary scientific education. The resurgence of the Indian Knowledge System is also an effort to find the scientific knowledge available in ancient times and look into its possible use in modern research, sustainability, and technological development. This review discusses the key contributions the Indian Knowledge

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System made to the basic sciences and mathematics, astronomy, chemistry, metallurgy, and life sciences. It also gives emphasis on the scientific approach that was inherent in the ancient Indian knowledge traditions.



Figure 1: Illustration of the Indian Knowledge System (IKS) applicability in Ancient India.

2. Contributions to Mathematics

Mathematics is one of the most prominent contributions of the Indian Knowledge System to the development of world science. Early Indian mathematicians were the earliest to discover number theory, algebra, geometry and trigonometry. Aryabhata (476 CE) contributed a lot to trigonometry and algebra. He created the concept of sine functions in his *Aryabhatiya* and gave correct astronomical computations. These ideas were later extended by other mathematicians like Brahmagupta and Bhaskara II, who devised ways of solving quadratic equations and arithmetic progressions. Probably one of the most important contributions made by Indian mathematics is the concept of zero and the decimal number system. Zero and its operation were first defined by the Hindu astronomer and mathematician. Brahmagupta in 628 CE [6]. The invention of the place-value system enabled the effective representation of huge numbers and complicated mathematical operations. This system was later brought to the Arab world, which then spread to Europe, where it formed the basis of modern arithmetic. Vedic altar construction. Geometric constructions as described in the *Sulbasutras*, c. 800-500 BCE, were used to construct Vedic altars. These texts contain techniques to draw squares, rectangles, and circles and approximations of the square root of two. Other scholars believe that these texts have early forms of the Pythagorean theorem. These mathematical inventions heavily impacted the evolution of scientific thinking throughout the world, and they still form the foundation of modern mathematical systems.

3. Contributions to Astronomy

Aryabhata also hypothesized the rotation of the Earth on its axis, and this caused the observed movement of the stars in the sky. This concept was a challenge to previous geocentric interpretations and was a sign of an advanced knowledge of celestial mechanics. One more well-developed area of ancient India was astronomy. Indian astronomers made a good study on the motion of the planets, eclipses and celestial cycles. These observations were frequently compiled as astronomical treatises

called *Siddhantas*. The Indian astronomers also arrived at the correct ways of determining the positions of the planets and determining the solar and lunar eclipses. One of the most significant astronomical books, *Surya Siddhanta*, provides a detailed description of planetary orbits, the measure of time and trigonometric formulas which were used in astronomical observations. Besides the theory of astronomy, Indian scholars invented useful astronomical devices to tell time and the positions of stars. These tools were subsequently perfected in the medieval era, especially in the astronomic observatories established by Maharaja Jai Singh II in the eighteenth century. Indian astronomers made numerous contributions to the traditions of astronomy in the Islamic world, which eventually passed this knowledge to Europe during the Renaissance.

4. Contributions to Metallurgy

Distillation was also among the earliest methods of producing zinc, which was later done in India. Archaeological findings in India at the Zawar mines of Rajasthan have shown that a vast production of zinc was being done in the country centuries before it was recorded in Europe. These metallurgical accomplishments signify the empirical and experimental methods taken by ancient Indian intellectuals and craftsmen in their investigation of materials and chemical operations. Early chemistry and metallurgy also greatly contributed to ancient India. The chemical knowledge of the Indian tradition was usually equated with *Rasashastra*, a part of the study that dealt with metals, mineral and chemical processes. The metallurgists in India came up with sophisticated methods of mining and refining metals, including iron, copper, zinc, and gold. The Iron Pillar of Delhi is one of the most renowned relics of Indian metallurgical skill in the Indian subcontinent, dating back over 1600 years and has not corroded at all. The pillar shows the great degree of metallurgical skills that were held by Indian craftsmen in ancient times.

5. Perspectives of Integration of IKS in the Higher Education System

The National Education Policy (NEP) 2020 is a major landslide in the revitalization and inclusion of the Indian Knowledge System (IKS) into the modern educational system of India. It is one of the policies that puts a vehement emphasis on the inclusion of traditional Indian knowledge in all levels of education, including school education, up to higher education. NEP 2020 has acknowledged the value of the intellectual tradition of India and the intention to systematically bring disciplines like ancient sciences, philosophy, arts, linguistics and traditional technologies to the contemporary academic curriculum. The policy attempts to fill the divide between classical knowledge traditions and modern scientific inquiry by promoting interdisciplinary learning and contextual education. The Government of India realized the need to provide more institutional support to IKS, and accordingly, increased financial allocation towards Indian Knowledge Systems by a great margin. The budget of 2022-2023 in the Union Budget has raised the amount spent on IKS initiatives to about 20 crores, which indicates that the government takes traditional knowledge system research, education, and distribution seriously. In addition, marketing of IKS has been included under larger national development programs like the Vision 2047 and *Bharatiya Rasayanashastra*, to investigate the role of Indian chemical sciences in the modern scientific research and innovation. The

initiative is a sign of increasing interest in reviving traditional science and considering how it can be used in the context of the current scientific and technological evolution.

The National Credit Framework (NCF) has made such provisions in order to enable students to gain academic credits by taking courses related to the ancient science of India, arts, and cultural traditions, in order to meet the objectives of NEP 2020. This framework allows flexibility of learning routes and allows students to study the scientific and philosophical input of India's traditional knowledge systems. Consequently, Vedic math, Ayurveda, classical architecture, astronomy, and other traditional knowledge-related courses are slowly being integrated into universities and institutions in the course of higher education.

In addition to this, the University Grants Commission (UGC) has unveiled a number of policy initiatives that have enabled IKS to be incorporated in higher education. The UGC policy suggests that an Indian university should have about 5 percent of the total academic credits of undergraduate and postgraduate level programs on Indian Knowledge Systems. This program is an effort to have the students exposed to the intellectual legacy of India and modern-day scientific fields. Besides curriculum creation, the UGC has also been engaged in massive capacity-building programs to empower the teaching and research environment in the region. Among the key targets is to educate the close to 1.5 million teachers in Indian Knowledge Systems by 2025 [1]. To do this, the UGC has introduced a number of training programs and an online Massive Open Online Course (MOOC) specifically on Indian Knowledge Systems, which allows educators and learners in the country to gain access to organized scholarly materials about the traditions of traditional Indian knowledge. In October 2020, a new government department within the Ministry of Education, Government of India, was created as the Indian Knowledge Systems (IKS) Division, also referred to as the Bharti Airtiya Jnanapara Vibhag. The division has its headquarters at the headquarters of the All-India Council of Technical Education (AICTE), New Delhi and also operates as a national body of managing research, teaching and spreading traditional Indian knowledge [1]. The IKS division focuses on recording, storing and publicizing the various intellectual traditions in India and on interdisciplinary studies that can interrelate ancient knowledge and current scientific as well as societal issues.

6. Conclusion

The IKS division has been able to fund projects on traditional agriculture, architecture, environmental sustainability, health sciences, metallurgy and other practices of indigenous knowledge through various academic and research projects. These programs are aimed at analysing the scientific foundations of the ancient traditions and discussing how they could be applied to contemporary issues like global warming, environmentally friendly use of resources, and the integrated healthcare systems. In a wider sense, the efforts of the IKS division are indicative of an academic and policy interest in the decolonisation of the Indian education system by identifying and incorporating indigenous knowledge traditions historically relegated in the colonial and post-colonial academic paradigm. By understanding both the traditional wisdom and the scientific knowledge of Ancient India, we can gain valuable insights into how our civilisation can progress toward a more balanced and holistic education system. Such a system would integrate the advancements of modern global science while also recognizing and preserving India's rich intellectual and cultural traditions.

Funding

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