

From Stopgap Workforce to Strategic Cadre: Realizing the Promise of Allied Health Professionals under the NCAHP Act and Budget 2026

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A LEGAL-POLICY APPRAISAL OF INDIA'S NEW REGULATORY ARCHITECTURE AND EXPANSION PLANS

India's health system has long relied on allied and healthcare professionals (AHPs) as an invisible backbone of service delivery.¹⁻³ Yet, their education, regulation, and career trajectories have remained fragmented and weakly governed. The National Commission for Allied and Healthcare Professions (NCAHP) Act, 2021, and the Union Budget 2026.⁴⁻¹¹ Announcement to add one lakh allied health professionals and train 1.5 lakh caregivers over 5 years have brought this neglected cadre to the center of policy discourse.^{1,7,8} The critical question now is whether these initiatives will create a genuinely competent, regulated and motivated allied workforce, or merely multiply numbers without changing systemic realities.

The NCAHP Act, 2021: Architecture, Intent and Early Experience

The NCAHP Act, 2021, was enacted to provide a legal framework for the regulation and maintenance of standards of education and services of AHPs, including the creation of central and state registers, assessment and rating of institutions, and enforcement of professional conduct.¹ The Act establishes a National Commission, multiple professional and autonomous boards, and envisages State Councils to oversee education and practice, supported by detailed rules and regulations.^{1,2}

Its stated objectives are ambitious: Standardizing curricula, ensuring quality and uniformity of education, recognizing qualifications, and protecting the interests of both professionals and patients.¹ The Act attempts to bring within one umbrella a wide range of professionals who were previously regulated in a piecemeal manner or not at all, including lab and OT technicians, imaging technologists, physiotherapists, optometrists, physician associates, behavioral health professionals, and many others.^{1,3}

Early implementation remains a work in progress. The law was notified in 2021, with rules following, and subsequent steps have included the launch of competency-based curricula, implementation directives and admission-related communications.^{2,4-6} Yet several key elements, such as the full operationalization of State Councils, harmonized scopes of practice, and clear bridge pathways for existing workers, are still evolving, generating uncertainty among institutions and practitioners. The promise of the Act lies in its potential to move AHPs from a loosely defined, largely unregulated

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workforce to a recognized cadre with entry standards, ethical codes and professional identity. The risk lies in slow or uneven implementation that leaves gaps between legal intent and lived reality on the ground.

Budget 2026: Expansion Without a Systems Roadmap?

Budget 2026 has brought allied health more visibly into the policy discourse, including a specific push on allied health.^{7,8} The Finance Minister announced that 1,00,000 allied health professionals would be added across 10 disciplines over 5 years, and that 1.5 lakh caregivers would be trained to respond to demographic ageing and rising needs for chronic and long-term care.^{7,8} This expansion could help relieve workload pressures on doctors and nurses, strengthen diagnostics, rehabilitation and perioperative care, and improve mental, geriatric and long-term support, if backed by deployment and financing reforms.

However, from a legal-policy perspective, the expansion narrative appears heavily input-centric. Budget documents and public statements emphasize seat creation, new institutions and training numbers.^{7,8} Still, they are less explicit about how these AHPs will be integrated into sanctioned posts, team-based care models and financing streams across public and private sectors. There is limited clarity on how expansion targets were derived from population-based HRH norms or health-system needs, or how they align with the categorization and competency frameworks being developed under NCAHP. Without a clear roadmap linking NCAHP's regulatory architecture and Budget 2026's quantitative goals, India risks repeating a familiar pattern: Large numerical targets for training without proportionate attention to quality, deployment and retention.

Implementation Realities: Regulation, Education and Deployment

Three domains are particularly salient for a balanced appraisal: Regulatory institutions, education and curricula, and service deployment.

First, regulatory institutions. National Commission for Allied and Healthcare Professions has issued public notices, online guidance, enrolment portals, and implementation communications relating to registration, recognized qualifications, and curricula.^{4–6,12} In some States and Union Territories, formal State Allied and Healthcare Councils are still being constituted or operationalized, leading to variability in registration, recognition, and enforcement of standards.⁵ The absence of fully functional State Councils means that provisions on licensure, disciplinary action, and institutional accreditation remain, in practice, aspirational in several regions.

Second, education, and curricula. Competency-based curricula for selected allied and healthcare professions are being rolled out with the intention that these will be implemented nationally from the 2026–2027 academic year.^{4–6} This is a welcome shift from knowledge-centric syllabi to outcome-oriented training, with greater emphasis on clinical skills, communication, and ethics. However, challenges abound: Mapping diverse legacy diplomas and certificates to new qualifications, creating bridge programs and recognition of prior learning (RPL) for the existing workforce, and ensuring adequate faculty and training infrastructure in both public and private institutions.

Third, service deployment and team-based care. Budget and policy pronouncements highlight AHP roles in diagnostics, perioperative care, rehabilitation, mental health and behavioural sciences, and community-based services.^{7,8} Existing public documents indicate relevant policy platforms in PM-ABHIM, Ayushman Arogya Mandirs and AB PM-JAY, but do not yet set out a clear allied-health deployment framework across these channels.^{9–11} Without such guidance, health facilities may continue to rely on *ad hoc* contractual appointments, outsourcing and informal task shifting, undermining the formal regulatory framework.

Key Legal-policy Challenges

Several structural challenges need to be confronted if the current moment is to translate into durable reform rather than a short-lived surge of interest.

One, conceptual ambiguity about “who is an AHP”. The Act defines AHPs and lists broad categories, but overlaps remain with other councils and with workforce categories created under skills and labor programs.^{1,3} This has implications for scopes of practice, entry requirements, and career progression, especially for cadres such as community-based rehabilitation workers, behavioral health professionals and emergency medical technicians.

Two, fragmented governance. The NCAHP must coordinate with the National Medical Commission, Indian Nursing Council, Dental, Pharmacy and Rehabilitation councils, as well as state governments and professional associations. In the absence of an explicit, integrated human resources for health (HRH) strategy that defines the role of AHPs in multidisciplinary teams across levels of care, there is a risk of parallel and sometimes conflicting regulations.

Three, uneven state capacity. States vary widely in their readiness to establish and run councils, regulate institutions, and finance positions for AHPs. Those with weaker regulatory and fiscal capacity may lag behind in enforcing standards and creating

posts, exacerbating geographic inequities in access to diagnostic, rehabilitative and allied services.

Four, education–service disconnect. Rapid expansion of seats without proportional investments in faculty development, skill labs, clinical training sites, and assessment reforms can produce graduates whose formal qualifications do not translate into real-world competence. This undermines patient safety, weakens trust in the new regulatory architecture, and may prompt further calls for parallel training streams outside the ambit of the Act.

Five, labor markets and migration. Allied professionals often face precarious contracts, low remuneration and limited career ladders in the public sector, while private and overseas markets may offer better prospects. Without careful attention to working conditions, pay structures and progression pathways, the new training pipeline could primarily benefit private tertiary providers and foreign health systems, leaving public facilities understaffed.

Six, voice and representation. Compared to doctors and nurses, many allied professions lack strong associations and bargaining power. Their participation in NCAHP rule-making, curriculum design and scope-of-practice decisions remains constrained, even though these directly affect their livelihoods and professional identities. Ensuring meaningful representation is crucial to avoid a top-down regulatory regime that is misaligned with field realities.

A STRUCTURED WAY FORWARD: TOWARDS A COHERENT HRH STRATEGY FOR AHPs

A balanced editorial should not only critique but also outline a concrete way forward. A five-pillar agenda can help structure this.

Pillar 1: A Coherent HRH Strategy for AHPs

India needs a national HRH strategy that explicitly quantifies required AHP numbers and skill mixes by level of care and specialty, linking these to sanctioned posts and financing lines. Such a strategy should integrate NCAHP categories with service-delivery needs emerging from Ayushman Arogya Mandirs, PM-ABHIM public health labs, and AB PM-JAY provider networks, ensuring that training is driven by health needs rather than only institutional supply.^{9–11}

Pillar 2: Accelerated but Accountable Implementation of NCAHP

The Centre and states should jointly adopt time-bound, publicly trackable milestones for setting up State Councils, establishing registers, accrediting institutions, and enforcing codes of ethics.^{1,2,5} Periodic implementation reports, tabled in legislatures or placed in the public domain, would enable accountability beyond internal government monitoring. Simultaneously, structured RPL and bridge programs are essential to integrate the existing workforce without jeopardizing livelihoods, using competency-based assessments aligned to new curricula.^{4–6}

Pillar 3: Quality-focused Education Expansion

Seat expansion under Budget 2026 should be conditional on adherence to minimum infrastructure, faculty, and clinical-exposure norms, with regulators applying a mix of supportive supervision and sanctions.^{7,8} Faculty development hubs—potentially anchored in public health and teaching institutions such as NIIHF and select medical colleges—can support curriculum roll-out, assessment reforms and mentoring for new colleges, including in states with weaker capacity.

Pillar 4: Team-based Care and Role Clarity

Model guidelines should articulate the roles and responsibilities of AHPs within multidisciplinary teams at each level of care, including their involvement in digital health, telemedicine and home-based services. Pilot projects in areas such as stroke rehabilitation, community mental health, geriatrics and palliative care could demonstrate the impact of well-integrated AHPs on health outcomes and patient experience, creating political and professional support for scale-up.

Pillar 5: Strengthening Professional Voice and Patient-centered Accountability

The NCAHP and state governments should actively facilitate the development and strengthening of professional associations for allied cadres and institutionalize their participation in consultations and boards. In parallel, regulatory and deployment decisions must be linked to patient-centered indicators—safety, functionality, satisfaction, and continuity of care—by embedding AHP-related metrics in quality-of-care frameworks and strategic purchasing under AB PM-JAY and state schemes.¹¹

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Mapping the Divergence of Intensive Care Unit Research Paradigms in European and Indian Critical Care Conferences

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ABSTRACT

Background: Critical care medicine faces similar global challenges, yet research priorities differ significantly across regions. This study compares research trends presented at the Indian Society of Critical Care Medicine (ISCCM) and the European Society of Intensive Care Medicine (ESICM) conferences from 2020 to 2024.

Methodology: We analyzed 5,929 research abstracts (ESICM: 4,837; ISCCM: 1,092) using three complementary text analysis techniques: Bidirectional encoder representations from transformers-based topic modeling (BERTopic) modeling, Latent Dirichlet allocation (LDA), and term frequency-inverse document frequency (TF-IDF) analysis. We examined temporal trends and regional differences in research focus.

Results: COVID-19 research peaked in 2022 (ISCCM: 32%, ESICM: 40%) before declining sharply by 2024 (ISCCM: Minimal, ESICM: 9.7%). Core areas maintained stability: Sepsis (ISCCM: 11.2%, ESICM: 18.2% by 2024), respiratory care (ISCCM: 8.8–9.3%, ESICM: 15–20%), and acute kidney injury (AKI) (ISCCM: 6–6.8%, ESICM: 12–15%). Indian Society of Critical Care Medicine emphasized tropical infections (7.2%), poisoning (12%), and point-of-care diagnostics, while ESICM focused on extracorporeal membrane oxygenation (ECMO), artificial intelligence (AI) (7%), and neurological care (8.4%).

Conclusion: Critical care research demonstrates remarkable adaptability, balancing pandemic response with sustained focus on foundational topics. By 2024, research largely returned to pre-pandemic patterns with notable growth in technology integration and specialized care protocols.

Keywords: COVID-19, Critical care research, Regional differences, Research trends, Text analysis.

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INTRODUCTION

Critical care medicine addresses the needs of the most severely ill patients, yet research priorities vary significantly across regions despite facing similar global challenges, including the COVID-19 pandemic, rising antibiotic resistance, and increasing demand for intensive care resources.¹ Understanding these differences is crucial for fostering global collaboration, informed policy-making, and appropriate resource allocation.²

Conference abstracts serve as important barometers of contemporary research activity, capturing current trends that may precede journal publications by 1–2 years.³ Unlike peer-reviewed publications, conference presentations encompass a broader spectrum, including preliminary findings, negative results, and practice innovations that reflect practical concerns of the critical care community.⁴

To explore divergence in critical care research priorities, we analyzed presentations from two leading conferences: The Indian Society of Critical Care Medicine (ISCCM) and the European Society of Intensive Care Medicine (ESICM) from 2020 to 2024. Indian Society of Critical Care Medicine represents India's diverse healthcare landscape, spanning resource-intensive tertiary centers to resource-limited settings, with unique epidemiological challenges including tropical infectious diseases.⁵ European Society of Intensive Care Medicine represents a consortium of European nations with high healthcare expenditure, advanced technological infrastructure, and aging populations facing distinct challenges.⁶ The COVID-19 pandemic provided an unprecedented opportunity to observe how critical care research communities respond to global crises while maintaining attention to pre-existing priorities.

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AIM

To compare research trends at ISCCM and ESICM conferences (2020–2024) and assess the impact of COVID-19, persistent topics, and emerging priorities.

OBJECTIVES

- Track COVID-19 research trajectory.
- Identify core and emerging research areas.
- Highlight regional differences in research priorities.

METHODOLOGY

Study Design and Data Collection

We conducted a comparative cross-sectional study with longitudinal trend analysis examining research presentations from ISCCM and ESICM conferences over 5 years (2020–2024). Both organizations

maintain publicly accessible online archives of conference abstracts accessed during June–August 2024.

Inclusion Criteria

All research-related abstracts, including original research, systematic reviews, case series, observational studies, and randomized controlled trials with sufficient textual information (minimum three words in title).

Exclusion Criteria

Non-research content (advertisements, workshop descriptions), duplicate abstracts, and those lacking adequate textual information.

Final Dataset

A total of 5,929 abstracts were included (ESICM: 4,837; ISCCM: 1,092).

Text Preprocessing and Analysis

All abstract titles underwent systematic preprocessing, including lowercase conversion, special character removal, stopword elimination, lemmatization, and tokenization, following established biomedical text mining practices.⁷

We employed three complementary computational text analysis methods to ensure robust topic detection:

1. Bidirectional encoder representations from transformers-based topic modeling: This method uses transformer-based embeddings (BERT) to capture semantic meaning and context in medical terminology. Abstracts were embedded into a 768-dimensional vector space, reduced using uniform manifold approximation and projection (UMAP), clustered using hierarchical density-based spatial clustering (HDBSCAN), and topics extracted using class-based term frequency-inverse document frequency (TF-IDF). Dynamic topic modeling tracked evolution over time. This method excels at capturing subtle semantic relationships and identifying emerging trends.⁸
2. Latent Dirichlet Allocation (LDA): A probabilistic model uncovers latent themes and their connections. Abstracts were converted to bag-of-words representations, and LDA models were trained with varying numbers of topics ($k = 15\text{--}30$), selecting optimal numbers based on coherence scores. Latent Dirichlet allocation reveals connections between topics and provides probabilistic quantification of prevalence.⁹
3. Term Frequency-inverse Document Frequency: Quantified term importance and tracked keyword frequency change over time. Terms appearing frequently in specific years but rarely in others received high scores, identifying rising and declining keywords. This method provides clear quantitative metrics of term importance changes.

Comparative Analysis

For each identified topic, we calculated prevalence (percentage of total abstracts) separately for ISCCM and ESICM. Temporal trends were mapped year-by-year (2020–2024). Chi-square tests assessed statistical significance of regional differences ($p < 0.05$). The convergence of findings across all three methods validated that identified trends represent genuine patterns rather than analytical artifacts.

Data Availability

The complete dataset, including preprocessed text and topic assignments, is publicly available at: https://figshare.com/articles/dataset/_/28738052.

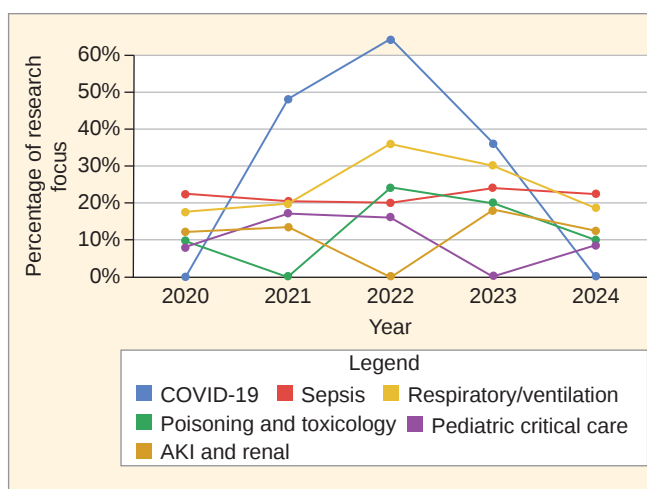


Fig. 1: Indian Society of Critical Care Medicine Conference Topic Trends (2020–2024)

RESULTS

Analysis of 5,929 abstracts revealed distinct patterns in critical care research priorities, organized into COVID-19 impact trajectory, persistent core areas, regional differences, and emerging trends.

COVID-19 Research Impact Trajectory

COVID-19-related research demonstrated dramatic but transient dominance across both conferences. In the emergence phase (2020–2021), ESICM responded more rapidly, with COVID-19 dominating approximately 30% of research in 2020, reflecting Europe's earlier severe outbreak. Indian Society of Critical Care Medicine showed a gradual increase from 15% in 2020 to 23.9% in 2021, corresponding with India's major surge in spring 2021. Bidirectional encoder representations from transformers-based topic modeling analysis identified granular sub-topics, including COVID-19 mechanical ventilation strategies, ICU outcomes and mortality, inflammatory markers, and thrombosis management.

Both conferences reached maximal COVID-19 research focus in 2022 (ISCCM: 32%; ESICM: 40%), representing the highest concentration throughout the study period. Term frequency-inverse document frequency analysis showed peak scores for terms such as "COVID-19," "SARS-CoV-2," "pandemic," and "respiratory failure" during this year, appearing significantly more frequently than any other keywords (Fig. 1).

The decline phase (2023–2024) showed a precipitous reduction in COVID-19 research. Indian Society of Critical Care Medicine dropped from 32% in 2022 to 18% in 2023, becoming virtually absent by 2024. European Society of Intensive Care Medicine showed a similar decline from 40% in 2022 to 25% in 2023, further declining to 9.7% by 2024. The remaining COVID-19 research in 2024 focused on long-term sequelae and post-ICU recovery rather than acute management, indicating transition to endemic status and return to broader critical care priorities (Fig. 2).

Persistent Core Research Areas

Despite the pandemic's impact, foundational critical care topics maintained a substantial presence throughout the study period. Sepsis research showed remarkable resilience across both conferences, though with different patterns. In ISCCM, sepsis research temporarily declined during peak pandemic years



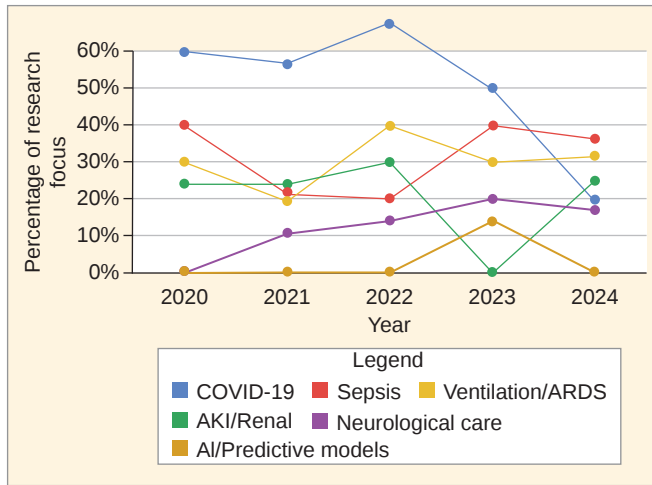


Fig. 2: European Society of Intensive Care Medicine Conference Topic Trends (2020–2024)

(2021–2022) to approximately 7–8%, but rebounded to 11.2% by 2024, nearly matching pre-pandemic levels. European Society of Intensive Care Medicine maintained a more consistent focus throughout, ranging from 10–15% during pandemic years and increasing to 18.2% by 2024, the highest recorded level. This sustained focus at ESICM may reflect Europe's aging population and high sepsis incidence. Latent Dirichlet allocation analysis identified persistent sub-themes, including antimicrobial stewardship, biomarkers for early detection, hemodynamic management, and source control across all years.

Respiratory care and mechanical ventilation research maintained a relatively stable prevalence in ISCCM (8.8–9.3%) and a higher focus in ESICM (15–20%) throughout the study. While COVID-19 temporarily merged with traditional ventilation research, traditional terms such as "ARDS," "prone positioning," "PEEP," and "driving pressure" maintained a consistent presence, returning to prominence by 2024.

Acute kidney injury (AKI) research demonstrated notable regional differences. European Society of Intensive Care Medicine showed substantially higher focus (12–15% prevalence) compared with ISCCM (6–6.8%) throughout the study period. This difference likely reflects Europe's higher chronic kidney disease prevalence in aging populations and greater availability of continuous renal replacement therapy. Bidirectional encoder representations from transformers-based topic modeling identified consistent sub-topics, including AKI biomarkers, renal replacement timing and dosing, AKI in sepsis, and nephrotoxicity prevention, appearing regularly across all years (Fig. 3).

Regional Differences in Research Priorities

Substantial regional differences reflected distinct epidemiological, resource, and healthcare contexts. Indian Society of Critical Care Medicine demonstrated a unique focus on tropical infections and region-specific infectious diseases (7.2% of abstracts in 2020), including dengue fever, malaria, scrub typhus, and leptospirosis—conditions rarely encountered in European ICUs. The most striking regional difference was ISCCM's emphasis on poisoning and toxicology, peaking at 12% in 2022 and maintaining 8–10% in other years, reflecting India's significant public health challenge with intentional and accidental poisonings, particularly pesticide

exposures. In contrast, poisoning research was minimal at ESICM (<2%) (Fig. 4).

Indian Society of Critical Care Medicine showed growing emphasis on point-of-care diagnostics and ultrasound, increasing from 4% in 2020 to 6–7% by 2024. Bidirectional encoder representations from transformers-based topic modeling identified specific topics, including point-of-care ultrasound protocols, venous excess ultrasound (VEXUS) for fluid assessment, optic nerve sheath diameter measurement, and focused echocardiography. This emphasis likely reflects the need for cost-effective, rapidly available diagnostic tools in resource-varied settings.

European Society of Intensive Care Medicine demonstrated substantially greater focus on extracorporeal membrane oxygenation (ECMO) research (4–6% prevalence) compared to minimal presence at ISCCM (<1%), reflecting the resource-intensive nature of ECMO programs requiring specialized equipment and trained personnel more readily available in European settings. One of the most striking temporal trends was the emergence of artificial intelligence (AI) and predictive modeling research at ESICM, growing from essentially 0% in 2020 to 7% by 2023. Term frequency-inverse document frequency analysis showed rapid increases in terms such as "machine learning," "artificial intelligence," "predictive modeling," and "neural networks," specifically in ESICM abstracts during 2022–2023. Indian Society of Critical Care Medicine showed more modest growth, emphasizing traditional prognostic scores and biomarkers (3.6–8.7%).

European Society of Intensive Care Medicine demonstrated increasing focus on neurological critical care, growing from a minimal presence in 2020 to 8.4% by 2024, including research on stroke management, traumatic brain injury, and neurocritical monitoring. This may reflect Europe's aging population with increasing stroke incidence. European Society of Intensive Care Medicine also maintained consistently higher focus on ethical issues, goals of care discussions, and end-of-life decision-making (6–8%) compared with ISCCM (2–5%), though ISCCM showed notable growth from 2.4 in 2020 to 5% in 2024, possibly reflecting pandemic-induced ethical dilemmas.

Chi-square analysis confirmed several regional differences were statistically significant ($p < 0.001$): Poisoning/toxicology (ISCCM: 10.2% vs ESICM: 1.8%), tropical infections (ISCCM: 7.2% vs ESICM: 0.5%), ECMO (ESICM: 5.2% vs ISCCM: 0.8%), AI/predictive modeling (ESICM: 5.5% vs ISCCM: 2.1%), neurological critical care (ESICM: 6.8% vs ISCCM: 3.4%), and AKI (ESICM: 13.5% vs ISCCM: 6.4%).

Emerging Research Trends

Both conferences demonstrated growing attention to post-ICU syndrome, ICU-acquired weakness, cognitive impairment after critical illness, and long-term functional outcomes. This research area grew from approximately 2–3% prevalence in 2020 to 5–7% by 2024 across both conferences, possibly catalyzed by "long COVID" concerns. The pandemic may have accelerated this shift toward comprehensive recovery conceptualization beyond acute survival.¹⁰

Nutritional research showed differential patterns but overall increasing attention. European Society of Intensive Care Medicine maintained a relatively stable focus (4–8%), while ISCCM showed growth from 3.7 to 4–6% in 2023–2024. Quality improvement and patient safety research showed modest but consistent growth in both conferences, with increasing prominence of terms such as "bundle compliance," "quality indicators," and "implementation science" during 2023–2024.

Fluid management and hemodynamic monitoring demonstrated increasing sophistication, particularly in ISCCM,

ESICM Conference Analysis (2020–2024): BERTopic and TF-IDF Results			
Year-by-year comparison			
Year	BERTopic top topics	Percentage	TF-IDF top terms
2020	COVID-19 ICU management	30%	“COVID-19” (highest weight)
	Sepsis/infection	20%	“ARDS”
	ARDS/ventilation	15%	“Sepsis”
	AKI/renal	12%	“Ventilation”
	Trauma/neurology/Cardiology	23%	“Mortality”
2021	COVID-19 critical care	28.5%	“COVID-19” (18.2%)
	AKI and renal care	12.1%	“ICU” (15.7%)
	Sepsis and infections	10.7%	“Patients” (14.9%)
	Mechanical ventilation and ARDS	9.8%	“Mortality” (9.8%)
	ICU outcomes and prognostics	8.3%	“Ventilation” (8.3%)
2022	COVID-19	40%	“COVID-19”
	Ventilation/ARDS	20%	“ARDS”
	AKI/renal	15%	“Sepsis”
	Cardiovascular	10%	“Mechanical ventilation”
	Other (Delirium, surgery, etc.)	15%	“Mortality”
2023	COVID-19/ARDS	25%	“Acute respiratory”
	Sepsis/infections	20%	“Septic shock”
	Ventilation/ECMO	15%	“Critically ill”
	Delirium/cognition	10%	“Mechanical ventilation”
	Trauma/neuro	10%	“COVID-19 patients”
2024	Sepsis and septic shock	18.2%	“Sepsis”
	Mechanical ventilation	15.8%	“ICU”
	Acute kidney injury	12.5%	“Mortality”
	Critical care outcomes	11.3%	“Patients”
	COVID-19 and ARDS	9.7%	“Acute”

Fig. 3: European Society of Intensive Care Medicine BERTopic analysis

where it increased from 4 in 2020 to 6–7% by 2024. Bidirectional encoder representations from transformers-based topic modeling identified emerging topics, including dynamic fluid responsiveness predictors, passive leg raising, VEXUS protocol for venous congestion, and goal-directed fluid therapy (Fig. 5).

Term frequency-inverse document frequency word cloud visualizations confirmed these temporal patterns. In 2020, both conferences showed prominence of COVID-19-related terms alongside traditional terms like “sepsis,” “shock,” and “mortality.” By 2022, COVID-19 terms had achieved maximum dominance. However, by 2024, word clouds demonstrated remarkable reversion with traditional critical care terms regaining prominence. New terms appearing prominently in 2024 included “AI,” “prediction,” “ultrasound,” “VEXUS,” “recovery,” and “outcomes,” reflecting identified emerging trends (Fig. 6).

DISCUSSION

This comprehensive analysis reveals a dynamic research landscape characterized by remarkable responsiveness to global health crises while maintaining sustained focus on foundational critical care priorities. The COVID-19 research trajectory—rapid rise, peak dominance in 2022, and subsequent decline—demonstrates the critical care community’s capacity for rapid research mobilization and eventual return to broader priorities.¹¹ The differential timing of research peaks between ESICM (earlier) and ISCCM (later) precisely corresponds with regional pandemic waves, confirming that conference research reflects lived clinical experiences.

The evolution of COVID-19 research content merits attention. Early pandemic research (2020–2021) focused on descriptive epidemiology and basic management. As the pandemic progressed

ISCCM Conference BERTopic vs TF-IDF Analysis (2020–2024)				
Year	BERTopic top topics	%	TF-IDF analysis top terms	Score
2020	Sepsis and antimicrobial resistance	11.2%	Unigrams: “Sepsis”	0.48
	Respiratory failure and ventilation	8.8%	“ICU”	0.42
	Tropical infections and dengue	7.2%	Bigrams: “Critically ill”	0.45
	Acute kidney injury and renal support	6.0%	“Acute kidney”	0.40
	Critical care procedures and ultrasound	5.6%	Trigrams: “High flow nasal”	0.30
			“Renal replacement therapy”	0.28
2021	COVID-19 and respiratory care	23.9%	Bigrams: “Non-invasive ventilation”	0.45
	Case reports (rare cases)	12.5%	“Acute respiratory failure”	0.41
	Sepsis and shock management	10.2%	Trigrams: “Septic shock”	0.38
	Pediatric critical care	8.5%	“Prone positioning”	0.35
	Cardiovascular issues	8.0%		
	Acute kidney injury (AKI)	6.8%		
2022	COVID-19 complications and management	32.0%	“COVID-19”	0.85
	Critical care procedures	18.0%	“ARDS”	0.72
	Poisoning and toxicology	12.0%	“Mechanical ventilation”	0.68
	Sepsis and infections	10.0%	“Neutrophil-lymphocyte ratio (NLR)”	0.65
	Pediatric critical care	8.0%	“Sepsis”	0.60
	Neurological emergencies	7.0%	“HFNC (High-flow nasal cannula)”	0.55
	Cardiovascular ICU	5.0%	“ECMO”	0.50
	Nutrition and metabolic	4.0%	“Prone positioning”	0.48
	Delirium and ICU-acquired weakness	3.0%	“Scrub typhus”	0.45
	Rare case reports	1.0%	“Procalcitonin”	0.42
	COVID-19 and respiratory care	18.0%	Bigrams: “COVID-19 ARDS”	0.45
	Critical care and ICU management	15.0%	“Mechanical ventilation”	0.42
2023	Infections and antimicrobial resistance	12.0%	“Acute kidney injury”	0.38
	Poisoning and toxicology	10.0%	Trigrams: “Critically ill patients”	0.50
	Renal and metabolic disorders	9.0%	“Tertiary care hospital”	0.47
	Sepsis management	11.2%	Unigrams: “sepsis”	0.45
	Respiratory failure and ventilation	9.3%	“Ventilation”	0.38
	Critical care outcomes and biomarkers	8.7%	“Critically”	0.32
	Antimicrobial resistance and infections	7.5%	Bigrams: “Critically ill”	0.42
	Liver and renal dysfunction	6.2%	“Septic shock”	0.38
	Poisoning and toxicology	5.0%	Trigrams: “Acute respiratory failure”	0.28
	Pediatric critical care	4.3%	“Neutrophil to lymphocyte”	0.25

Fig. 4: Indian Society of Critical Care Medicine BERTopic analysis

into 2022, research became more sophisticated, addressing ventilation strategies, pharmacological interventions, and prognostic factors. By 2024, residual COVID-19 research transformed from acute management to long-term sequelae and healthcare system lessons. The precipitous decline raises questions about research sustainability—while adaptability is valuable, equally

rapid departure from COVID-19 research may risk premature abandonment of important questions regarding long-term outcomes and healthcare system resilience.

The persistence of sepsis, respiratory failure, and AKI research throughout the pandemic demonstrates their enduring importance. Sepsis remains the leading cause of ICU admission and mortality



Fig. 5: Word cloud of TF-IDF term summaries of ESICM from 2020 to 2024

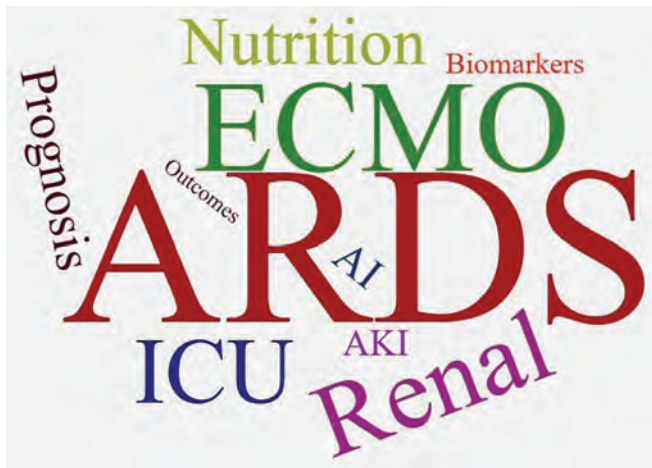


Fig. 6: Word cloud of TF-IDF term summaries of ISCCM from 2020 to 2024

globally, affecting millions annually.¹² The higher sepsis research prevalence at ESICM may reflect Europe's older population with more comorbidities, established sepsis research networks, and potentially different recognition patterns. Acute kidney injury's sustained focus, though more prominent at ESICM, reflects that kidney complications affect 40–60% of critically ill patients and independently predict mortality.¹³

Regional differences provide valuable insights into how healthcare contexts shape research agendas. Indian Society of Critical Care Medicine's emphasis on tropical infections and poisoning directly reflects India's specific healthcare challenges. Dengue causes approximately 1,00,000 hospitalizations annually in India, with significant ICU admissions, while pesticide poisoning represents a major public health burden with over 1,00,000 estimated deaths annually.⁵ These conditions, virtually absent in European ICUs, appropriately receive substantial Indian research attention. Indian Society of Critical Care Medicine's focus on point-of-care ultrasound reflects both necessity and opportunity in resource-varied settings where immediate access to comprehensive imaging may be limited.

European Society of Intensive Care Medicine's emphasis on ECMO, advanced AI, and neurological critical care reflects different healthcare realities. Extracorporeal membrane oxygenation represents one of the most resource-intensive interventions,

requiring specialized equipment, dedicated personnel, and sophisticated infrastructure more readily available in European settings. The AI research peaked at 7% in 2023, followed by a modest decline, which may reflect initial enthusiasm followed by recognition of implementation challenges, including validation requirements and integration difficulties.¹⁴ European Society of Intensive Care Medicine's growing neurological care research likely reflects Europe's aging demographics, with increasing stroke and neurodegenerative conditions.

Emerging trends in post-ICU recovery, technology integration, and quality improvement suggest future research directions. The growing focus on long-term outcomes represents a welcome maturation of critical care's conceptual framework beyond short-term survival.¹⁰ Artificial intelligence and predictive modeling, despite implementation challenges, have demonstrated the capability for early sepsis detection, mortality prediction, and clinical decision support.¹⁴ Future research must address not only algorithm development but implementation science questions regarding effective deployment in real-world settings.

Study Strengths and Limitations

Strengths include the comprehensive dataset (5,929 abstracts), longitudinal design capturing the complete pandemic arc, multi-method triangulation enhancing confidence through convergent findings, direct regional comparison providing unprecedented insights, and clinical validation by critical care physicians ensuring appropriate interpretation.

Limitations include analysis of abstract titles only rather than full abstracts, potential conference selection bias, categorization challenges, particularly separating COVID-19 from general respiratory research during pandemic years, sample size disparity between conferences (though year-to-year consistency suggests stable findings), and inability to distinguish whether regional differences reflect actual research conducted vs conference submission patterns. Our observational design documents associations but cannot definitively establish causation for observed patterns.

Implications and Recommendations

Findings have practical implications for research strategy and international collaboration. Funding mechanisms should balance support for rapid crisis response with protection of core research infrastructure. International collaborative networks should facilitate knowledge exchange, enabling adaptation of innovations across diverse contexts—European advances in ECMO and AI could inform other settings, while Indian innovations in point-of-care diagnostics and resource-efficient approaches have global applicability. Research infrastructure investment in resource-limited settings would enable more comprehensive investigation of region-specific challenges while contributing to global knowledge.

CONCLUSION

Critical care research demonstrates remarkable adaptability, balancing pandemic response with sustained focus on foundational topics. COVID-19 research peaked dramatically in 2022 before declining sharply by 2024, demonstrating both rapid mobilization capacity and eventual return to broader priorities. Core research areas, including sepsis, respiratory care, and AKI, maintained substantial presence throughout, confirming their enduring

importance. By 2024, research distributions largely returned to pre-pandemic patterns with notable additions including technology integration, post-ICU recovery emphasis, and specialized care protocols.

Regional differences—India's focus on tropical infections, poisoning, and point-of-care diagnostics vs Europe's emphasis on ECMO, AI, and neurological care—appropriately reflect distinct epidemiological and resource contexts. These divergences represent adaptive research prioritization rather than deficiencies, while highlighting opportunities for mutually beneficial knowledge exchange. Maintaining this balance between global responsiveness and local relevance, between crisis adaptation and sustained core focus, and between technological innovation and pragmatic implementation will be essential for advancing both the science and practice of critical care worldwide.

Artificial Intelligence (AI) Disclosure

OpenAI's ChatGPT was used solely for language editing and improvement of readability. The scientific content, interpretations, analyses, and conclusions were developed entirely by the authors. The authors reviewed all suggested revisions and take full responsibility for the final manuscript.

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Understanding Perceptions of Economically Disadvantaged: Critical Determinants for Effective Health Services in Punjab

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ABSTRACT

Introduction: With an emphasis on identifying crucial factors that affect hospital operations' efficacy, this study explores the opinions and experiences of Punjab's economically deprived inhabitants on hospital services.

Method: A mixed-methods approach is followed that included a sample of 730 out patient department (OPD) as well as in patient department (IPD) patients. The economically disadvantaged patients were identified, using the criteria of NCAER-2012, from public and private hospitals of selected 8 districts of Punjab is considered for this study.

Result: The factor "Patient Centric Environment", "Economical and Prompt Services", "Specialized Services", "Adequate Infrastructure and HR", "Quick Service Delivery", "Accommodating Amenities in Hospital Premises" along with the demographic variable "Monthly Income of Family" are found to be significant at 1 per cent level, whereas demographic variables "Type of Hospital" and "Facility accessed by Patient" are significant at 5 per cent.

Discussion: Results show that systemic neglect and operational inefficiencies have a major influence on satisfaction in these communities and shape the healthcare experiences of the underprivileged population. The report offers a number of doable suggestions for enhancing policy alignment, resource allocation, and patient participation. This study emphasizes the pressing need for inclusive, equity-driven changes in Punjab's hospital operations to improve service quality and health outcomes by bringing to light the lived experiences of the underprivileged.

Originality: To the best of our knowledge and belief, this research study contains no material previously published or written by another person except where due reference is made in the paper itself.

Keywords: Determinants, Economically disadvantaged, Health, Perception.

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INTRODUCTION

The Punjab Human Development Report from 2004 claims that Punjab is at a more advanced stage of human development than many other Indian states and ranks among the states with the greatest per capita income. Punjab's life expectancy and infant mortality ratios fall into the category of nations with medium levels of human development when compared to worldwide norms. In rural areas, the public sector provides just 7% of non-hospitalized treatment; the remaining 93% is provided by others (private sector, charitable hospitals, and NGOs); in urban areas, the percentages are 6 and 91%, respectively, as stated in the Punjab State Human Development Report (SHDR) 2004. The health system in Punjab is beset by high rates of absenteeism, poor levels of satisfaction with the quality of care received, subpar clinical care, and pervasive corruption. The three main obstacles are the expenses incurred, distributing the financial burden of illness fairly, and guaranteeing higher-quality medical care.

The primary and secondary healthcare systems are dominated by the private healthcare industry. Unfilled positions in the Punjab Public Health System and absenteeism are the factors that have impacted the provision of healthcare services in the public sector. Punjab is outperforming both the national average and expectations in terms of women's health outcomes. Thanks to Janani Suraksha Yojana (JSY), Punjab has outperformed other states in terms of institutional deliveries and prenatal care.¹ Nearly half (53%) of the participants use public health facilities. Private services are used more frequently for non-communicable diseases and accidents, whereas public services are used for infections, respiratory issues, and other conditions.² Private and public hospitals across the nation account for roughly 55–42% of all

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in-hospitalization cases, respectively, according to data from the 75th round of the NSSO, MOSPI.

The economic theory states that as income levels rise, so do living standards and health indicators; however, the empirical analysis shows that Punjab still lags behind in terms of water supply, sanitation, and health amenities and that the state's supply of medicine and disease prevention and control programs are out of sync. The number of health facilities in rural areas, where 60% of the population lives, has not increased. Additionally, private health care is functioning in the state without complying with legislation, which creates a barrier to universal access to healthcare services. Compared to public healthcare, the private sector has access to the newest equipment and technology, even though its primary goal is profit. Punjabi households are dependent on out-of-pocket

(OOP) spending due to low public spending on the health sector; the Punjab government is also supporting the corporate sector by giving them lands at subsidized rates, even though private medical care is extremely expensive in Punjab but the impoverished are inclined toward it.³

According to the Punjab HDR 2004, a kid in Punjab can expect to live for an average of more than 67 years.⁴ The report's data indicates that Punjab living in urban areas tend to live longer than those living in rural areas. Punjab's infant mortality rate (IMR) has dropped and is now lower than the national average for India. In 2001, it was 52 per 1,000 live births; by 2012, it had dropped to 28. Research indicates that in Punjab, compared to other parts of the country, having an educated woman reduces the likelihood of a newborn dying. When it is discovered that, in Punjab, income does not statistically significantly lower child mortality, however, this is not the case throughout India. Although Punjab does not have a lower incidence of diabetes than the rest of India, Punjabi women's health outcomes are generally significantly better than those of ordinary Indian women. Punjabi women have outperformed Indian women in the maternal mortality rate (MMR). Punjab's MMR was 172 per 1,000 live births in 2007–2009, compared with 212 for all of India. However, Punjab's MMR has not improved since then. Richer and more educated women in Punjab are less likely to be predicted to have tuberculosis (TB) or anemia, but among other factors, the distance to a health center has a significant role in exacerbating asthmatic women's symptoms. In 2019, the state's highest number of institutional instances of non-communicable diseases are attributable to cardiovascular diseases and traffic accidents, while the lowest number is attributable to cancer. Within the category of communicable diseases, the highest number of instances are caused by acute respiratory infections and acute diarrheal illnesses, while the lowest number is caused by chicken pox and diphtheria. Punjab has the longest life expectancy at birth and for the first 10 years of life among all the Indian states, according to the province's Economic Survey (2019–2020). As per an India Brand Equity Foundation (IBEF) report, the state's population served per hospital bed is 1,100, while the birth, death, and IMR rates are 14.9, 6.0, and 21, respectively. The private sector provides all care—90% of non-hospitalized care and 67% of hospitalized care.

Review of Literature

There was a quality gap in the services of both in-country groups and groups of private and foreign hospitals. Private health care was performing better in terms of the availability of drugs, tangibility and empathy of nurses, and the perceived costs of private hospitals were significantly higher than that of public hospitals in the minds of Bangladeshi patients.⁵ In the evaluation of performance of private and public healthcare systems in low- and middle-income countries, it was documented that a higher proportion of outpatient services in these countries appeared to be provided by the private sector. The OOP expenditure for patients was highest for private not-for-profit, lowest for public and medium for private self-financed providers. It did not support the fact that private-sector care was more efficient, accountable or effective than sector.⁶ public In-service quality assessment of public and private hospitals in the Asian context, it is found that patients were dissatisfied with the quality of services, and they switched to another hospital due to a lack of trust in services. It was further concluded that there was a scarcity of resources, improper utilization, a lack of hierarchy, and management interest in servicing customers, and patients were more inclined toward private hospitals.⁷ The most important factor

of service quality was empathy, and in the public sector, patient satisfaction was highly associated with it. In the private sector, satisfaction was highly stronger with the responsiveness, and tangibility was insignificant to the satisfaction of patients of both public and private hospitals.⁸ In the investigation of the mediating effect, the effect of the adequacy of healthcare resources on the relationship between responsiveness and tangibility and patients' healthcare experience was supported, while empathy, reliability, and assurance were not supported.⁹ The personnel quality of hospitals was highly correlated with customer satisfaction for both patients and attendants, and satisfaction of patients was more influenced by clinical care, image, and trustworthiness of hospitals, while satisfaction of attendants was influenced by infrastructure and administrative procedures.¹⁰ Private hospitals were performing better in providing quality service according to the needs and requirements of the patients. It is found that 70% of patients in the case of public hospitals and 97% in the case of private hospitals had a medium level of satisfaction. It was examined that perceived service quality was closely related to satisfaction.¹¹ It is found that cost is the most important criterion for selecting a hospital, along with the distance to be traveled to access a dispensary or hospital, and concluded that overall service quality in government hospitals as compared to private clinics and charitable hospitals was very poor. Most of the beneficiaries were not aware of the 10% quota scheme for economically backward classes (EBC) in private hospitals, and each family spent 5–10% of their monthly income (range: Rs. 5,000–10,000) on average routine medical care.¹² There are overall positive ratings for the efficiency of healthcare staff. A large number of respondents found the services perfectly adequate, and the author revealed that there were more negative responses than positive ones for the effectiveness of any medical center, which depends upon the service delivery. The analysis showed that beneficiaries were mostly dependent upon the facilities available at the rural healthcare centers.¹³ Half of the respondents were not provided with adequate information at the reception stage, and the respondents expressed their dissatisfaction. A total of 70% of the respondents of all the hospitals had to wait for very little time, and the majority of the responses revealed that for X-ray and scanning processes, waiting time was less, and 80% of respondents of each hospital gave a positive response about recommending hospitals to others.¹⁴ On the basis of differences of factors like infrastructural facilities, treatment, workload, and utilization pricing of hospitals' services, it is highlighted that the government allocated a little of its GDP (1.1%) on public healthcare, which was additionally privately financed. It was found that admissions of patients were higher in government hospitals than in private hospitals due to differences in cost or payment structure and the higher catchment areas of government hospitals.¹⁵ Identification of the service quality dimensions that played an important role in patient perception of service quality found six factors, i.e., esthetic (concerned with beauty or art), accessibility and affordability, promptness, professionalism, caring staff, and medicine availability. The first four factors had significant positive relations, while the remaining two had a negative impact on patient satisfaction in public hospitals.¹⁶ A fact is highlighted that factors like service delivery, facilities, location, and look significantly affected the patients' satisfaction, and before diagnosis, patients gave priority to infrastructural facilities, atmosphere, and tangibility aspects of a healthcare facility.¹⁷ The demographic variables were significant in patient satisfaction with healthcare services. All the dimensions of healthcare service quality, i.e., empathy, assurance, tangibility,

Table 1: Income profile of respondents across districts

District	Low income less than Rs. 16,666		Lower-middle income Rs. 16,666–41,666		Upper-middle income Rs. 41,666–83,333		Grand total
		%		%		%	
Amritsar	36	30.0	56	46.7	28	23.3	120
Ferozepur	62	72.9	21	24.7	2	2.4	85
Jalandhar	34	40.5	40	47.6	10	11.9	84
Ludhiana	35	39.3	49	55.1	5	5.6	89
Mansa	55	68.8	16	20.0	9	11.3	80
Pathankot	57	62.6	34	37.4	0	0.0	91
Ropar	24	26.1	50	54.3	18	19.6	92
SBS Nagar	48	53.9	38	42.7	3	3.4	89
Grand total	351	48.1	304	41.6	75	10.3	730

Source: Survey of perception of patients 2023, N = 730

responsiveness, and reliability, scored negatively in respondents' perceptions.¹⁸

Objectives of the Study

- To explore and identify the significant factors influencing the perceptions of patients for the effective functioning of hospitals in Punjab.
- To explore demographic and socioeconomic variations in patient perceptions for the effective functioning of hospitals.

Research Methodology

The State of Punjab consists of a total of 23 districts. According to regional classification, it is divided into three regions, i.e., Majha, Malwa, and Doaba. The districts in Majha are Amritsar, Pathankot, Gurdaspur, and Tarn Taran. The districts in the Doaba region are SBS Nagar, Jalandhar, Kapurthala, and Hoshiarpur. All the remaining 15 districts lie in Malwa, which is the largest among all three regions. A multistage sampling method is followed for selecting districts and then hospitals. At first, to select sample districts, a composite score called the human development score (HDI) is calculated for all 23 districts to evaluate and rank these according to their levels of human development. It takes into account three important factors: (1) standard of living, (2) Education, and (3) Health.

A total of eight districts are finalized according to their HDI rankings, representing more than one-third of the whole state. From each region, the top-ranking districts and the lowest-ranking districts in the index are included for this study to represent developed as well as semi-developed districts in the state. Three public and three private hospitals from each selected district (four each from Amritsar) are taken (total of 25 public and 25 private hospitals). The sequence followed in the public sector is as follows: One district hospital, two sub-divisional hospitals (SDHs), and one community health center (in case two SDHs are not there in any selected district). Multispecialty private hospitals are chosen according to the bed capacity of public hospitals in the corresponding district to make a suitable base for comparison. From each hospital, 10 out patient department (OPD) and 5 in patient department (IPD) patients have been considered for responses. The sample consists of 730 respondents in total.

The primary data is required to know the perception of patients in the Punjab state, and for this purpose, a questionnaire-cum-schedule method is employed.¹⁹ The statements are included in it on a five-point Likert scale about the availability of infrastructure, facilities, working environment, government policies, and time and cost involved to avail healthcare facilities, which contribute

Table 2: Distribution of respondents according to their occupation

Occupation	Type of hospital		Total
	Public	Private	
Private employee	43	49	92
Farmer	29	31	60
Government employee	10	22	32
Daily wage earner	80	46	126
Own business	21	53	74
Housewife	149	135	284
Professional	2	6	8
Student	6	1	7
Retired Govt. employee	8	15	23
Unemployed	12	12	24
Total	360	370	730

Source: Survey of perception of patients 2023, N = 730

to the effective functioning of hospitals. The whole instrument is divided into five parts. The questionnaire-cum-schedule method is used to collect primary data from the patients of public and private hospitals of eight districts, i.e., Amritsar, Pathankot, SBS Nagar, Jalandhar, Ropar, Ludhiana, Ferozepur, and Mansa. The results are given below in tables. The permission for conducting the survey has been taken from the Directorate of Health & Family Welfare, Punjab. In the case of private hospitals, the Managing Heads are approached, and after discussing the objectives of the study and the required information, permission has been granted by them for collecting data from respondents. For identifying the low- and middle-income groups, the criteria given by NCAER, which was published in the year 2012, are taken.²⁰ The middle-income group is further divided into two sub-groups, i.e., seekers (lower-middle) and strivers (upper-middle). Table 1 exhibits information about the number of respondents from low- and middle-income groups across the districts. It is noticed that out of the total sample size, the major portion comprises respondents from the low-income group, i.e., 48.1%, followed by 41.6% from the lower-middle and 10.3% from the upper-middle-income group.

Table 2 depicts the distribution of respondents according to their occupation. The highest number of respondents, i.e., 284, are housewives. It is followed by daily wage earners (126), private employees (92), own business (74), farmers (60), government employees (32), and retired government employees (23). There are 24 respondents who are unemployed, and seven are students.



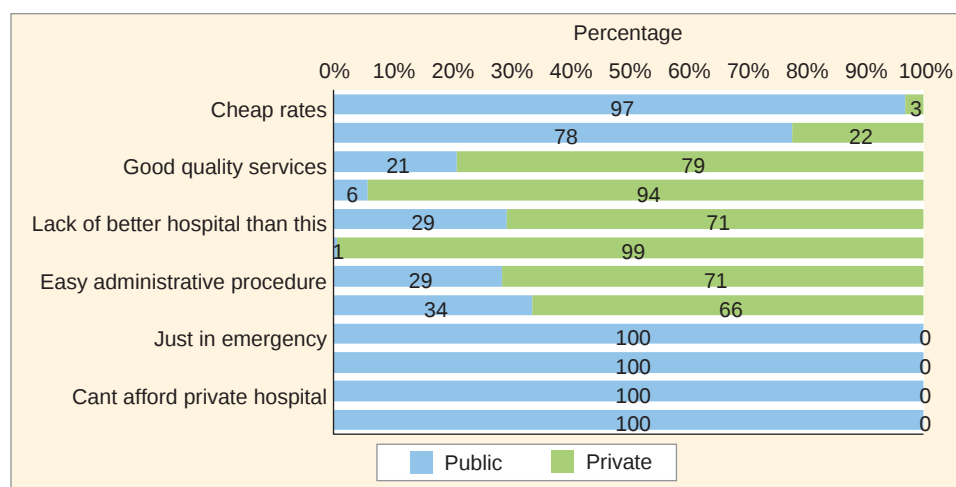


Fig. 1: Reasons behind availing services in this hospital

Source: Survey of perception of patients 2023, $N = 730$

RESULTS AND DISCUSSION

Figure 1 reports the respondents' reasons to avail services from the hospital they are currently visiting. The main reason to get treatment from public hospitals is the cheap rates, followed by the availability of expert doctors in these hospitals. A total of 78% of the total 81 respondents are residing near the public hospitals, which is the reason for accessing the services of these hospitals. The prime reason to get treatment from private hospitals is the availability of expert doctors, followed by the timely availability of doctors in private hospitals. A total of 173 respondents of private hospitals believe that in these hospitals, the time consumed is less compared to public hospitals, and 170 are availing services here due to the good quality services. In case of emergency, people go to public hospitals only, and there is one respondent who he/she cannot afford a private hospital, and one instance is where children forcefully admit their parents to a public hospital. A total of 10 respondents report that there is no other hospital in their locality, due to which they have to access the services of public hospitals.

To know about the factors contributing to the effective functioning of hospitals of the state in the opinion of patients from low- and middle-income groups, the first step is the refinement of scale by eliminating the items with low reliability with the help of reliability analysis (Table 3). The reliability analysis has been conducted on the variables/statements that affect the effective functioning of the hospital in the opinion of patients in the healthcare system of the state. Table 4 discloses the overall reliability coefficient. Cronbach's α of the scale is estimated as 0.942. Alpha values for items D4, D5, D12, D20, D25, D30, D57, and D6 are found to be greater than the overall α value of 0.942. The deletion of these items has resulted in an increased α value of 0.970. Further deletion of items D45, D46, D49, D59, D61, D67, D68, and D69 on the same lines has resulted in a final α value of 0.975. Therefore, the application of this technique has reduced the 65-item scale to a 49-item scale, and the final Cronbach α value is disclosed in Table 3.

After checking the reliability of the scale, the data adequacy and appropriateness are checked by using measures like Kaiser-Meyer-Olkin (KMO), measure of sampling adequacy (MSA), and Bartlett's test of sphericity, respectively. Kaiser-Meyer-Olkin MSA is 0.969, as quoted in Table 5. It indicates that the sample taken

Table 3: Descriptive, item-total correlation, and Cronbach's α (final)

	Item-total statistics			
	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's α if item deleted
D1	170.50	1450.747	0.644	0.974
D2	169.52	1445.383	0.684	0.974
D3	169.84	1429.899	0.723	0.974
D7	170.36	1439.840	0.676	0.974
D9	169.93	1422.633	0.801	0.974
D10	169.82	1418.847	0.828	0.974
D11	169.34	1424.730	0.813	0.974
D13	169.85	1449.848	0.705	0.974
D14	170.49	1453.712	0.612	0.974
D15	170.24	1431.349	0.716	0.974
D16	169.83	1448.214	0.679	0.974
D17	168.93	1462.719	0.594	0.974
D18	169.96	1412.693	0.807	0.974
D19	170.07	1412.345	0.820	0.974
D21	169.44	1447.480	0.725	0.974
D22	169.50	1431.553	0.785	0.974
D23	169.36	1433.393	0.700	0.974
D24	170.27	1402.960	0.713	0.974
D27	169.97	1451.249	0.663	0.974
D28	169.74	1441.421	0.767	0.974
D31	169.76	1443.373	0.765	0.974
D32	169.42	1438.339	0.742	0.974
D33	169.89	1466.524	0.533	0.975
D34	170.20	1431.840	0.793	0.974
D36	170.66	1437.635	0.698	0.974
D37	169.98	1450.446	0.626	0.974
D38	170.36	1456.564	0.550	0.975
D39	169.28	1449.154	0.679	0.974
D40	169.65	1466.701	0.536	0.975
D41	168.89	1461.858	0.651	0.974

(Contd...)

Table 3: (Contd...)

	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's α if item deleted
D42	168.84	1459.192	0.682	0.974
D43	169.88	1403.207	0.802	0.974
D44	168.95	1484.582	0.468	0.975
D47	169.59	1471.647	0.443	0.975
D48	169.98	1465.993	0.532	0.975
D50	169.97	1461.347	0.589	0.974
D51	169.67	1416.779	0.775	0.974
D52	168.94	1465.504	0.600	0.974
D53	169.61	1434.696	0.718	0.974
D54	169.70	1420.201	0.773	0.974
D55	170.06	1415.625	0.736	0.974
D56	169.59	1431.079	0.711	0.974
D58	170.32	1459.265	0.563	0.974
D62	170.60	1443.860	0.561	0.975
D63	169.94	1472.879	0.396	0.975
D64	170.03	1475.104	0.369	0.975
D66	169.79	1435.575	0.792	0.974
D60	170.68	1450.679	0.471	0.975
D26	169.77	1486.268	0.203	0.975

Overall Cronbach α = 0.975Source: Compiled from the survey on perception of patients 2023, $N = 730$ **Table 4: Sampling adequacy analysis (KMO measure and Bartlett's test)**

<i>KMO and Bartlett's test</i>	
KMO MSA	0.969
Bartlett's test of sphericity	–
Approx. Chi-square	31999.920
df	1,176
Sig.	0.000

Source: Compiled from the survey on Perception of Patients 2023, $N = 730$. KMO, Kaiser-Meyer-Olkin; MSA, measure of sampling adequacy

for running factor analysis is adequate as well as statistically significant. Bartlett's test of sphericity is the statistical test applied in the study for verifying that there is no redundancy between the variables, and data reduction techniques, such as factor analysis, can compress the data in a meaningful way. It is found to be highly significant at 1% with a p -value of 0.000 (Table 4). So, it can be said that variables are correlated enough where the correlation matrix diverges significantly from the identity matrix, and the dataset is suitable for the data reduction technique.

Hence, all the requirements indicated that the present dataset is fit for running factor analysis. The 49 variables/items have been finalized for factor analysis using principal component analysis with direct oblimin rotation to extract the factors contributing to the effective functioning of hospitals in the opinion of patients (Table 5). The pattern matrix extracted eight factors based on eigenvalues of more than one (Table 6). The total variance explained by these eight factors is 71.44% (Table 7). Table 8 portrays the summary of the results of factor analysis. The extracted factors contributing to the effective functioning of the hospital have been assigned suitable labels as described in the table.

SIGNIFICANT FACTORS CONTRIBUTING TO THE EFFECTIVE FUNCTIONING OF THE HOSPITAL

The next step is to find out the significant factors among all these eight that have a significant effect on the effective functioning of the hospital, in the opinion of patients. A model has been framed for examining the important factors which asserts that in the opinion of patients, the effective functioning of the hospital is a function of: Patient-centric environment, economical and prompt services, adequate infrastructure for handling emergencies, specialized services, adequate infrastructure and human resource (HR), ease of access, quick service delivery, and accommodating amenities in hospital premises (Table 5). Table 6 defines variables considered for regression analysis.

The effect of extracted factors on the effective working of hospitals was estimated with the help of ordered logistic regression. The following 11 possible hypotheses have been formulated.

Table 5: Mean satisfaction, percentage of variance explained, and Eigenvalues of extracted factors

<i>Factors with variables</i>	<i>Mean agreement</i>	<i>Factor loading</i>	<i>Eigenvalue</i>	<i>Percentage of variance explained</i>
F1: Patient-centric environment	3.75	–	23.05	47.059
D64 Suggestion/complaint box is placed in a visible place	3.32	0.733	–	–
D63 Bill payment mechanism is transparent	3.41	0.650	–	–
D66 You feel assured by your visit to the doctor	3.57	0.452	–	–
D23 No discrimination	4.00	0.423	–	–
D28 You feel a sense of belongingness to this hospital	3.62	0.393	–	–
D11 Proper attention is given by doctors	4.02	0.379	–	–
D39 Patients are served on a first come first serve basis	4.07	0.367	–	–
D22 Doctors/staff motivate you	3.85	0.367	–	–
D21 Instructions for medication and follow-up care are clearly given	3.91	0.352	–	–
F2: Economical and prompt services	3.34	–	3.58	7.317
D60 Advance payment is demanded for admitting a patient	2.68	0.823	–	–
D62 Cashless payments are accepted	2.75	0.710	–	–
D24 Medications prescribed by doctors are available in the hospital pharmacy	3.08	0.696	–	–

(Contd...)



Table 5: (Contd...)

<i>Factors with variables</i>	<i>Mean agreement</i>	<i>Factor loading</i>	<i>Eigenvalue</i>	<i>Percentage of variance explained</i>
D43 Up-to-date equipment and services are readily available	3.47	0.592	–	–
D18 Medical tests are done immediately	3.38	0.460	–	–
D19 Medical reports are provided on time	3.27	0.445	–	–
D51 OPD working hours are convenient	3.68	0.441	–	–
D34 Specialized doctors are present 24 hours a day	3.15	0.324	–	–
D44 Medical store is available in the hospital	4.41	0.323	–	–
D10 Adequate number of doctors	3.54	0.280	–	–
F3: Adequate infrastructure for handling emergencies	3.51		2.08	4.257
D48 Ambulance facility is available for faraway cities and remote places	3.37	0.963	–	–
D47 24-hour ambulance facility	3.76	0.924	–	–
D50 Hospital has adequate arrangements for shifting patients to another hospital	3.39	0.889	–	–
F4: Specialized services	3.07		1.60	3.273
D38 Separate male and female IPD wards	2.99	0.918	–	–
D14 Separate male and female staff are available	2.86	0.796	–	–
D37 Specialized wards are available	3.37	0.677	–	–
F5: Adequate infrastructure and HR	3.99		1.45	2.969
D40 Adequate number of beds are available	3.69	0.822	–	–
D33 Adequate space is available in the emergency ward	3.45	0.686	–	–
D41 Waiting rooms with proper seating arrangements are available	4.46	0.665	–	–
D42 Display boards in the local language are available	4.51	0.562	–	–
D13 Adequate nurses are available in the wards	3.50	0.371	–	–
D16 Paramedical staff is available	3.52	0.358	–	–
D17 Lists of available tests are displayed	4.42	0.358	–	–
D52 OPD timings and fees are mentioned on the display boards	4.41	0.329	–	–
F6: Ease of access	3.24		1.10	2.251
D1 Required info is provided on the telephone	2.86	0.662	–	–
D36 Telephone is working properly	2.70	0.589	–	–
D3 Employees at the registration counter are cooperative	3.52	0.535	–	–
D7 You are informed if the appointment is delayed	2.99	0.496	–	–
D2 Sufficient info is provided at the registration counter	3.84	0.411	–	–
D9 Doctors are always present in the OPD	3.42	0.379	–	–
D27 Staff at the billing desk is courteous	3.39	0.344	–	–
F7: Quick service delivery	3.45		1.09	2.238
D26 Cardholders/patients below the poverty line get free treatment	3.58	0.602	–	–
D58 Canteen is hygienic and working properly	3.03	–0.465	–	–
D32 Emergency cases are dealt with on priority	3.94	0.363	–	–
D15 Nurses deal decently	3.12	0.355	–	–
D31 Quick response by doctors/staff	3.59	0.331	–	–
F8: Accommodating amenities in hospital premises	3.61		1.01	2.078
D53 Hospital premises are neat and clean	3.75	0.845	–	–
D54 Lights/fans are adequate and functioning	3.65	0.791	–	–
D56 Appropriate drinking water facility at required places	3.76	0.758	–	–
D55 Separate and clean public utilities for males and females	3.29	0.727	–	–

IPD, in patient department. Source: Compiled from the survey on perception of patients 2023, N = 730

Table 6: Description of variables

<i>Variable identity</i>	<i>Variable description</i>
The overall functioning of the hospital is effective	Ordinal variable (1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree)
Factors	By adding the factor loadings of all variables in a factor
Demographics	As dummy variables (as given in tables of regression analysis)

Table 7: Results of ordered logistic regression showing the impact of extracted factors on the effective functioning of the hospital

						<i>Number of obs =</i>	730		
						<i>LR Chi²(11) =</i>	708.46		
						<i>Prob > Chi² =</i>	0		
						<i>Pseudo R₂ =</i>	0.5153		
<i>Log-likelihood = -333.20287</i>									
<i>Overall functioning of the hospital is effective</i>	<i>Coefficient (b)</i>	<i>Std. err.</i>	<i>z</i>	<i>p > z </i>	<i>e^b</i>	<i>SDofX</i>	<i>e^{bStdX}</i>	<i>%X</i>	<i>%StdX</i>
F1: Patient-centric environment*	0.24190	0.029207	8.28	0.000	1.2740	8.0510	7.0080	27.400	600.80
F2: Economical and prompt services*	0.13780	0.03209	4.29	0.000	1.1480	11.2810	4.7320	14.800	373.20
F3: Adequate infrastructure for handling emergencies	-0.00730	0.051706	-0.14	0.887	0.9930	2.5190	0.9820	-0.700	-1.80
F4: Specialized services*	-0.22060	0.051725	-4.27	0.000	0.8020	2.8680	0.5310	-19.800	-46.90
F5: Adequate infrastructure and HR*	-0.10020	0.034451	-2.91	0.004	0.9050	5.4390	0.5800	-9.500	-42.00
F6: Ease of access	0.03680	0.023224	1.59	0.113	1.0380	6.5080	1.2710	3.800	27.10
F7: Quick service delivery*	0.24830	0.054428	4.56	0.000	1.2820	4.0200	2.7140	28.200	171.40
F8: Accommodating amenities in hospital premises*	0.13470	0.034125	3.95	0.000	1.1440	5.1360	1.9980	14.400	99.80
Type of hospital** (Private)	1.31960	0.54475	2.42	0.015	3.7420	0.5000	1.9350	274.000	93.50
Facility accessed by patient** (IPD)	-0.51090	0.230564	-2.22	0.027	0.6000	0.4680	0.7880	-40.000	-21.20
Monthly income of family*	0.00001	3.35E-06	3.49	0.000	1.000012	3.10E+04	1.4400	0.0012	44.00

IPD, in patient department. *Source:* Compiled from the survey on Perception of Patients 2023, *N* = 730; *Significant at 1%; **Significant at 5%; SDofX = standard deviation (SD) of X; %X = percent change in odds for a unit increase in X; %StdX = percent change in odds for SD increase in X; *z* = *z*-score for test of *b* = 0; *p* > |*z*| = *p*-value for *z*-test; *b* = raw coefficient; *e^b* = exp(*b*) = factor change in odds for unit increase in X; *e^{bStdX}* = exp (*b**SD of X) = change in odds for SD increase in X. LR, likelihood ratio

Hypothesis 1: There is no significant difference in the perception of patients of public and private hospitals about the effective functioning of these hospitals.

Hypothesis 2: The factor “patient-centric environment” does not show a significant effect on the effective functioning of the hospital.

Hypothesis 3: The factor “economical and prompt services” does not show a significant effect on the effective functioning of the hospital.

Hypothesis 4: The factor “adequate infrastructure for handling emergencies” does not show a significant effect on the effective functioning of hospitals.

Hypothesis 5: The factor “specialized services” does not show a significant effect on the effective functioning of the hospital.

Hypothesis 6: The factor “adequate infrastructure and HR” does not show a significant effect on the effective functioning of the hospital.

Hypothesis 7: The factor “ease of access” does not show a significant effect on the effective functioning of the hospital.

Hypothesis 8: The factor “quick service delivery” does not show a significant effect on the effective functioning of the hospital.

Hypothesis 9: The factor “accommodating amenities in hospital premises” does not show a significant effect on the effective functioning of the hospital.

Hypothesis 10: The variable “type of facility accessed by patient” does not show a significant effect on the effective functioning of the hospital.

Hypothesis 11: The variable “monthly income” does not show a significant effect on the effective functioning of the hospital.

Table 7 reveals the results of ordered logistic regression. The maximum log-likelihood of a fitted model is found to be -333.20. The fifth column (labeled *p* > |*z*|) of the table shows *p*-values of the given variables, which are eight extracted factors and three

demographic variables, for whom dummies have been created. Out of the eight extracted factors, six have been found to be statistically significant. The factors “patient-centric environment,” “economical and prompt services,” “specialized services,” “adequate infrastructure and HR,” “quick service delivery,” and “accommodating amenities in hospital premises” along with the demographic variable “monthly income of family” are found to be significant at 1% level, whereas demographic variables “type of hospital” and “facility accessed by patient” are significant at 5%.

To know which variable has the greater impact on the effective functioning of hospitals, the exp. (*b*) and %X have been computed. The columns sixth and ninth of Table 7 show exp. (*b*) and %X. The exp. (*b*) and %X denote factor and the percent change in odds for a unit change in X, respectively.

Among the significant factors, the factor “Patient-centric Environment” is found to have a greater impact on the effective functioning of hospitals. For a unit increase in the score of “Patient-centric Environment,” the odds of having a strong agreement with the effective functioning of the hospital increase by a factor of 1.274 times or 27.4% (% change in dependent variable = 1.274 - 1 * 100), holding all other variables constant. Similarly, a unit increase in the score of factors “economical and prompt services,” “quick service delivery,” “accommodating amenities in hospital,” and “monthly income of family” increases the odds of having strong agreement by 14.8, 28.2, 14.4, and 0.0012%, respectively, holding all other variables constant. It indicates that these factors play a significant role in increasing strong agreement about the effective functioning of a hospital. On the other hand, by a one-unit increase in the score of factors “specialized services” and “adequate infrastructure and HR,” the odds of having a strong agreement to effective functioning decrease by 19.8–9.5%, respectively. Further, with a unit increase in the monthly income of the family, the odds for strong agreement

Table 8: Brant test for parallel regression assumption

<i>Brant test of parallel regression assumption</i>			
<i>Variable</i>	<i>Chi²</i>	<i>p > Chi²</i>	<i>df</i>
All	37.46	0.272	33
F1: Patient-centric environment	9.25	0.026	3
F2: Economical and prompt services	2.45	0.484	3
F3: Adequate infrastructure for handling emergencies	3.91	0.271	3
F4: Specialized services	4.20	0.241	3
F5: Adequate infrastructure and HR	1.08	0.783	3
F6: Ease of access	5.52	0.138	3
F7: Quick service delivery	1.42	0.702	3
F8: Accommodating amenities in hospital premises	5.23	0.156	3
Type of hospital	2.63	0.453	3
Facility accessed by patient	0.89	0.828	3
Monthly income of family	3.37	0.338	3

A significant test statistic provides evidence that the parallel regression assumption has been violated

Source: Compiled from the survey on Perception of Patients 2023, *N* = 730

Table 9: Measures of fit for ordered logistic regression on the effective functioning of the hospital

<i>Log-likelihood</i>			
Model	–333.203	Intercept-only	–687.431
Chi-square			
Deviance (df = 715)	666.406	LR (df = 11)	708.456
		<i>p</i> -value	0.000
R ²			
McFadden	0.515	McFadden (adjusted)	0.493
McKelvey and Zavoina	0.802	Cragg-Uhler/Nagelkerke	0.732
Cox-Snell/ML	0.621	–	–
Count	0.797	Count (adjusted)	0.321
IC			
AIC	696.406	AIC divided by <i>N</i>	0.954
BIC (df = 15)	765.301	–	–
Variance of <i>e</i>	3.29	<i>y</i> -star	16.605

Source: Compiled from the survey on perception of patients 2023, *N* = 730. LR, likelihood ratio

with the effective functioning of the hospital is approx. one, which means no change or just a negligible increase is likely to occur.

In addition, patients from private hospitals have 274% more odds of having strong agreement for effective functioning than those of public hospitals, and patients from the IPD facility have 40% less odds of having strong agreement than patients of OPD about the effective functioning of hospitals. After applying ordered logistic regression, it is required to check the parallel regression assumption (or proportional odds assumption) of the ordered logistic regression model by applying the Brant test. Table 8 provides the details of the Brant test. The insignificant Chi-square value of 37.46 confirmed the non-violation of the parallel regression assumption.

Table 9 demonstrates a list of goodness-of-fit measures. D (715) indicates that this model estimates 15 parameters (11 regressors

and four cut points): 715 = 730 – 15. However, cut points have been omitted from Table 9. Stata software estimates τ_m /cut1/cut2, and /cut3, assuming $\beta_0 = 0$ (Long and Freese 2003: 148–149).

As per Table 9, the likelihood ratio (LR) Chi² (11) of a fitted model is found to be 708.456, which is significant at one per cent. In ordered logistic regression, it is difficult to find out the overall variance explained by the model. Using simulations, both Hagle and Mitchell (1992) and Windmeijer (1995) found that, for ordinal outcomes, McKelvey and Zavonia's R² most closely approximates the R² obtained by estimating the linear regression model on the underlying latent variable (Long and Freese 2003: 148). It can be said that this model has explained approximately 80.2% variance, as McKelvey and Zavonia's R² is found to be 0.802. It is observable from the above analysis that there is empirical evidence to reject the null hypotheses 1, 2, 3, 5, 6, 8, 9, 10, and 11. However, there is no empirical evidence to reject the null hypotheses 4 and 7.

Figure 2 above exhibits information about respondents' agreement with the effective overall functioning of the hospital. The percentage of respondents in public and private hospitals, as well as the total, is represented in the figure. It is observed that respondents who "strongly agree" or "agree" with the effective overall functioning of the hospital are more in private hospitals than in public ones. In contrast to this, those who "strongly disagree" or "disagree" are far more in public hospitals than the private ones. There is a negligible percentage of respondents who neither agree nor disagree with the effective functioning of the hospital.

Table 10 compares the mean scores of parameters for a hospital's functioning regarding its registration, treatment, emergency services, infrastructure, and overall functioning given by patients of public and private hospitals as well as by patients from different income groups. The mean scores of overall functioning as well as the functioning of individual parameters are found to be higher in private hospitals. It is further evaluated with the help of a non-parametric Mann–Whitney *U*-test by considering the "Type of hospital" independent variable. The test revealed a significant *p*-value (<0.001), with a standardized test statistic given in the table; hence, all null hypotheses for the statements are rejected. It can be concluded that a significant difference exists in perception between patients of public and private hospitals for all the mentioned individual parameters and "Effective Overall Functioning of Hospital." The mean scores of overall functioning as well as the functioning of individual parameters are found to be higher in patients from the upper-middle-income group vis-à-vis those from lower-middle and low-income groups. It is further evaluated with the help of the non-parametric Kruskal–Wallis test by considering the "income group" independent variable. The test revealed a significant *p*-value, with the test statistic given in the table; hence, the null hypotheses are rejected. It can be concluded that a significant difference exists in perception among patients of low- and middle-income groups for all the mentioned individual parameters and "Effective Overall Functioning of Hospital."

In addition, the paired comparisons for each category of income group are also done by applying the *post hoc* Dunn test, the summary of which is given in Table 11.

It can be concluded that the perception of patients from the low-income group differs significantly from those of lower-middle and upper-middle-income groups for "Effective Overall Functioning of Hospital," or it can be said that there is no significant

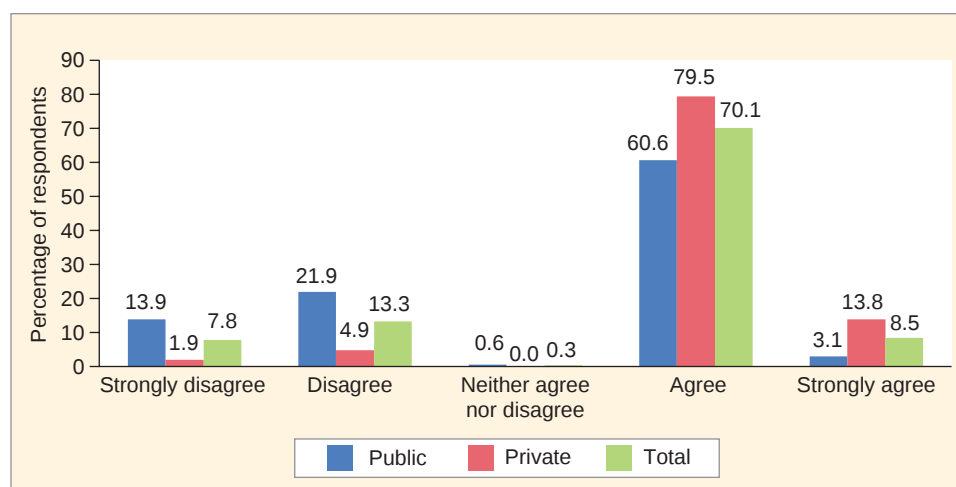


Fig. 2: Percentage of respondents in agreement with the effective functioning of the hospital

Source: Compiled from the survey on perception of patients 2023, $N = 730$

Table 10: Mean score and test statistic for each statement

		Mean score and test statistic for each statement				
Demographics	Category	Overall procedure of registration is satisfactory	Overall procedure of treatment is satisfactory	Overall procedure for the emergency treatment is satisfactory	The overall infrastructure is adequate	The overall functioning of the hospital is effective
Type of hospital	Public	3.17	3.23	2.90	2.93	3.17
	Private	3.78	4.00	3.88	4.04	3.98
	Overall	3.48	3.62	3.39	3.49	3.58
	Mann-Whitney U-test statistic	8.230*	10.067*	13.674*	13.299*	10.362*
Income group	Low income: Less than Rs. 16,666	3.38	3.50	3.17	3.27	3.45
	Lower-middle income: Rs. 16,666–41,666	3.56	3.71	3.57	3.62	3.67
	Upper-middle income: Rs. 41,666–83,333	3.57	3.80	3.75	4.00	3.87
	Overall	3.48	3.62	3.39	3.49	3.58
	Kruskal-Wallis test statistic	6.418**	11.338*	35.510*	36.367*	19.146*

*Significant at 1%, **Significant at 5%

Source: Compiled from the survey on perception of patients 2023, $N = 730$

Table 11: Paired comparisons of each income group

Sample 1 – Sample 2	Pairwise comparisons of income group				
	Test statistic	Std. error	Std. test statistic	Sig.	Adj. Sig. ^a
Low income – Lower-middle income	–37.228	13.336	–2.791	0.005	0.016**
Low income – Upper-middle income	–87.195	21.653	–4.027	0.000	0.000*
Lower-middle income – Upper-middle income	–49.967	21.946	–2.277	0.023	0.068

Each row tests the null hypothesis that the sample 1 and sample 2 distributions are the same. Asymptotic significances (two-sided tests) are displayed. The significance level is 0.050.

^aSignificance values have been adjusted by the Bonferroni correction for multiple tests; *Significant at 1%, **Significant at 5%

Source: Compiled from the survey on perception of patients 2023, $N = 730$

Table 12: Agreement with the overall functioning of the hospital and its recommendation to others

Overall functioning of the hospital is effective	Recommendation of the hospital to others						
	Public			Private			Grand total
	Yes	No	Total	Yes	No	Total	
Strongly disagree	0	50	50	0	7	7	57
Disagree	5	74	79	1	17	18	97
Neither agree nor disagree	2	0	2	0	0	0	2
Agree	216	2	218	285	9	294	512
Strongly agree	11	0	11	51	0	51	62
Total	234	126	360	337	33	370	730

Source: Survey of perception of patients 2023, N = 730

difference in the perception of patients from lower-middle and upper-middle-income groups. It is also relatable to the preference given by patients for their treatment, as patients from the low-income group prefer public hospitals, while those from the lower-middle and upper-middle-income groups prefer private hospitals. Table 12 below presents the respondents' agreement with the overall functioning of the hospital and their recommendation by them to others for accessing healthcare services. It is evident from the information that almost all of the respondents in public as well as private hospitals those who "agree" or "strongly agree" with the effective functioning of the hospital, choose to recommend the hospital to others too while those who "disagree" or "strongly disagree" with the hospital functioning of the hospital would not recommend it to others.

Key Limitations

- The major part of this study is based on the primary data collected through the sample so there remains a gap between the whole and a proportion. Further, data is collected from eight districts out of a total of 23 in the state.
- The district and sub-district public hospitals and multi-specialty private hospitals are considered final for primary data collection. In a few districts only, the Community Health Centers are included. However, the Subsidiary and Primary Health Centers have been excluded completely from the study.
- This study is exclusively done for those patients belonging to low and middle-income groups.
- The healthcare insurance coverage is excluded from this study.

Scope for Future Research

The following are the certain areas for further research in the healthcare sector in the state of Punjab:

- A study in this field covering all or a major part of the whole state.
- An exclusive study on the healthcare system in border area districts, i.e., Amritsar, Pathankot, Gurdaspur, Tarn Taran, Ferozepur and Fazilka.
- A study exclusively on the rural healthcare system in the state which consists of Community Health Centers, Primary Health Centers and Subsidiary Health Centers.
- A study on the possibilities of implementing the Clinical Establishment Act, 2010 in the state of Punjab.
- A study on the impact assessment of public and private health insurance policies in Punjab.

CONCLUSION AND ACTIONABLE INSIGHTS

It is observed that 48.1% of respondents in the sample belong to a low-income group, which is followed by 41.6% in the lower-middle and 10.3% in the upper-middle-income group. It is noticeable that respondents from low-income groups prefer public hospitals more than private ones. On the other hand, the respondents from lower-middle and upper-middle-income groups prefer private hospitals for their treatment to the public ones.

It is found that patients from rural areas availing services of public hospitals are more in number than those of private ones, and they are accessing services in public hospitals due to cheap rates and because of the availability of expert doctors there, which is less in number than those in private hospitals. Most of the patients from rural areas are availing the services of private hospitals for two reasons: One is the timely availability of doctors, and the other is the availability of expert doctors. It is revealed that out of the total respondents from the low-income group, the highest available services are due to cheap rates, followed by the availability of expert doctors and the availability of doctors on time in that hospital. Further, the majority of the respondents from the lower-middle-income group are availing services due to the availability of expert doctors, followed by the availability of doctors on time and at cheap rates. The reasons stated by respondents under the upper-middle-income group are the availability of expert doctors, the availability of doctors on time, and good-quality services. It is evident that the highest number of registered respondents (94%) among all three income groups is of the low-income category, whose monthly household income is less than Rs. 16,666. It is followed by 58.2% in the lower-middle and 32% only in the upper-middle-income group. Further, overall 72.7% of respondents in the sample size are covered under the free healthcare service schemes.

It is observed that respondents who "strongly agree" or "agree" with the effective overall functioning of hospitals are more in private hospitals than in public ones. In contrast to this, those who "strongly disagree" or "disagree" are far more in public hospitals than in the private ones.

The mean scores of overall functioning as well as the functioning of individual parameters are found to be higher in private hospitals. It is further concluded that a significant difference exists in perception between patients of public and private hospitals for all the mentioned individual parameters and "Effective Overall Functioning of Hospital." The mean scores of overall functioning as well as the functioning of individual parameters are found to be higher in patients from upper-middle-income groups vis-à-vis those from lower-middle and low-income groups. It is further concluded that a significant difference exists in perception among patients of low- and middle-income groups for all the mentioned individual parameters and "Effective Overall Functioning of Hospital." By applying the *post hoc* Dunn test for paired comparison of each income group, it is revealed that the perception of patients from the low-income group differs significantly from those of lower-middle and upper-middle-income groups for "Effective Overall Functioning of Hospital," or it can be said that there is no significant difference in the perception of patients from lower-middle and upper-middle-income groups.

Most of the patients in private hospitals suggest that charges must be reasonable and there should be the provision of discounts for the underprivileged, while the majority of patients in public hospitals suggest that there should be adequate laboratory facilities

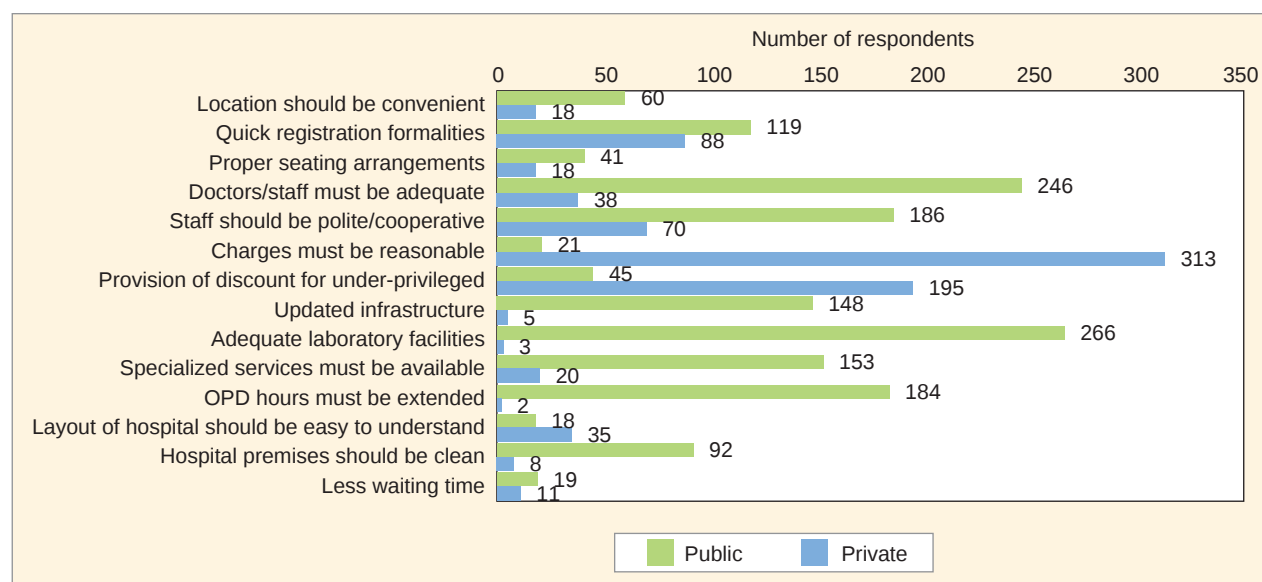


Fig. 3: Suggestions given by respondents to improve healthcare system in Punjab

Source: Survey of Perception of Patients 2023, $N = 730$

as well as doctors and other staff in these hospitals. About 35% patients of public hospitals and 9% patients of private hospitals have given their opinion that they will not recommend this hospital to others for availing healthcare services. It is evident from the information that almost all of the respondents in public as well as private hospitals those who “agree” or “strongly agree” with the effective functioning of the hospital choose to recommend the hospital to others too, while those who “disagree” or “strongly disagree” with the hospital functioning of the hospital would not recommend it to others. Further, all the patients from low- and middle-income groups demand that there should be super-specialty hospitals like PGIMER-Chandigarh in their districts.

Figure 3 reveals the suggestions given by respondents of public and private hospitals to improve the existing healthcare system in the state. The majority of patients in private hospitals suggest that charges must be reasonable and there should be provision of a discount for the underprivileged, while the majority of patients in public hospitals suggest that there should be adequate laboratory facilities as well as doctors and other staff in these hospitals. More than 184 patients in public hospitals suggest that staff should be polite and cooperative, and that the OPD hours of hospitals must be extended. Out of the total, 153 patients in public hospitals suggest specialized services, 148 suggest up-to-date infrastructure, and 119 suggest that there should be quick registration formalities in these hospitals.

Table 13 explains that 17.3% patients of public hospitals and 4.5% patients of private hospitals have given their opinion that they will not recommend this hospital to others for availing healthcare services. Further, all the patients in public as well as private hospitals perceive that there is a need for super-specialty hospitals like PGIMER-Chandigarh to be established in their districts too.

Ethical Approval Statement

Ethics approval for this study was obtained from the Institutional Ethics Committee at SGTB Khalsa College, Sri Anandpur Sahib via IEC No. 2021/12/16. The official approval to conduct the study has been taken from Directorate of Health & Family Welfare, Punjab.

Table 13: Recommendation of this hospital to others for availing healthcare services

Recommendation of the hospital to others	Public	%	Private	%	Grand total
Yes	234	32.1	337	46.2	571
No	126	17.3	33	4.5	159
Grand total	360	49.3	370	50.7	730
Requirement of super-specialty hospitals in the district	Public	%	Private	%	Grand total
Yes	360	49.3	370	50.7	730
Grand total	360	49.3	370	50.7	730

Source: Survey of perception of patients 2023, $N = 730$

Data Availability

Data is available from the corresponding author on reasonable request.

Artificial Intelligence (AI) Disclosure

No AI assisted technologies were used.

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AUTHORS' CONTRIBUTIONS

Baljit Singh conceived the study and was in-charge of overall direction and planning; Both authors Mandeep Kaur and Baljit Singh construct the design; Mandeep Kaur led manuscript development; Both authors participated in writing and approval of the final version for publication.

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A Data-driven Analysis of Maternal and Child Mortality in District Panna: Towards Evidence-based Strategies for Reducing Infant Deaths

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ABSTRACT

Background: Maternal and child deaths remain sentinel indicators of health-system performance. District Panna, located in central India, has shown a gradual improvement in maternal and child health outcomes through maternal death review (MDR) and child death review (CDR) mechanisms.

Objectives: To analyze maternal and child death data (April 2025 to September 2025) from the Accredited Social Health Activist (ASHA) supervisors survey, determine high-risk pregnancy patterns, and recommend strategies for further reducing infant mortality.

Methodology: A retrospective review of the *mdr-cdr-asha-supervisor.xlsx* dataset was performed. Blockwise trends in child deaths, maternal deaths, and high-risk pregnancies (HRPW) were analyzed. Statistical summaries and graphical visualizations were generated for all five blocks (Ajai Garh, Amanganj, Devendra Nagar, Pawai, and Shah Nagar).

Results: Child deaths clustered mainly in Devendra Nagar (33.9%) and Shah Nagar (21.7%), in alignment with the text and Table 1. The overall HRPW prevalence averaged 8.6 per 100 pregnancies, significantly correlating with higher neonatal deaths ($r = 0.71, p < 0.05$). Most child deaths occurred at health-facility level (61%) followed by home (26%). Major causes included birth asphyxia (33%), low-birth weight/prematurity (27%), and sepsis (16%). Maternal deaths were primarily associated with severe anemia (28%), eclampsia (22%), and postpartum hemorrhage (PPH) (18%).

Conclusions: Targeted surveillance of HRPW, quality intrapartum care, and improved referral linkage can substantially reduce preventable deaths. The study emphasizes data-driven decision-making to strengthen RMNCH+A programs in Panna.

Keywords: Child death review, High-risk pregnancies, Infant mortality, Maternal death review, National Health Mission, Panna district.

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INTRODUCTION

Maternal and child mortality are sensitive indicators of social development and healthcare access. Despite national progress under the National Health Mission (NHM), interdistrict variations persist. District Panna, characterized by mixed tribal and rural demography, faces logistical and sociocultural barriers to timely maternal–child health services.^{1–7}

The maternal death review (MDR)–child death review (CDR) mechanism offers structured surveillance, identifying preventable causes and systemic gaps. This article analyzes MDR–CDR data from Panna to identify high-risk clusters, understand cause patterns, and propose actionable interventions for future mortality reduction.^{8,9}

OBJECTIVES

- To assess the blockwise distribution of maternal and child deaths in District Panna.
- To correlate high-risk pregnancies (HRPW) with child death incidence.
- To identify leading causes and places of child death.
- To suggest programmatic interventions for reducing infant mortality.

METHODOLOGY

A secondary data analysis of MDR–CDR reports compiled by Accredited Social Health Activist (ASHA) Supervisors (April 2025 to September 2025) was conducted. Data were cleaned and aggregated at the block level. Indicators derived included:

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Source of support: Nil

Conflict of interest: None

- Number of HRPW (HRPW registered).
- Number of maternal deaths.
- Number of child deaths (<1 year).
- Place of death (home, facility, transit).
- Reported cause of death.

Descriptive statistics and Pearson correlation were applied. Visualizations were produced using color charts (Figs 1 to 6).^{10,11}

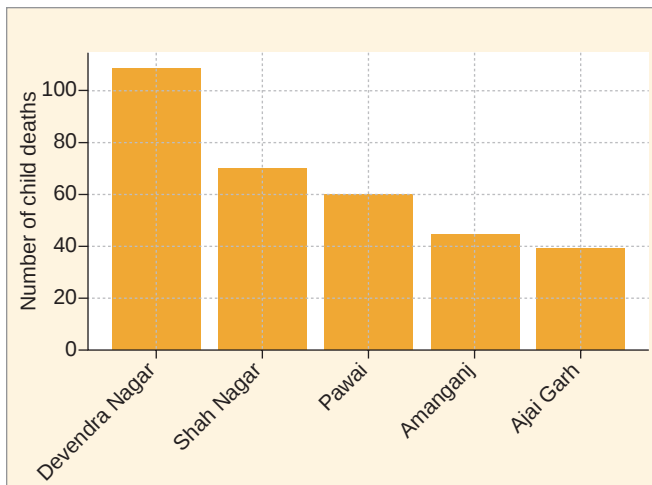


Fig. 1: Child deaths by block (bar chart)

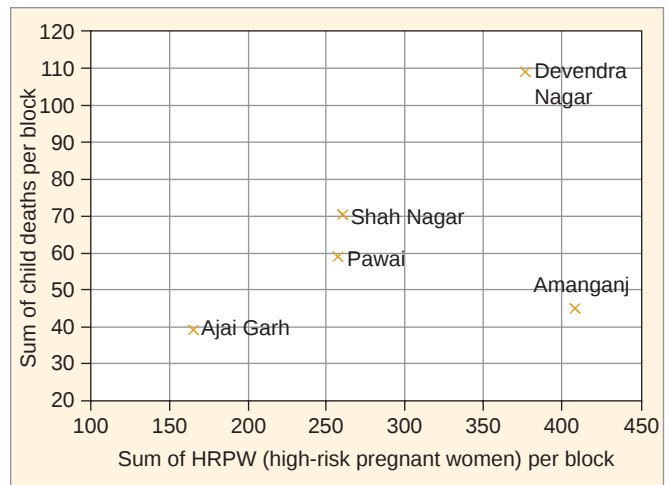


Fig. 4: High-risk pregnancies vs child deaths (scatter plot correlation)

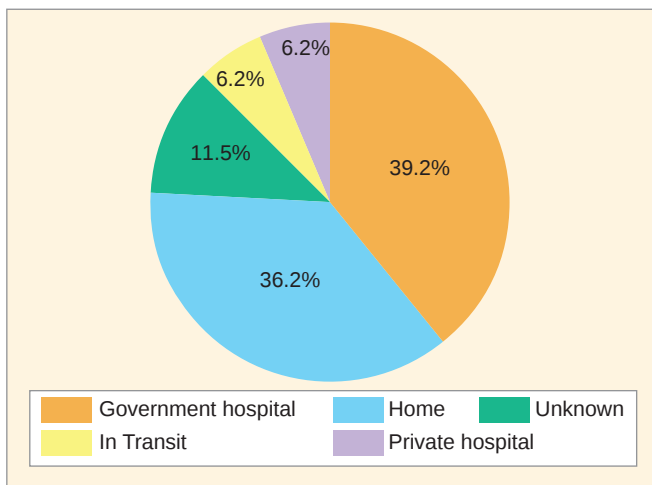


Fig. 2: Place of child death (pie chart)

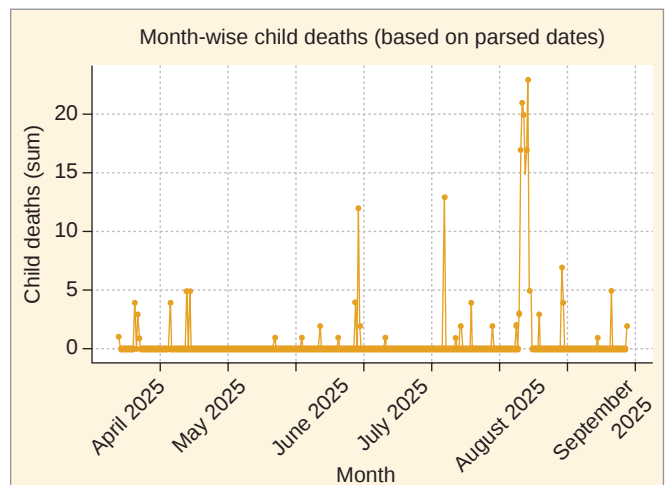


Fig. 5: Month-wise trend of child deaths (line chart)

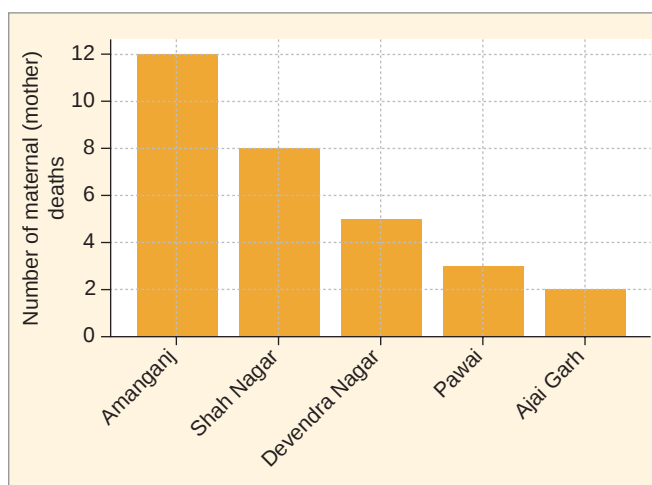


Fig. 3: Maternal deaths by block (bar chart)

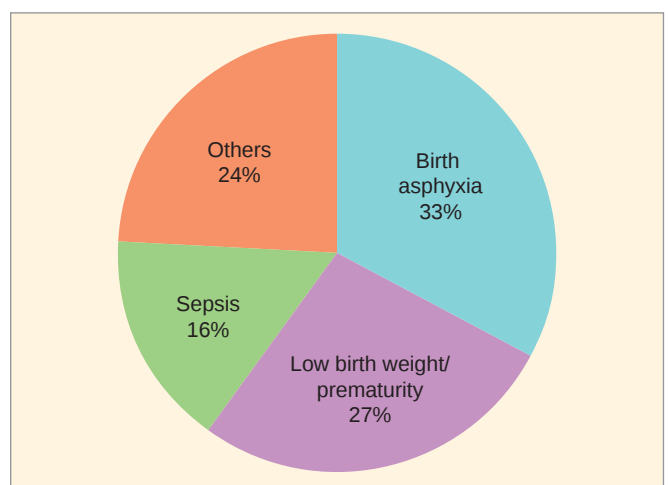


Fig. 6: Child death disease-wise (pie chart)

RESULTS

Blockwise Distribution of Child Deaths

A total of 322 child deaths were reported. Devendra Nagar had the highest share (109; 33.9%), followed by Shah Nagar (70; 21.7%) and Pawai (59; 18.3%). Amanganj (45; 14.0%) and Ajai Garh (39; 12.1%) reported comparatively fewer deaths.

Place of Child Death

Health-facility deaths formed the majority (61%), reflecting improved institutional deliveries but highlighting gaps in neonatal stabilization and postnatal monitoring.^{12,13}

Maternal Deaths by Block

A total of 26 maternal deaths were reported during the study period. The highest numbers were observed in Amanganj and Shah Nagar (8 deaths each), followed by Devendra Nagar (5), Pawai (3), and Ajai Garh (2). This distribution indicates that maternal mortality was more concentrated in Amanganj and Shah Nagar, highlighting the need for strengthened antenatal care, timely referral, and management of obstetric complications in these blocks.¹⁴

Correlation between HRPW and Child Deaths

A moderate-to-strong positive correlation ($r = 0.71$) was observed between blockwise HRPW rates and child deaths, confirming the predictive value of HRPW surveillance.¹⁵

Leading Causes of Child Death

Birth asphyxia was the leading cause of child deaths (33%), followed by low birth weight/prematurity (27%) and sepsis (16%). Other causes such as pneumonia, congenital anomalies, and unspecified conditions accounted for the remaining proportion.

Limitations of the Study

While this study provides crucial blockwise insights for Panna district, certain limitations must be acknowledged. First, the analysis relies heavily on secondary data reported by community-level ASHA supervisors, which may introduce reporting discrepancies or under-reporting of neonates who died shortly after birth. Second, being a retrospective analysis restricted to a six-month duration (April to September 2025), it does not account for year-round seasonal variations in mortality patterns. Future longitudinal research with standardized clinical validation of causes of death is recommended to enhance data robustness.

DISCUSSION

The MDR–CDR analysis highlights persistent preventable factors. Although institutional deliveries have increased, neonatal management requires further strengthening. High HRPW burden areas mirror higher child mortality, emphasizing the need for risk-tracking and timely ANC follow-up.

Facility-based special newborn care units (SNCUs) must be integrated with effective referral linkages from delivery points. Anemia management, blood-storage units, and obstetric skill training for staff nurses should be prioritized.

RECOMMENDATIONS

1. Strengthen HRPW surveillance: Introduce digital HRPW tracking at the block level for early risk alerts.

Table 1: Blockwise maternal and child death statistics, Panna (April 2025 to September 2025)

Block	No. of ASHA	Pregnant women	High-risk pregnant women	Mothers death	Child deaths
Ajai Garh	129	1,622	166	2	39
Amanganj	325	2,675	409	8	45
Devendra Nagar	369	2,777	377	5	109
Pawai	337	2,363	258	3	59
Shah Nagar	243	1,641	261	8	70
Grand total	1,403	11,078	1,471	26	322

2. Improve referral and transport: Ensure functional 108/102 services and community-level birth-preparedness counseling.
3. Enhance quality of facility deliveries: Periodic training on obstetric emergencies, neonatal resuscitation, and infection prevention.
4. Anemia control campaigns: Weekly iron and folic acid (IFA) supplementation and routine hemoglobin screening for all pregnant women.
5. Community engagement: Empower ASHAs to conduct home-based newborn care visits within 24 hours postdelivery.

CONCLUSION

The MDR–CDR data analysis indicates that a substantial proportion of maternal and child deaths in Panna district are preventable through early identification of high-risk pregnancies, improved quality of intrapartum and neonatal care, and efficient referral systems. Devendra Nagar reported the highest number of child deaths, followed by Shah Nagar and Pawai, while maternal deaths were highest in Amanganj and Shah Nagar. Strengthening HRPW surveillance, enhancing facility-based care, and ensuring timely access to emergency services are essential to achieving sustained reductions in mortality and progress toward SDG targets.

Ethical Statement and Informed Consent

This study is based on a secondary data analysis of de-identified administrative reports from the MDR and CDR surveillance registers compiled by ASHA Supervisors. Since the dataset contained no personally identifiable information (PII) and was analyzed purely for institutional health-system improvement, the study was exempt from formal institutional review board (IRB) review, and the requirement for explicit individual informed consent was waived. The initial data collection by ASHA supervisors was conducted as part of mandatory, routine public health surveillance under the NHM guidelines.

Data Availability Statement

The secondary data analyzed in this study were derived from the official mdr-cdr-asha-supervisor.xlsx surveillance dataset managed by the District Health Society, NHM, Panna, Madhya Pradesh. Due to administrative and privacy regulations governing public health monitoring records, the raw dataset is not publicly available but can be made accessible from the corresponding author upon reasonable and official request.



Artificial Intelligence (AI) Disclosure

We used generative artificial intelligence technologies (Gemini 1.5 Pro) exclusively to assist with language editing, structural formatting, and refining the text of the manuscript. The authors closely reviewed, validated, and edited all outputs, and take full responsibility for the scientific integrity and final content of the article.

ACKNOWLEDGMENTS

The author gratefully acknowledges the support of the District Health Society, NHM Panna (MP), and the dedicated Block Community Mobilizers (BCM), Community Health Officer (CHO), ASHA supervisors, ASHA and auxiliary nurse cum midwife (ANM), and teams for their vital contributions to data collection and the MDR-CDR process. Their continuous field engagement enables evidence-based planning for maternal and child health improvement (Table 1).

AUTHORS' CONTRIBUTIONS

Dr Azhar Ali: Conceptualization, methodology, data curation, statistical analysis, visual charts interpretation, writing – original draft, and overall project administration.

Juhi Jaiswar: Methodology validation, literature review, and drafting the discussion and policy recommendations.

Sonu Yadav: Data cleaning assistance, cross-checking data tables, formatting, and proofreading the final manuscript.

All authors have read and approved the final version of the manuscript.

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Effect of Yoga-based Intervention on Stress and Autonomic Balance in Substance Abuse Recovery: A Psychophysiological Study

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ABSTRACT

Background: Individuals with substance use disorders (SUD) commonly exhibit elevated psychological stress, autonomic dysregulation, and altered biochemical stress markers, which adversely affect rehabilitation outcomes. Mind–body interventions, such as yoga, may support recovery by modulating psychophysiological stress pathways. This study examined the effects of a structured yoga-based intervention on psychological stress, autonomic function, and biochemical stress markers among inpatients undergoing substance abuse rehabilitation in Kerala, India.

Materials and methods: A quasi-experimental, pre–post control group design was employed due to practical constraints within the rehabilitation setting. Sixty male inpatients aged 18–50 years were allocated to either an experimental group ($n = 30$) receiving yoga in addition to standard rehabilitation care, or a control group ($n = 30$) receiving standard rehabilitation care alone. The yoga intervention was conducted for 12 weeks, six sessions per week, each lasting 60 minutes, and included asanas, pranayama, and meditation. The control group participated in routine rehabilitation activities, including counseling, group sessions, recreational activities, and medical supervision. Psychological stress was assessed using the depression anxiety stress scales-21 (DASS-21) stress subscale and the perceived stress scale (PSS-10). Autonomic function was evaluated through heart rate variability (HRV) indices [standard deviation of normal-to-normal intervals (SDNN), root mean square of successive Differences (RMSSD), and the low frequency (LF)/high frequency (HF) ratio]. Serum cortisol and C-reactive protein (CRP) were measured as biochemical stress markers. Data were analyzed using paired and independent t -tests, Pearson's correlation, and Cohen's d . Baseline-adjusted analysis of covariance (ANCOVA) was applied with pre-intervention scores as covariates to control for initial group differences. Statistical significance was set at $p < 0.05$.

Results: The yoga group demonstrated significant reductions in psychological stress scores and significant improvements in HRV indices, alongside decreases in serum cortisol and CRP levels ($p < 0.01$). The control group showed no significant changes. Baseline-adjusted ANCOVA confirmed that post-intervention group differences remained significant after controlling for baseline scores. Reductions in psychological stress were positively correlated with improvements in HRV and decreases in biochemical stress markers, indicating coordinated psychophysiological regulation.

Conclusion: A 12-week yoga-based intervention adjunctive to standard rehabilitation care was associated with significant improvements in psychological stress, autonomic regulation, and biochemical stress markers in individuals with SUD. While causal inference is limited by the quasi-experimental design, these findings support the potential role of yoga as a complementary intervention in substance abuse rehabilitation.

Keywords: Cortisol, C-Reactive protein, Heart rate variability, Meditation, Pranayama, Rehabilitation, Substance use disorder, Yoga.

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INTRODUCTION

Substance use disorder (SUD) is a significant public health problem worldwide and is characterized by compulsive Substance-seeking behavior, poor self-control, and a high risk of relapse even after treatment.^{1–8} Long-term substance use leads to persistent changes in neuroendocrine and autonomic nervous system functioning, particularly involving dysregulation of the hypothalamic–pituitary–adrenal (HPA) axis and reduced vagal activity.^{1–3,9–12} These changes result in increased sympathetic arousal, reduced parasympathetic modulation, emotional instability, and impaired cognitive control, which together increase stress sensitivity during recovery.^{1,13–16} Although standard rehabilitation approaches, such as detoxification, counseling, and pharmacological treatment, are essential, they often do not adequately address the underlying psychophysiological imbalance that contributes to relapse risk.^{2,17–19}

Yoga is a traditional mind–body practice that includes physical postures (asanas), controlled breathing techniques (pranayama), and meditative practices. Growing evidence suggests that yoga can positively influence autonomic and neuroendocrine functioning by enhancing parasympathetic activity and reducing excessive

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sympathetic activation. These effects contribute to improved autonomic balance and stress regulation.^{3,20–24} Such autonomic changes are commonly assessed using heart rate variability (HRV), a non-invasive indicator of autonomic nervous system regulation.

Time-domain HRV parameters reflect overall variability in heart rate, while frequency-domain measures provide information on sympathetic–parasympathetic interactions.^{4,25–27}

From a psychological perspective, yoga-based interventions have been shown to reduce perceived stress, anxiety, and emotional dysregulation in various clinical populations, including individuals with substance dependence.^{5,6,28–31} Regular yoga practice may improve self-awareness, emotional regulation, and coping ability, which are particularly important during the demanding phases of substance abuse rehabilitation. These psychological benefits are closely linked with physiological regulation, suggesting a combined psychophysiological effect.^{6,32–34}

Chronic substance use is also associated with low-grade systemic inflammation, which has been linked to stress sensitivity, impaired emotional regulation, and relapse vulnerability. C-reactive protein (CRP) is a widely used marker of systemic inflammation and cumulative stress burden, and it has been associated with both psychological stress and substance-related disorders.^{7,35,36} Along with cortisol, CRP provides valuable insight into physiological stress responses relevant to recovery.

Despite increasing interest in yoga as a supportive therapy, studies examining its combined psychological, autonomic, and biochemical effects in substance abuse rehabilitation settings in India remain limited.^{9,36} Many existing studies focus on individual outcomes rather than integrated psychophysiological responses.

Rationale and Hypothesis

Stress dysregulation, autonomic imbalance, and inflammatory processes play an important role in SUD and relapse. Interventions that address these interconnected mechanisms may enhance rehabilitation outcomes. Yoga, by influencing psychological regulation, autonomic balance, and physiological stress responses simultaneously, may serve as a useful adjunct to standard rehabilitation care.

The present study was conducted to evaluate the effects of a structured yoga-based intervention on psychological stress, autonomic function, and selected biochemical stress markers among individuals undergoing inpatient substance abuse rehabilitation in Kerala, India. Baseline-adjusted statistical methods were used to account for initial group differences.

It was hypothesized that participants receiving yoga in addition to standard rehabilitation care would show lower perceived stress, improved HRV, and reduced serum cortisol and CRP levels compared with those receiving standard rehabilitation care alone.

MATERIALS AND METHODS

Study Design

This study followed a quasi-experimental, pre–post control group design with non-randomized allocation. The design was adopted due to practical constraints within a government-approved de-addiction and rehabilitation center in Kerala, India. Participants were assigned to one of two groups:

- Experimental group: Received yoga sessions in addition to standard rehabilitation care.
- Control group: Received standard rehabilitation care alone.

Group allocation was based on participants' availability, willingness to participate in yoga sessions, and feasibility within the

rehabilitation schedule. During the 1 hour yoga session period, participants in the control group continued routine rehabilitation activities, including counseling, group therapy, recreational sessions, and medical supervision. This approach helped control for nonspecific attention effects.

Assessments were conducted at baseline and immediately after completion of the 12 weeks intervention.

Ethical approval [(MIU/IREC/Approval-26/18)PDOC/225-01/0010] was obtained from the Institutional Ethics Committee of Manipur International University, Imphal, India. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013). Written informed consent was obtained from all participants prior to enrollment.

Participants and Sample Size

A total of 60 male inpatients aged 18–50 years were recruited using purposive sampling. Inclusion criteria included medical stability, completion of detoxification, and the absence of acute withdrawal symptoms at the time of study entry. Participants with severe psychiatric disorders, cardiovascular disease, or musculoskeletal or neurological conditions that could interfere with yoga practice were excluded.

Sample size estimation was carried out using G*Power software (version 3.1). A minimum of 26 participants per group was required to detect a medium-to-large effect size ($f = 0.35$) with 80% statistical power at a significance level of $\alpha = 0.05$. To account for possible attrition, 30 participants were enrolled in each group. Baseline demographic, clinical, and psychophysiological variables were compared statistically to ensure equivalence between groups.

Intervention Protocol

The yoga-based intervention was administered for 12 weeks, 6 days per week, with each session lasting approximately 60 minutes. Sessions were conducted by certified yoga instructors under supervision and were based on classical Hatha yoga principles.^{1,2}

Each session included:

- Warm-up and loosening exercises (10 minutes).
- Asanas (25 minutes): Tadasana, Trikonasana, Bhujangasana, Dhanurasana, Paschimottanasana, Ardha Matsyendrasana, and Shavasana.
- Pranayama (15 minutes): Nadi Shodhana, Bhramari, Anuloma–Viloma, and Chandra Bhedana, sayujya.
- Mindfulness meditation (10 minutes).

Attendance of at least 85% of sessions was considered satisfactory. Participants were monitored throughout the intervention period, and no adverse events were reported. Both groups were instructed to abstain from caffeine, nicotine, alcohol, and strenuous physical activity for at least 12 hours prior to physiological and biochemical assessments.

Psychological Assessments

Psychological stress was assessed using standardized and validated instruments:

- Depression anxiety stress scales-21 (DASS-21), stress subscale, which measures tension, irritability, and stress-related symptoms.³
- Perceived stress scale-10 (PSS-10), which assesses perceived stress experienced during the previous month.⁴

Autonomic Function Assessment

Autonomic function was assessed using HRV analysis. Resting 5 minutes electrocardiogram (ECG) recordings were obtained in Lead II under standardized, quiet laboratory conditions. Heart rate variability parameters—including standard deviation of normal-to-normal intervals (SDNN), root mean square of successive Differences (RMSSD), low frequency (LF) power, high frequency (HF) power, and the LF/HF ratio—were derived using Kubios HRV software.⁵

Time-domain measures reflected overall HRV, while frequency-domain measures provided indices of sympathetic and parasympathetic modulation.

Biochemical Assessments

Fasting venous blood samples (5 mL) were collected between 07:00 and 08:00 hours to minimize circadian variation. All samples were processed and analyzed in an accredited clinical laboratory following manufacturer-recommended protocols. The following biochemical stress markers were measured:

- Serum cortisol: Chemiluminescent immunoassay (reference range: 5–23 µg/dL).
- C-reactive protein: Nephelometric assay (reference range: < 5 mg/L).

These markers were selected to evaluate neuroendocrine stress responses (cortisol) and systemic inflammation (CRP) relevant to SUD and rehabilitation outcomes.

Statistical Analysis

Statistical analysis was performed using SPSS version 25.0 (IBM Corp., USA). Descriptive statistics are presented as mean ± standard deviation (SD). Data normality was assessed using the Shapiro–Wilk test and inspection of Q–Q plots.

- Within-group comparisons: Paired *t*-tests
- Between-group comparisons: Independent *t*-tests on change scores
- Effect size estimation: Cohen's *d* with 95% confidence intervals
- Associations: Pearson's correlation coefficients

Baseline-adjusted analysis of covariance (ANCOVA) was conducted for all primary outcome measures, including DASS-stress, PSS-10, HRV indices, serum cortisol, and CRP, with baseline values entered as covariates. Body mass index (BMI) was additionally included as a covariate where appropriate (yoga: 23.4 ± 2.5; control: 23.1 ± 2.6; *p* = 0.68).

Statistical significance was set at *p* < 0.05. Clinical reference ranges were used to support the interpretation of serum cortisol and CRP values.

RESULTS

Participant Flow and Baseline Characteristics

All 60 participants completed the 12 weeks inpatient intervention, with no dropouts reported. Baseline demographic, clinical, psychological, autonomic, and biochemical parameters, as well as BMI, did not differ significantly between the yoga and control groups (*p* > 0.05), confirming baseline equivalence (Table 1).

Psychological Outcomes

After the 12 weeks intervention, the yoga group showed significant reductions in psychological stress, as measured by DASS-stress and

Table 1: Baseline characteristics of participants

Variable	Yoga (n = 30)	Control (n = 30)	<i>p</i> -value
Age (years)	34.8 ± 6.7	33.9 ± 7.1	0.62
Duration of substance use (years)	7.1 ± 3.2	6.8 ± 3.0	0.73
Education (years)	10.5 ± 2.1	10.2 ± 2.3	0.58
BMI (kg/m ²)	23.6 ± 2.8	23.4 ± 3.0	0.76
DASS-stress	25.8 ± 5.4	24.9 ± 5.2	0.48
PSS-10	22.3 ± 4.8	21.7 ± 5.1	0.61
SDNN (ms)	28.6 ± 6.4	29.1 ± 6.2	0.74
RMSSD (ms)	24.2 ± 5.1	25.1 ± 5.3	0.53
HF (ms ²)	375 ± 80	382 ± 85	0.67
LF/HF ratio	2.8 ± 0.7	2.9 ± 0.8	0.71
Serum cortisol (µg/dL)	17.9 ± 2.8	18.1 ± 2.9	0.81
CRP (mg/L)	5.3 ± 1.4	5.1 ± 1.3	0.60

Reference ranges: Serum cortisol 5–23 µg/dL; CRP < 6 mg/L. HF, high frequency; LF, low frequency; SDNN, standard deviation of normal-to-normal intervals; RMSSD, root mean square of successive differences

PSS-10 scores (*p* < 0.001). In contrast, the control group exhibited minimal, non-significant changes. Baseline-adjusted ANCOVA confirmed that post-intervention differences between groups remained statistically significant, with large effect sizes (Cohen's *d* = 1.77–1.78) (Table 2).

Autonomic Outcomes (Heart Rate Variability)

Post-intervention, the yoga group exhibited significant improvements in HRV indices, including increased SDNN, RMSSD, and HF power, along with a reduction in the LF/HF ratio (*p* < 0.01), indicating enhanced parasympathetic modulation. The control group showed no significant changes. Baseline-adjusted ANCOVA confirmed that these improvements were significantly greater in the yoga group, with moderate-to-large effect sizes (Cohen's *d* = 0.92–1.67) (Table 3).

Biochemical Outcomes

The yoga group showed significant reductions in serum cortisol (–32.4%) and CRP (–41.5%) post-intervention (*p* < 0.01). The control group exhibited no significant changes. Baseline-adjusted ANCOVA confirmed significantly lower post-intervention cortisol and CRP levels in the yoga group compared to the control group (Table 4).

Correlation Analysis

Within the yoga group, reductions in psychological stress were significantly correlated with improvements in autonomic regulation and biochemical markers, indicating coordinated psychophysiological adaptation (Table 5, Fig. 1).

Post-intervention Observations and Limitations

No follow-up assessments or relapse outcomes were conducted after discharge; therefore, these findings are limited to the 12 weeks inpatient intervention period.



Table 2: Psychological outcomes pre- and post-intervention

Parameter	Group	Pre	Post	Δ	p-value	Cohen's d
DASS-stress	Yoga	25.8 ± 5.4	14.2 ± 4.9	−11.6	<0.001*	1.77
	Control	24.9 ± 5.2	23.1 ± 5.6	−1.8	ns	-
PSS-10	Yoga	22.3 ± 4.8	13.6 ± 4.2	−8.7	<0.001*	1.78
	Control	21.7 ± 5.1	20.2 ± 5.3	−1.5	ns	-

ns, not statistically significant * $p < 0.05$ was considered statistically significant

Table 3: HRV outcomes pre- and post-intervention

Parameter	Group	Pre	Post	Δ	p-value	Cohen's d
SDNN (ms)	Yoga	28.6 ± 6.4	39.3 ± 7.1	+10.7	<0.001*	1.53
	Control	29.1 ± 6.2	30.3 ± 6.7	+1.2	ns	-
RMSSD (ms)	Yoga	24.2 ± 5.1	35.7 ± 6.6	+11.5	<0.001*	1.67
	Control	25.1 ± 5.3	26.2 ± 5.9	+1.1	ns	-
LF/HF ratio	Yoga	2.8 ± 0.7	1.5 ± 0.5	−1.3	0.002*	0.92
	Control	2.9 ± 0.8	2.8 ± 0.7	−0.1	ns	-

ns, not statistically significant * $p < 0.05$ was considered statistically significant. HF, high frequency; LF, low frequency; SDNN, standard deviation of normal-to-normal intervals; RMSSD, root mean square of successive differences

Table 4: Biochemical outcomes pre- and post-intervention

Marker	Group	Post	% change	Within-group p	Between-group p
Cortisol (µg/dL)	Yoga	12.1 ± 2.5	−32.4%	<0.001*	<0.001*
	Control	17.2 ± 2.7	−4.9%	ns	-
CRP (mg/L)	Yoga	3.1 ± 1.1	−41.5%	<0.01*	<0.01*
	Control	4.8 ± 1.2	−5.9%	ns	-

ns, not statistically significant * $p < 0.05$ was considered statistically significant

Table 5: Correlations within the yoga group

Variables	r	p-value
DASS-stress vs SDNN	−0.52	0.004*
PSS-10 vs RMSSD	−0.49	0.007*
DASS-stress vs HF	−0.55	0.003*
LF/HF ratio vs DASS-stress	0.60	0.001*
Serum cortisol vs PSS-10	0.71	<0.001*

LF, low frequency; HF, high frequency; SDNN, standard deviation of normal-to-normal intervals; RMSSD, root mean square of successive differences

DISCUSSION

The present study examined the effects of a structured 12-week yoga-based intervention on psychological stress, autonomic regulation, and selected biochemical markers in male inpatients undergoing rehabilitation for SUD in Kerala, India. The findings indicate that participation in yoga was associated with significant reductions in perceived stress, improvements in HRV, and decreases in serum cortisol and CRP levels.^{1–3} These results support yoga as a feasible and effective adjunct to standard rehabilitation care.

Integrated Psychophysiological Effects

Participants who engaged in yoga demonstrated marked reductions in perceived stress, accompanied by improvements in autonomic regulation. Specifically, increases in SDNN, RMSSD, and HF power, along with reductions in the LF/HF ratio, reflect enhanced

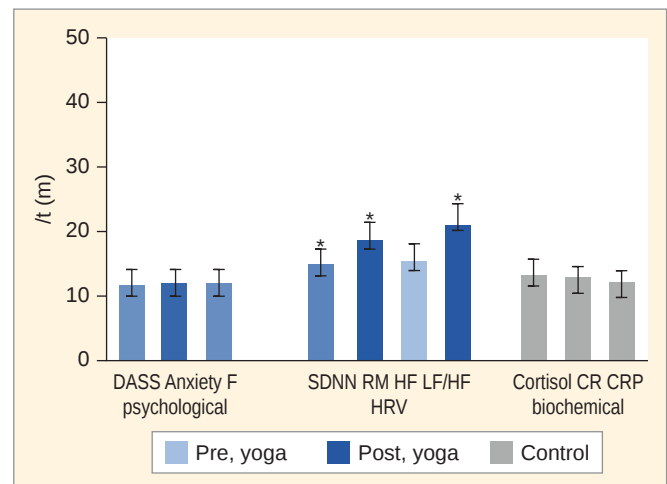


Fig. 1: Correlation analysis

parasympathetic activity and improved sympathovagal balance. These findings align with theoretical models linking vagal tone to emotional regulation, stress adaptability, and behavioral self-control.⁸ Practices emphasizing breath regulation and mindfulness may facilitate autonomic recalibration by reducing sympathetic overactivity and enhancing parasympathetic influence, thereby promoting emotional stability during recovery.^{2,3}

Baseline-adjusted analysis of covariance, controlling for baseline values and BMI, confirmed that improvements in psychological and

autonomic outcomes were significantly greater in the yoga group than in the control group. This strengthens confidence that the observed effects were attributable to the yoga intervention rather than pre-existing group differences or confounding factors.⁵

Biochemical Effects

The yoga intervention was also associated with substantial reductions in serum cortisol and CRP, indicating attenuation of neuroendocrine stress responses and systemic inflammatory activity.^{4,6} Chronic stress and low-grade inflammation are known contributors to substance-related pathology;^{4,6} therefore, these findings suggest that yoga may positively influence recovery-relevant biological pathways.⁵ Although CRP is a non-specific inflammatory marker, its significant reduction—combined with controlled sampling conditions and the absence of acute illness—supports the interpretation of reduced physiological stress burden. Future studies incorporating additional biomarkers, such as pro-inflammatory cytokines or neurotrophic factors, could further elucidate the biological mechanisms underlying yoga-related adaptations.

Correlational Observations

Correlational analyses within the yoga group revealed that reductions in psychological stress were associated with improvements in HRV indices and decreases in serum cortisol. These relationships suggest coordinated regulation across psychological, autonomic, and biochemical domains. While causal inferences are limited by the quasi-experimental design, the convergence of findings across multiple outcome systems—and minimal changes observed in the control group—supports a specific intervention-related effect rather than nonspecific co-variation.

Control Group Considerations

To minimize nonspecific attention and Hawthorne effects, the control group continued standard rehabilitation activities during the intervention period.⁵ Despite comparable time exposure and institutional support, the control group exhibited no meaningful changes across measured outcomes. This pattern reinforces the specificity of the yoga intervention and suggests that the observed benefits cannot be attributed solely to increased attention or engagement.

Strengths and Contributions

This study contributes to the growing body of evidence supporting yoga-based interventions in addiction recovery by integrating psychological assessments with objective autonomic and biochemical measures. The multidimensional evaluation strengthens clinical relevance and provides insight into the psychophysiological mechanisms through which yoga may support rehabilitation. Importantly, the study addresses a relative gap in Indian rehabilitation settings by systematically examining coordinated psychological and physiological outcomes.

Limitations and Future Directions

Several limitations should be acknowledged. First, the non-randomized design may introduce selection bias, although baseline equivalence and baseline-adjusted analyses were applied to mitigate this concern. Second, the moderate sample size and single-center setting limit generalizability. Third, the absence of blinded outcome assessment may have contributed to expectancy effects. Fourth, outcomes were assessed only immediately post-intervention, precluding conclusions regarding long-term

benefits or relapse prevention. Finally, biochemical assessment was limited to cortisol and CRP.

Future research should employ randomized controlled designs with larger, multisite samples, blinded assessments, extended follow-up periods, and broader biomarker panels. The inclusion of relapse and functional outcomes would further clarify the clinical significance of yoga as an adjunctive strategy for sustained recovery from SUD.

CONCLUSION

A structured 12-week yoga-based intervention is a feasible and effective adjunct to standard inpatient rehabilitation for individuals with SUD. Participation in the yoga program resulted in significant reductions in psychological stress, improvements in autonomic regulation—as indicated by HRV indices—and decreases in neuroendocrine (serum cortisol) and inflammatory (CRP) markers. Correlational analyses further demonstrated coordinated psychophysiological changes, suggesting that the observed effects were specific to the intervention rather than reflecting nonspecific improvements.

The control group, which received standard rehabilitation care—including counseling, group therapy, recreational activities, and routine medical supervision during yoga sessions—showed minimal changes across psychological, autonomic, and biochemical outcomes. This highlights the specificity of the yoga intervention and reduces the likelihood of confounding due to attention or Hawthorne effects. Baseline BMI values were comparable between groups (yoga: 23.6 ± 2.8 kg/m²; control: 23.4 ± 3.0 kg/m², $p = 0.76$) and were included as covariates in baseline-adjusted ANCOVA, confirming that improvements were attributable to the yoga intervention. Clinical reference ranges for serum cortisol (5–23 µg/dL) and CRP (<5 mg/L) were incorporated to enhance interpretability and clinical relevance.

While these findings underscore yoga as a supportive, multidimensional adjunct to standard rehabilitation care, the quasi-experimental, non-randomized design and absence of long-term follow-up limit conclusions regarding sustained recovery and relapse prevention. Future research should employ randomized, multicenter trials with larger samples, blinded assessments, extended follow-up periods, and broader panels of neurobiological and inflammatory markers. The inclusion of relapse-specific outcomes will strengthen the evidence base for the durability, generalizability, and clinical impact of yoga-based interventions in SUD rehabilitation.

DECLARATIONS

Data Availability Statement

The data used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Artificial Intelligence (AI) Disclosure

No AI-assisted technologies were used in the preparation of this manuscript.

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AUTHORS' CONTRIBUTIONS

Sanil Kumar P conceptualized and designed the study, conducted the yoga intervention, collected the data, performed the statistical analysis, interpreted the findings, and prepared the manuscript. Dr Nongthombam Ibohal Singh contributed to the study design, supervised the research work, reviewed the analysis and interpretation of data, critically revised the manuscript, and provided academic guidance. Both authors read and approved the final manuscript.

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A Preliminary Exploratory Analysis of Quality of Life, Caregiver Burden, and Disease Management Awareness among Caregivers of Patients with Hepatic Encephalopathy

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ABSTRACT

Background: Chronic liver disease (CLD) is a major public health concern, with hepatic encephalopathy (HE) manifesting in a wide spectrum of cirrhotic patients, affecting approximately 20–80% of cases. The prevalence further increases among those with decompensated liver disease. The resulting neuropsychiatric impairment and compromised self-care abilities in these patients impose a considerable caregiving burden on family members, significantly affecting their quality of life (QOL).

Materials and methods: This paper reports preliminary exploratory findings of a larger cross-sectional descriptive study, conducted among 117 caregivers of patients with HE at a tertiary hepatology hospital to assess QOL, caregiver burden, and disease management awareness.

Results: One-fourth of patients were in grade IV HE. Most caregivers were female (59.8%), married (75.2%), and spent 6–9 hours daily on caregiving. Spouses formed the largest group (43.6%), with 41% caring for grade IV HE patients. Over half (54.7%) experienced mild to moderate burden, while 20.5% reported moderate to severe burden. The majority (91.5%) showed good disease management awareness. Significant differences in QOL as per the physical and mental components of the SF-36 questionnaire were noted across relationships with patient, income, personal illness, and disease duration. The number of dependents correlated significantly with burden, while income, socioeconomic status, and wage loss were determined to be the key predictors.

Conclusion: Caregivers of patients with HE experience considerable physical, emotional, and socioeconomic burden despite good disease management awareness. Lower income, poorer socioeconomic status, and wage loss significantly contribute to higher caregiver burden, underscoring the need for structured support and counseling interventions to enhance caregiver well-being and QOL.

Keywords: Awareness, Caregiver burden, Cirrhosis, Disease, Hepatic encephalopathy, Quality of life.

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INTRODUCTION

Chronic liver disease (CLD) is a growing global public health challenge, with rising incidence and burden over recent decades. Chronic liver disease causes progressive deterioration of hepatic functions—including synthesis of clotting factors and proteins, detoxification of metabolic by-products, and bile excretion—through ongoing inflammation, hepatocyte damage, and fibrotic remodeling leading to cirrhosis. Hepatic encephalopathy (HE) is a frequent and serious neuropsychiatric complication of CLD, affecting a broad spectrum of cirrhotic patients (20–80%) and with overt forms occurring in 10–14% in general, among individuals with decompensated cirrhosis the prevalence rises to 16–21%, 10–50% in patients with trans jugular intrahepatic portosystemic shunt (TIPS) and 30–40% of cirrhotic patients will develop overt HE over time.^{1–3}

The pathogenesis of HE remains incompletely understood, but multiple precipitating factors—such as infection, gastrointestinal bleeding, renal dysfunction, electrolyte disturbances, medication non-adherence, excessive protein intake, sedatives, dehydration, and portosystemic shunting—have been implicated.⁴ In particular, HE may worsen following TIPS placement.⁵ Early recognition and risk stratification of HE are crucial for guiding management and predicting outcomes. The Child–Turcotte–Pugh (CTP) and model for end-stage liver disease (MELD) scores remain standard tools for assessing hepatic dysfunction and short-term prognosis in cirrhosis.^{6,7}

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The HE assessment validation and numeric (HEAVEN) criteria provide a structured framework to objectively grade HE severity based on cognitive and neuromotor domains, improving interobserver consistency and clinical decision-making.⁸ Together, these scoring systems enable timely identification of high-risk patients and guide appropriate therapeutic strategies.

While HE imposes substantial morbidity on patients, its ripple effects on informal caregivers are often underappreciated. Hepatic encephalopathy reduces patients' functional capacity, cognitive

performance, and quality of life (QOL), thereby increasing reliance on caregivers.⁹ Caregivers of HE patients frequently manage complex medication regimens, monitor neurocognitive changes, provide emotional support, and coordinate health services. This augmented role often leads to physical exhaustion, psychological distress, social isolation, and financial strain.¹⁰ Evidence from recent reviews underscores the multidimensional burden borne by caregivers of HE patients, advocating for caregiver inclusion in care strategies and health policy planning.¹¹

In India, liver disease ranks among the leading causes of mortality. On World Liver Day 2018, the WHO highlighted that one in 10 Indians is affected by liver disease. Given the high prevalence of HE and its substantial impact on patients' daily functioning and healthcare demands, caregiver outcomes merit closer attention in this context.^{12,13} Hence, this study has been undertaken. This paper reports pilot study findings of a larger cross-sectional research.

MATERIALS AND METHODS

Study Design and Population

The study was carried out prospectively followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.¹⁴ The caregivers of patients with HE were recruited for a survey conducted in July–August 2025 from the hepatology wards, in a tertiary care Liver and Biliary Hospital. The inclusion criteria included age ≥ 18 years, involvement in giving direct care to the patient, identification as an unpaid caregiver, and willingness to give written informed consent. The exclusion criteria included professional or paid caregivers.

Sample Size and Sampling Technique

This preliminary investigation included 117 participants, representing approximately 39% of the planned sample size for the main study ($n = 300$). For preliminary and exploratory studies, formal power-based sample size calculation is not mandatory; instead, sample sizes are selected to obtain stable estimates of descriptive parameters and explore initial relationships among variables. Methodological literature suggests that samples exceeding 100 participants provide reasonably stable estimates for exploratory analyses and parameter estimation. Accordingly, the sample size was considered sufficient to generate preliminary data on disease management awareness, caregiver burden, and QOL, and to inform the methodology and sample size planning of the subsequent main study.¹⁵

Data Collection

Basic sociodemographic and clinical data were collected by analyzing patients' records. The grading of the HE was evaluated using West heaven's criteria: stage 0—no abnormalities; stage I—alterations in behavior, mild confusion, disordered sleep, slurred speech, euphoric or depression; stage II—lethargy, moderate confusion, asterixis; stage III—marked confusion, incoherent speech, sleeping but arousable; stage IV—coma, initially responsive to noxious stimuli, later unresponsive. Grade I was considered to be covert HE, and grades II–IV were the overt HE.

For the caregiver's data, demographic variables were recorded. A standard Zarit burden interview questionnaire was used for assessing caregiver burden, had 22 items, and the total scoring ranged from 0 to 88.

However, the SF-36 questionnaire was used for measuring QOL, which measured eight dimensions of health, including physical

functioning, physical role limitations, emotional role limitations, social functioning, bodily pain, mental health, vitality, and general health, and had a total of 36 items with scores ranging from 0 to 100. Hepatic encephalopathy awareness is a structured tool developed by the primary researcher, a 20-item tool with scores ranging from 0 to 20.

Statistical Analysis

Data entry and analysis were performed using the statistical package for the social sciences (SPSS), version 26. Continuous variables were presented as mean $\pm$ standard deviation (SD) for data following a normal distribution, while categorical variables were expressed as frequencies and percentages. Inferential statistics, including Chi-square, *F*-test, and *t*-test, were applied to determine associations between variables. Karl Pearson's correlation coefficient was used to assess relationships among continuous variables. Binary logistic regression was employed to identify predictors of caregiver burden in relation to sociodemographic factors. A *p*-value of <0.05 was considered statistically significant.

RESULTS

Demographic Characteristics of Patients and Caregivers

Patients

More than half were aged 39–59 years (53%), predominantly male (88.9%) and married (70.9%). Alcohol-related liver disease was the most common etiology (43.6%). Most had advanced disease (MELD 15–22: 41.9%; Child-Pugh class C: 52.1%), with gastrointestinal bleeding as the leading precipitating factor (40.2%). A majority (86.9%) had consumed alcohol for over one year, and 43.6% had a recent episode of HE.

Caregivers

Most were female (59.8%), married (75.2%), and aged 18–38 years (47.9%). Spouses formed the largest group (43.6%), and over half were employed (54.7%). A majority (83.8%) lived with the patient and provided ≥ 6 hours of daily care. Over half (57.3%) had a monthly income above ₹ 100,000, and 54.7% reported wage loss due to caregiving, reflecting a substantial social and financial burden.

Description of QOL, Caregiver Burden, and Disease Management Awareness

Table 1 shows the QOL of Caregivers as per the SF-36 questionnaire, a moderate impairment in overall QOL, with the physical (mean = 50.7 ± 19.2) and mental (mean = 46.6 ± 14.7) component summaries both below optimal levels have been noted. Domains such as general health, vitality, and social functioning showed lower mean scores, indicating reduced energy, social participation, and overall well-being. In contrast, relatively higher scores in role limitation due to emotional and physical health suggest that while caregivers face substantial burden, many continue to fulfil their caregiving roles despite physical and emotional strain.

Figure 1 shows that most caregivers (54.70%) experienced mild to moderate burden, 21.36% reported little or no burden, 20.51% had moderate to severe burden, and 3.41% experienced severe burden.

For the caregivers' awareness regarding disease management of HE ($n = 117$). A majority of caregivers (91.45%) demonstrated an understanding of HE, with a mean score of 2.19 ± 0.96 .

Table 1: Mean, SD, and range of QOL scores as per the SF-36 questionnaire among caregivers of patients with hepatic encephalopathy

SF-36 domains	Possible score range	Mean $\pm$ SD
Physical Functioning (PF)	0–100	55.0 $\pm$ 18.3
Role limitation—physical (RP)	0–100	58.1 $\pm$ 42.0
Bodily pain (BP)	0–100	46.5 $\pm$ 21.1
General health (GH)	0–100	43.2 $\pm$ 13.1
Physical component summary (PF + RP + BP + GH)	0–100	50.7 $\pm$ 19.2
Vitality (VT)	0–100	38.6 $\pm$ 15.3
Social functioning (SF)	0–100	44.0 $\pm$ 15.8
Role limitation—emotional (RE)	0–100	56.2 $\pm$ 42.4
Mental health (MH)	0–100	47.7 $\pm$ 12.2
Mental component summary (VT + SF + RE + MH)	0–100	46.6 $\pm$ 14.7

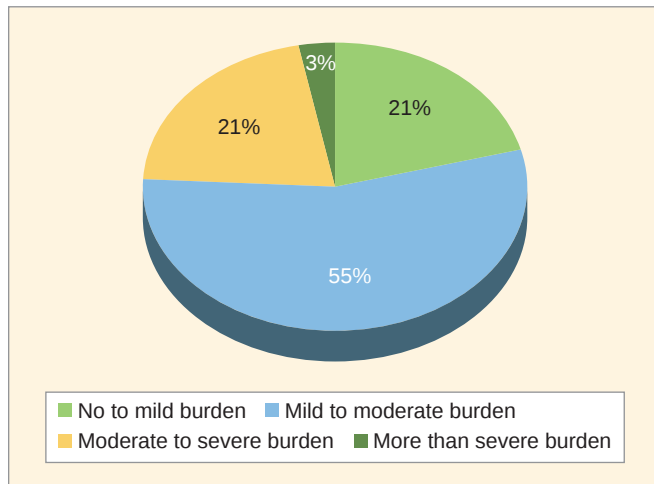


Fig. 1: Pie chart showing the percentage distribution of caregiver burden as per the Zarit caregiver burden scale

Awareness of risk factors was reported by 81.19% of caregivers (mean = 1.33 ± 0.90), while 75.21% were aware of the symptoms of HE (mean = 1.45 ± 1.07). Similarly, 75.21% of caregivers reported knowledge about medication management (mean = 1.79 ± 1.20), and 68.37% were aware of dietary recommendations for patients with HE (mean = 2.24 ± 1.28). Awareness of infection risk was observed in 63.24% of caregivers (mean = 2.11 ± 1.38), and 83.76% understood the importance of regular follow-up (mean = 1.31 ± 0.73). Overall, these findings indicate that while caregivers generally have good awareness of HE and its management, knowledge gaps exist particularly in diet and infection prevention. The total possible score ranged from 0 to 23, reflecting varying levels of disease management awareness among caregivers.

As shown in Table 2, Caregivers' QOL was significantly influenced by duration of disease, gender, having children, relationship with the patient, family income, and personal history of chronic illness. Longer caregiving duration (>10 years) was associated with markedly lower physical and mental component scores ($p < 0.001$). Female caregivers and those without children had higher mental component scores ($p < 0.05$). Caregivers who were siblings, children, or spouses reported better QOL than friends

or parents ($p < 0.05$). Higher family income and absence of chronic illness were also linked to better physical and mental health, while caregiving hours, marital status, job status, number of dependents, proximity, and wages lost showed no significant association.

As shown in Table 3, significant associations were observed between disease management awareness and caregivers' relationship with the patient, family monthly income, and duration of disease ($p < 0.05$). Caregiver burden showed a significant association with family monthly income and wage loss experience ($p < 0.05$). No significant relationship was found with age, gender, marital status, or other demographic factors.

A significant positive correlation was observed between the physical and mental components of QOL ($r = 0.76, p < 0.001$), while a weak negative correlation was found between physical component scores and disease management awareness ($r = -0.20, p = 0.03$). No significant correlations were noted between caregiver burden and other variables.

Post-hoc analysis (Table 4) revealed that caregivers' own health condition and the duration of the patient's illness had a significant influence on their QOL. Caregivers with diabetes or hypertension showed markedly lower physical component summary (PCS) and mental component summary (MCS) health scores compared to those without chronic illness, while those caring for patients with illness lasting more than ten years reported the poorest PCS and MCS scores, indicating the cumulative strain of long-term caregiving. Among relationship categories, parents demonstrated significantly lower mental health than siblings, reflecting a higher emotional burden. Age and family income did not show any significant impact on either physical or mental health scores. For the disease management awareness, all *post hoc* pairwise comparisons for the relationship with patient, family monthly income, duration of disease, and duration of treatment were non-significant ($p > 0.05$).

Table 5 shows that binary logistic regression identified family monthly income ($p = 0.011$), socioeconomic status ($p = 0.013$), and wage loss experience ($p = 0.046$) as significant predictors of caregiver burden. Caregivers from lower-income or lower socioeconomic groups and those who experienced wage loss were more likely to report higher burden. No significant association was found with age, gender, marital status, or other demographic variables.

DISCUSSION

The present study examined the demographic profile, QOL, caregiver burden, and disease management awareness among caregivers of patients with HE. The findings highlight that caregivers experience a moderate level of burden and compromised physical and mental health, influenced by socioeconomic and caregiving-related factors. Most patients were middle-aged males with alcohol-related liver disease, consistent with prior studies identifying alcohol use disorder as a predominant etiology of HE in developing countries.¹⁵ The majority had advanced disease (Child-Pugh C, MELD 15–22), and gastrointestinal bleeding was the leading precipitating factor, in line with existing evidence linking recurrent variceal hemorrhage and hepatic decompensation.^{16,17} Caregivers were predominantly spouses, reflecting traditional caregiving roles observed in Indian Families.^{18,19} Caregivers were largely in the younger to middle age group and often employed, indicating that caregiving responsibilities add to existing family and occupational demands. The predominance of female caregivers has been repeatedly associated with higher emotional stress and physical

Table 2: Association between QOL and disease management awareness with selected demographic variables

Demographic variable	PCS (mean $\pm$ SD)	df/F or t	p-value	MCS (mean $\pm$ SD)	df/F or t	p-value
Age (yrs)	18–38: 53.6 $\pm$ 18.6 39–59: 48.9 $\pm$ 18.33 60–80: 43.9 $\pm$ 25.6	2/1.537	0.219	48.3 $\pm$ 14.65/46.8 $\pm$ 14.41/37.2 $\pm$ 14.80	2/2.669	0.074
Gender	Male: 49.72 $\pm$ 21.25 Female: 51.44 $\pm$ 17.98	t = -0.471	0.083	45.89 $\pm$ 16.70/47.18 $\pm$ 13.42	t = 0.461	0.03*
Having children	Yes: 36.5 $\pm$ 11.1 No: 29.1 $\pm$ 7.2	t = -1.310	0.719	36.9 $\pm$ 15.7/33.1 $\pm$ 11.9	t = -2.617	0.010*
Caregiving hours/day	<5: 65.8 $\pm$ 10.99 6–9: 50.2 $\pm$ 18.96 10–14: 47.5 $\pm$ 21.56 15–19: 50.02 $\pm$ 16.67 20–24: 51.3 $\pm$ 19.6	4/1.303	0.273	57.07 $\pm$ 10.08/45.8 $\pm$ 17.67/ 45.3 $\pm$ 12.7/47.8 $\pm$ 14.1/ 45.8 $\pm$ 13.2	4/1.001	0.410
Marital status	Married: 48.8 $\pm$ 18.8 Unmarried: 55.7 $\pm$ 19.7 Div/separated/widowed: 71.4 $\pm$ 13.4	3/2.503	0.063	45.7 $\pm$ 14.24/51.5 $\pm$ 16.00/ 42.6 $\pm$ 4.44	3/2.346	0.07
Relationship with the patient	Parents: 39.5 $\pm$ 20.11 Siblings: 55.72 $\pm$ 16.7 Friends: 26.04 $\pm$ 12.9 Children: 54.34 $\pm$ 20.19 Spouse: 51.86 $\pm$ 17.9	4/3.460	0.010**	37.9 $\pm$ 15.36/51.2 $\pm$ 17.34/ 29.2 $\pm$ 4.86/48.3 $\pm$ 13.8/ 47.76 $\pm$ 12.92	4/3.321	0.013**
Job status	Employed: 53.73 $\pm$ 17.2 Housework: 50.11 $\pm$ 19.41 Retired: 44.39 $\pm$ 21.5 Unemployed: 43.85 $\pm$ 25.2	3/1.55	0.205	49.4 $\pm$ 15.4/44.0 $\pm$ 10.18/ 40.08 $\pm$ 16.76/44.8 $\pm$ 14.6	3/1.975	0.122
Number of dependent	1: 31.2 $\pm$ 15.57 2: 37.6 $\pm$ 15.54 3: 51.9 $\pm$ 20.22 >3: 51.98 $\pm$ 18.7	3/1.945	0.126	41.45 $\pm$ 18.2/34.61 $\pm$ 15.44/46.71 $\pm$ 14.42/48.0 $\pm$ 14.5	3/1.867	0.139
Family income (₹)	20–40 k: 38.9 $\pm$ 27.7 50–70 k: 42.5 $\pm$ 21.4 80–100 k: 49.9 $\pm$ 19.2 >100 k: 54.3 $\pm$ 16.9	3/2.960	0.035**	36.01 $\pm$ 16.7/41.9 $\pm$ 14.48/ 48.5 $\pm$ 12.5/48.0 $\pm$ 15.15	3/2.117	0.102
Proximity to the patient	Same house: 51.6 $\pm$ 18.4 Close: 46.2 $\pm$ 22.86 >1 hr away: 52.11 $\pm$ 23.5 Other: 31.4 $\pm$ 20.5	3/1.552	0.205	46.77 $\pm$ 14.44/51.7 $\pm$ 18.04/ 44.9 $\pm$ 15.46/40.12 $\pm$ 18.62	3/0.533	0.661
Chronic illness in caregiver	Diabetes: 37.6 $\pm$ 20.03 Hypertension: 52.4 $\pm$ 18.23 Others: 86.9 $\pm$ 0.0 None: 56.7 $\pm$ 0.0	3/4.230	0.007**	35.3 $\pm$ 12.89/48.4 $\pm$ 14.43/ 44.2 $\pm$ 0.0/53.8 $\pm$ 0.0	3/3.951	0.010*
Duration of disease (yrs)	<1: 61.7 $\pm$ 12.85 1–10: 51.9 $\pm$ 17.17 >10: 29.78 $\pm$ 15.89	2/31.83	0.000**	53.2 $\pm$ 10.81/47.89 $\pm$ 15.11/ 33.0 $\pm$ 10.6	2/18.706	0.000**
Wages lost due to caregiving	No: 53.5 $\pm$ 18.94 Yes: 48.42 $\pm$ 19.42	t = 1.439	0.902	46.47 $\pm$ 15.15/46.8 $\pm$ 14.57	t = -0.29	0.936

* $p < 0.05$ significant; ** $p < 0.01$ highly significant

exhaustion, as women tend to assume greater responsibility in providing daily care and emotional support.²⁰

Quality of life assessment revealed moderate impairment across both physical and mental health components. Domains such as vitality, social functioning, and general health were particularly affected, indicating emotional strain, fatigue, and limited social engagement. Similar findings have been reported in cohorts of caregivers for cirrhotic patients, who show lower QOL with high rates of anxiety and depression.^{21,22}

Correlation analysis demonstrated a negative association between caregiver burden and QOL, indicating that increased burden corresponded with decreased well-being. These results align with prior studies emphasizing the bidirectional impact of physical strain and emotional exhaustion on caregivers of patients with CLD.^{21,22}

For the HE awareness among caregivers, the majority (91.5%) showed an understanding of HE; awareness of the risk factors was reported by 81.2%, while 72.1% were aware of the symptoms

Table 3: Association of disease management awareness and caregiver burden with selected socio-demographic and treatment-related variables of caregivers ($n = 117$)

Demographic/treatment variable	Disease management awareness			Caregiver burden		
	$\chi^2/t/F$	df	p-value	t/F	df	p-value
Age	5.17	2	0.270	0.65	2	0.547
Gender	1.286	2	0.526	0.30	115	0.687
Having children	4.82	2	0.090	-1.38	115	0.215
Marital status	2.545	6	0.865	0.353	3	0.787
Relationship with the patient	13.01	8	0.03*	1.321	4	0.266
Family monthly income	11.643	6	0.05*	3.187	3	0.027*
Stages of HE	4.612	6	0.594	0.597	3	0.618
Personal history of chronic illness	4.882	6	0.59	1.45	3	0.231
Duration of disease/treatment	4.85	1	0.028*	2.06	2	0.131
Wage loss experience	0.64	2	0.72	4.52	115	0.003*

* $p < 0.05$ statistically significant**Table 4:** Post-hoc comparisons of PCS and MCS scores for significant multi-group variables

Variable and comparison	PCS mean $\pm$ SE	p	MCS mean $\pm$ SE	p
Age				
18–38 vs 39–59 yrs	4.65 $\pm$ 3.73	0.428	1.48 $\pm$ 2.83	0.860
18–38 vs 60–80 yrs	9.69 $\pm$ 6.33	0.280	11.08 $\pm$ 4.80	0.059
39–59 vs 60–80 yrs	5.03 $\pm$ 6.39	0.711	9.60 $\pm$ 4.85	0.122
Relationship with the patient				
Parents vs siblings	-16.18 $\pm$ 6.21	0.076	-13.29 $\pm$ 4.76	0.048
Parents vs others ^a	NS	–	NS	–
Family income (Rs.)				
All comparisons	NS	–	NS	–
Chronic illness				
Diabetes vs others	-19.96 $\pm$ 5.70	0.004	-16.10 $\pm$ 4.39	0.002
Diabetes vs none	-19.00 $\pm$ 4.37	<0.001	-14.82 $\pm$ 3.36	<0.001
Hypertension vs others	-14.95 $\pm$ 4.25	0.003	-11.10 $\pm$ 4.31	0.054
Hypertension vs none	-19.96 $\pm$ 5.70	0.004	-9.85 $\pm$ 3.27	0.017
Duration of disease				
<1 yr vs 1–10 yrs	9.86 $\pm$ 3.26	0.009	5.29 $\pm$ 2.70	0.159
<1 yr vs >10 yrs	32.00 $\pm$ 4.02	<0.001	20.17 $\pm$ 3.33	<0.001
1–10 yrs vs >10 yrs	22.13 $\pm$ 3.83	<0.001	14.88 $\pm$ 3.18	<0.001

PCS, physical component summary; MCS, mental component summary; NS, not significant. * $p < 0.05$ = significant; * $p < 0.01$ = highly significant. ^aOthers include friends, children, and spouse

and management. However, only 68.4% were aware of dietary recommendations, 63.3% recognized infection risk, and 83.8% acknowledged the necessity of regular follow-up. These findings are inconsistent with available evidence, where only 48% were aware of previous HE episodes, 6% knew their relative was on treatment, and 6% understood treatment effects.²³ The relatively higher awareness observed in the present study may be attributed to the setting of a tertiary care hepatology hospital, where caregivers are more likely to receive structured education, regular counselling, and exposure to specialized care protocols related to HE management.^{23,24}

Binary logistic regression identified family income, socioeconomic status, and wage loss as significant predictors

of higher caregiver burden, suggesting that financial hardship amplifies psychological stress and caregiving difficulty. These results highlight the need for economic and psychosocial support interventions to alleviate caregiver distress.

Strengths and Limitations of the Study

Strengths of the study include that it was conducted in a tertiary care hepatology hospital, allowing access to well-defined clinical profiles and providing more reliable and specific information on HE and its caregiving context. Use of standardized and validated tools to assess caregiver burden, QOL, and disease management awareness ensured objectivity and comparability with other



Table 5: Predictors of caregiver burden with socio-demographic variables using binary logistic regression among caregivers ($n = 117$)

<i>Variables</i>	<i>Categories</i>	<i>Little/no burden</i>	<i>Mild-severe burden</i>	<i>COR (95% CI)</i>	<i>p-value</i>
Age (years)	18–38	40	16	1.406	0.509
	39–59	41	09		
	60–80	08	03		
Gender	Male	35	12	2.056	0.305
	Female	54	16		
Having children	Yes	65	19	0.680	0.587
	No	24	09		
Marital status	Married	68	20	0.946	0.832
	Unmarried	19	06		
	Divorced/widowed/separated	02	02		
Relationship with patient	Parents	14	02	0.846	0.803
	Siblings	12	08		
	Friends	03	00		
	Children	20	07		
	Spouse	40	11		
Job status	Employed	44	20	1.411	0.483
	Housework	21	05		
	Retired	13	03		
	Unemployed	11	00		
No. of dependents	One	02	00	0.944	0.804
	Two	03	04		
	Three	29	10		
	More than three	55	14		
Family monthly income (₹)	20,000–40,000	07	00	0.340	0.011**
	50,000–70,000	11	04		
	80,000–100,000	24	10		
	>100,000	47	14		
Proximity to patient	Lives together/close/far	–	–	0.884	0.745
Caregiving hours/day	<5	05	02	1.547	0.206
	6–9	28	11		
	10–14	22	07		
	15–19	11	05		
	20–24	23	03		
Chronic illness (self)	Diabetes/hypertension/others/none	–	–	0.684	0.225
Duration of illness (patient)	<1 year	33	07	1.080	0.783
	1–10 years	38	15		
	>10 years	18	06		
Socioeconomic status (BG Prasad)	Upper	33	14	3.882	0.013**
	Upper middle	35	10		
	Lower middle	15	02		
	Upper lower	06	02		
Wage loss experience	No	45	08	0.530	0.046**
	Yes	44	20		

** $p < 0.05$ statistically significant

studies. Findings contribute to the limited Indian evidence base on caregiver outcomes in HE, an under-researched area in nursing and hepatology. The study highlights modifiable predictors (e.g., income, socioeconomic status, and wage loss), which can guide targeted interventions for caregiver support and education.

Limitations of the study include being a cross-sectional study; causal relationships between caregiver burden, awareness, and QOL could not be established. Conducted in a single tertiary care setting, where caregivers are likely to have higher awareness due to ongoing education and specialized counseling; thus, findings may not generalize to community or primary care settings. Self-reported data may be subject to recall or social desirability bias, especially regarding burden and awareness measures. The relatively small sample size ($n = 117$) may limit the power of subgroup analyses, particularly for regression and correlation models. The study did not explore psychological or coping mechanisms in depth, which could provide further understanding of caregiver adaptation and resilience.

CONCLUSION

Caregivers of patients with HE face a considerable burden affecting their physical and mental well-being, though awareness of disease management is generally good, likely due to tertiary care exposure. Socioeconomic factors, including income and wage loss, significantly predict caregiver burden. Targeted interventions addressing financial, educational, and psychosocial support are essential to improve caregiver well-being and patient care outcomes.

Ethical Approval

The ethical permission for the study was obtained from the competent authorities (CONEC/ILBS/MSc/01/24/012). All the ethical Principles as per Declaration of Helsinki were followed. The voluntary participation was ensured with the freedom to withdraw from study at any point of time.

Availability of Data and Materials

The dataset used and/or analyzed during the current study are available from the first author on reasonable request.

Artificial Intelligence (AI) Disclosure

No AI-assisted technologies were used.

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AUTHOR'S CONTRIBUTIONS

Gyan Wati - Conceptualization, data collection and analysis. Sunita Srivastava - Conceptualization, data analysis, preparing first draft of the manuscript and revising it. Harshvardhan Tevethia - Conceptualization and critique and review of the revised draft. Ms Gyan Wati has full access to all the data in the study and take full responsibility for the integrity of the data and accuracy of the data analysis. All authors have read and approved the final version of the manuscript.

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A Study to Assess the Skills of Mid-level Healthcare Providers/Community Health Officers in Delivering Primary Healthcare Services in Selected Districts of Andhra Pradesh and Haryana

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ABSTRACT

Background: In order to achieve Universal Health Coverage through comprehensive primary healthcare services and attain sustainable development goals (SDGs), the Government of India (GOI) has taken an initiative to create a new cadre called community health officers (CHOs)/mid-level healthcare providers (MLHP) under the Ayushman Bharat scheme at the Ayushman Arogya Mandir [erstwhile Health and Wellness Center (HWC)].

Aim: To assess the skills of CHOs in the provision of comprehensive primary healthcare services across selected districts in two Indian states.

Subjects and methods: A descriptive cross-sectional study was conducted among 366 CHOs [225 from Andhra Pradesh (AP), 141 from Haryana] selected using multistage random sampling. The core skills of CHOs were assessed through an objective structured clinical examination (OSCE) using a model and categorized as inadequate ($\leq 50\%$), moderately adequate (50–75%), or adequate ($> 75\%$).

Results: Out of the total 366 participants, 79.2% were female, and 61% were aged 21–30 years; 68.8% held a BSc Nursing qualification. Mid-level healthcare providers/CHOs in Haryana (68%) had over 1 year of experience compared to AP (36%). Community health officers had adequate skills in blood pressure measurement (manual – 100%), random blood sugar (RBS) monitoring (83%), breast cancer screening (74%), and oral cancer screening (62%). Only 6% in Haryana and 41% of CHOs in AP could perform the procedure of newborn resuscitation accurately. Similarly, only 22% of CHOs of both states knew when to start the partograph.

Conclusion: The assessment of overall skills of CHOs in the provision of primary healthcare services indicated that, except for blood pressure recording, urine testing, and RBS monitoring, their skills in other key areas such as neonatal resuscitation, plotting and interpreting the partograph to assess the progress of labor, elderly assessment, and screening for breast and oral cancers were found to be inadequate. This highlights the need for continuing education programs to strengthen their clinical competencies and enhance the quality of primary healthcare delivery.

Keywords: Ayushman Bharat, Community health officers, Health and wellness centers, Neonatal resuscitation, Skills assessment.

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INTRODUCTION

Primary health care (PHC) is the best approach to ensure access to health care with equity and efficiency, according to the World Health Organization (WHO).¹ Ensuring access to curative care at the primary level is an important component of PHC as it reduces mortality and the need for secondary and tertiary care.^{2,3} India is also committed to implementing PHC.⁴ It was a key proposal in India's National Health Policy, 2017.⁵

As per 2021 data, more than two-thirds (65%) of India's population lives in rural areas. For providing adequate, accessible, and affordable health care to all population and achieving Universal Health Coverage, adequate human resources with appropriate skills are essential. Recognizing this fact, the Government of India (GOI) created a new cadre called Community Health Officer (CHO) in 2018 under the Ayushman Bharat scheme at Aarogya Mandir [erstwhile Health and Wellness Center (HWC)] to deliver a comprehensive package of PHC in 12 domain areas viz. reproductive, maternal, and child health, non-communicable diseases (NCDs), ophthalmic, ENT, oral health, mental health, elderly and palliative care, and basic emergency services at the sub-health centers (HWC).

The CHOs are basically mid-level healthcare providers (MLHPs) with a GNM/BSc Nursing or Ayurveda degree. Their main focus is primary and secondary prevention as well as health promotion

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at the community level in addition to acting as a team lead for the primary healthcare team at the HWC. It is expected that these CHOs are equipped with adequate skills to provide comprehensive primary healthcare (CPHC) services to the community. However, there are issues of a lack of appropriate skill acquisition in pre-service education, leading to the production of healthcare providers with variable competencies to provide services. As the health outcomes are mainly based on the skills of the care provider, it

Table 1: List of PHC/CHC selected in Haryana and AP

Name of state	Name of district	Name of PHC/CHC
AP	Krishna	Penamaluru
		Uppuluru
		Thotlavalluru
		Indupalli
		Pakala
	Chittoor	Vadamalpetta
		Gudipala
		Kolamasanapalli
		Radour
		Sadhaura
Haryana	Yamuna Nagar	Pratap Nagar
		Chaurmastpur
		Firozpur Jhirka
		Puhana
		Nuh
	Nuh	

AP, Andhra Pradesh; CHC, Community health center; PHC, primary health care

becomes critical that their knowledge and skills in the context of their job functions need to be examined. Moreover, the quality of services the Arogya Mandir/HWC is able to provide, and the degree of credibility it establishes within the community it serves, is greatly influenced by the performance of the provider. Keeping these facts in mind, the present study was conducted to assess the core skills of CHOs based on their job responsibilities in the provision of services at the selected HWCs of Haryana and Andhra Pradesh (AP).

SUBJECTS AND METHODS

This descriptive cross-sectional study was conducted during 6 months in the year 2022 in AP and Haryana, India. Two districts from each state, Yamuna Nagar and Nuh (Haryana), Chittoor and Krishna (AP), were selected using a multistage random sampling technique. Districts were scored on 10 *NFHS-5* health indicators, assigning one point for performance above and zero for performance below the state average (maximum score = 10). Based on total scores, districts were stratified as better performing (>5) and less performing (≤5), and one district from each stratum was randomly selected. Then, from each selected district, two blocks and four community health centers (CHCs) (two near and two distant from the district headquarters) were chosen randomly for assessing the skills of 366 CHOs in total. The selected CHCs/PHCs are listed in Table 1.

The study variable was the skill of CHOs in primary healthcare services such as BP measurement, urine testing, blood sugar monitoring, neonatal resuscitation, partograph, health assessment of elderly persons, and screening for oral and breast cancer. The core skills of CHOs based on their job responsibilities were assessed through an objective structured clinical examination (OSCE) using a model/dummy. Data were collected using a structured questionnaire for demographic details and an observation checklist of 16 steps on basic neonatal resuscitation using a dummy model, bag and mask, towel, tray, shoulder roll, and stethoscope. For skill scoring, based on the number of steps/items in each procedure with "Yes" or "No" observations, for each correct step of "Yes," 1 score was given, and each incorrect step of "No" 0 score was given. To assess the skills in each procedure, scores were divided into

Table 2: Level of BP recording skills of CHOs using sphygmomanometer

Level of skills	<50%		50–75%		>75%		Total (state)	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Haryana	0	0	0	0	118	100.0	118	100.0
AP	0	0	0	0	47	100.0	47	100.0
Total	0	0	0	0	165	100.0	165	100.0

AP, Andhra Pradesh

Table 3: Level of BP recording skills of CHOs by using electronic sphygmomanometer

Level of skills	<50%		50–75%		>75%		Total (state)	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Haryana	0	0	30	27.8	78	72.2	108	100.0
AP	0	0	8	8.6	85	91.4	93	100.0
Total	0	0	38	18.9	163	81.1	201	100.0

AP, Andhra Pradesh

Table 4: Skills of CHOs on urine testing

Level of skills	<50%		50–75%		>75%		Total (state)	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
AP	8	3.6	35	15.6	182	80.9	225	100.0
Haryana	23	16.3	42	29.8	76	53.9	141	100.0
Total	31	8.5	77	21.0	258	70.5	366	100.0

AP, Andhra Pradesh

III grades: <50 – inadequate skill, 50–75 – moderately adequate skill, and >75 – adequate skill.

Data Collection and Analysis

Tools were pre-tested among five CHOs (excluded from the main study). After obtaining official permissions and informed consent, data were collected from an average of 20 CHOs per day, completing each district within 6 days. COVID-19 safety measures were followed. Data were coded, entered, and analyzed using SPSS with descriptive and inferential statistics.

Data Management and Ethics

Data were stored securely for 3 years and will be destroyed by shredding thereafter. Ethical approval and permissions were obtained from the concerned authorities. Participants' consent, confidentiality, and voluntary participation were ensured, adhering to the principles of autonomy, beneficence, non-maleficence, and justice.

RESULTS

When the samples were asked to measure the blood pressure using a sphygmomanometer, out of all CHOs (366), 322 CHOs had adequate skill, i.e., >75%, and 38 CHOs had moderate skill (50–75%), as can be seen from Tables 2 and 3.

Out of the total 366 CHOs who participated, 258 (71%) could perform the procedure of urine testing correctly (Table 4).

About 74% of CHOs in AP and 96% of Haryana could accurately perform the blood sugar assessment using a glucometer (Table 5).

When the CHOs were asked to perform the procedure of newborn resuscitation, it was found that 63% of CHOs in Haryana and 20% of CHOs in AP had inadequate skill, i.e., less than 50%.

Only 6% in Haryana and 41% of CHOs in AP could perform the procedure accurately. Out of the total 366 CHOs, 135 (37%) had inadequate skill (Table 6).

To assess the skills of CHOs on the partograph, case scenarios were given to the CHOs, and they were asked to plot the partograph. Only 22% of CHOs of both states knew when to start the partograph and could fill the partograph correctly when the case scenarios were given. About 69% of samples (84% in AP and 45% in Haryana) had less than 50% of skills in partograph plotting to assess the progress of labor (Table 7).

Table 8 shows that 51% of the CHOs from both states had adequate skill, i.e., >75% on geriatric assessment.

With regard to screening for breast cancer, 77% of CHOs in AP and 68% of CHOs in Haryana had adequate skill. A total of 74% of CHOs of both the study states had adequate, i.e., more than 75% of skill (Table 9).

Out of the total 366 CHOs, 225 (62%) CHOs could perform correctly the screening procedure to rule out oral cancer. Community health officers of Haryana had more skills (70%) than the CHOs of AP (56%) in screening for oral cancer (Tables 10 and 11).

DISCUSSION

The current study provides an overview of the clinical competence of mid-level cadres in the context of PHC being expanded through HWCs in India. The assessment of overall skills of CHOs in provision

of primary healthcare services indicates that, except BP recording, urine testing, and RBS monitoring in all other areas such as neonatal resuscitation, plotting and interpreting partograph to assess the progress of labor, elderly assessment, and screening for breast cancer and oral cancer, the skills of CHOs are less and require refresher training to strengthen their skills. It underscores

Table 7: Skills of CHOs in plotting and interpreting the partograph

Level of skill	<50%		50–75%		>75%		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
AP	189	84.0	8	3.6	28	12.4	225	100.0
Haryana	64	45.0	25	17.7	52	36.9	141	100.0
Total	253	69.1	33	9.0	80	21.9	366	100.0

AP, Andhra Pradesh

Table 8: Skills of CHOs on elderly care

Level of skill	<50%		50–75%		>75%		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Haryana	51	22.7	58	25.8	116	51.6	225	100.0
AP	28	19.9	44	31.2	69	48.9	141	100.0
Total	79	21.6	102	27.9	185	50.5	366	100.0

AP, Andhra Pradesh

Table 5: Skills of CHOs on random blood sugar (RBS) monitoring

Level of skills	<50%		50–75%		>75%		Total (state)	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
AP	11	4.9	47	20.9	167	74.2	225	100.0
Haryana	1	0.7	4	2.8	136	96.5	141	100.0
Total	12	3.3	51	13.9	303	82.8	366	100.0

AP, Andhra Pradesh

Table 6: Skills of CHOs on newborn resuscitation

Level of skills	<50%		50–75%		>75%		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
AP	46	20.4	86	38.2	93	41.3	225	100.0
Haryana	89	63.1	44	31.2	8	5.7	141	100.0
Total	135	36.9	130	35.5	101	27.6	366	100.0

AP, Andhra Pradesh

Table 9: Skills of CHOs on screening for breast cancer (clinical breast examination)

Level of skill	<50%		50–75%		>75%		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
AP	34	15.1	18	8.0	173	76.9	225	100.0
Haryana	13	9.2	32	22.7	96	68.1	141	100.0
Total	47	12.8	50	13.7	269	73.5	366	100.0

AP, Andhra Pradesh

Table 10: Skills of CHOs on screening for oral cancer

Level of skill	<50%		50–75%		>75%		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
AP	56	24.9	43	19.1	126	56.0	225	100.0
Haryana	12	8.5	30	21.3	99	70.2	141	100.0
Total	68	18.6	73	19.9	225	61.5	366	100.0

AP, Andhra Pradesh

Table 11: Overall skill level of CHOs in the provision of CPHC

Skills of CHO	No. of questions	Min–max score	AP mean $\pm$ SD	Haryana mean $\pm$ SD
BP recording using a sphygmomanometer	11	0–11	11 $\pm$ 0.00	10.95 $\pm$ 0.21
BP recording using an electronic sphygmomanometer	6	0–6	5.59 $\pm$ 0.70	5.90 $\pm$ 0.33
Urine testing	7	0–7	6.04 $\pm$ 1.27	5.28 $\pm$ 1.74
RBS monitoring	15	0–15	12.10 $\pm$ 2.28	13.30 $\pm$ 1.11
Newborn resuscitation	16	0–16	11.19 $\pm$ 3.71	7.69 $\pm$ 2.86
Plotting and interpreting the partograph	19	0–19	5.04 $\pm$ 6.31	9.45 $\pm$ 7.15
Elderly assessment	20	0–20	14.46 $\pm$ 3.05	13.72 $\pm$ 3.73
Screening for breast cancer	18	0–18	13.54 $\pm$ 5.20	13.8 $\pm$ 3.87
Screening for oral cancer	19	0–19	13.14 $\pm$ 6.17	15.8 $\pm$ 3.19

AP, Andhra Pradesh; RBS, random blood sugar; SD, standard deviation



the need to provide them with further training so as to enable them to manage a greater range of illnesses competently. Earlier studies have shown that continuous training is necessary and effective in improving the clinical performance of non-physician cadres in PHC.^{6,7} The National Health Mission in India has recently launched in-service capacity-building programs for the CHOs.⁸ In partograph plotting and interpreting, out of a total of 19 scores, the mean score obtained by the CHOs of AP was only 5, with the standard deviation (SD) of 6.31, while the CHOs of Haryana had the mean score of 9 with the SD of 7.1. Use of the partograph needs complete knowledge on the functions of the component parts of the partograph and how to identify abnormalities of labor, so respondents who had fair knowledge mean they do not have adequate or sufficient knowledge to use it. Training on proper use of the partograph may be effective in reducing perinatal death rates, particularly in resource-constrained countries.^{9–11} The findings underscore the growing importance of standardized treatment protocols in supporting non-physician cadres to deliver quality care. In particular, the development of condition-specific protocols for NCD management at HWCs has been emphasized as a critical enabler of effective service delivery. Experiences from Chhattisgarh, where standardized treatment procedures have been developed for CHOs, demonstrate how such protocols can enhance clinical competence and decision-making. However, the expanding scope of responsibilities assigned to CHOs often results in increased workloads, which may adversely affect productivity and, in turn, the quality of care. These findings align with existing evidence suggesting that task expansion without commensurate system support can undermine service delivery outcomes. Strengthening capacity-building mechanisms through structured training curricula, regular refresher training, on-the-job learning, mentorship, supportive supervision, and robust monitoring and evaluation frameworks emerges as a key strategy for sustaining performance. Furthermore, evaluations of CHOs/MLHPs in India highlight persistent gaps in training, particularly in managing a broader spectrum of conditions, and point to the need for more comprehensive monitoring designs that capture a wider range of illnesses.

CONCLUSION

The study findings reveal that there is not much intra- and interstate difference in the knowledge of CHOs in the provision of services as per their job description. However, the CHOs trained during the COVID pandemic period in both the study states lack skills drastically in comparison with the CHOs trained before, as the training during the COVID-19 pandemic was online, and there were no hands-on skills imparted to the CHOs. Thus, it is essential to organize skill enhancement training at regular intervals for the CHOs to make them competent for providing extended primary healthcare services. The non-physician MLHP cadre of CHOs deployed under India's primary healthcare reforms demonstrates considerable potential to manage ambulatory care at HWCs. However, realizing this potential at scale requires strengthened and continuous training to enable CHOs to manage a larger caseload and make timely, appropriate referrals based on clinical assessment and risk of complications. The sustained availability of standardized treatment protocols, essential medicines, and ongoing capacity-building support is critical to optimizing MLHP performance. Expanding access to comprehensive primary care

closer to communities remains central to primary healthcare delivery, and well-trained mid-level providers

Recommendations

Primary healthcare programs should prioritize structured, hands-on capacity building for MLHPs, including regular refresher and simulation-based training, particularly for high-risk areas such as neonatal care. These efforts should be supported through strengthened supportive supervision and mentorship, the routine dissemination of updated treatment protocols, and robust monitoring and evaluation systems. Ensuring the consistent availability of essential equipment at HWC is critical to enable effective translation of competencies into quality care.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available with the principle investigator.

Limitations

The study did not evaluate long-term knowledge retention or the practical application of skills in real-world settings, which are critical for understanding the sustained impact of the training.

Artificial Intelligence (AI) Disclosure

No AI or assisted technology was used.

AUTHORS' CONTRIBUTIONS

V Jaiswal B Subbiah N; methodology, V Jaiswal B Subbiah N; validation, V Jaiswal B Subbiah N and; formal analysis, Raj TP; writing—original draft preparation, V Jaiswal B Subbiah N; writing—review and editing, V Jaiswal visualization, V Jaiswal; supervision, Subbiah N; All authors have read and agreed to the published version of the manuscript.

Contributors List

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Environmental Hygiene and Its Health Implications: A Study of Knowledge, Attitudes, and Practices among Women in Urban Slum

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ABSTRACT

Environmental hygiene encompasses both natural elements, such as air, water, and vegetation, and human-made components, including housing, transportation, waste, and technology, all of which significantly impact public health. In low-resource settings such as urban slums, poor housing, overcrowding, and lack of basic amenities such as clean water, sanitation, and electricity create serious health risks, particularly for women and children. Women play a central role in maintaining household hygiene, yet their practices are often constrained by limited knowledge and inadequate resources. This study assessed the knowledge, attitudes, and practices (KAP) of women regarding environmental hygiene in selected urban slum areas. Using simple random sampling, 500 households were surveyed through structured interviews and direct observations, with an emphasis on demographic factors and their association with hygiene behavior. Findings revealed significant gaps in hygiene knowledge and practices, underscoring the vulnerability of these communities. The results underscore the pressing need for targeted health education, awareness campaigns, and enhanced access to sanitation facilities. Strengthening women's hygiene literacy and providing supportive infrastructure are crucial steps toward improving public health and fostering healthier living environments in urban slums.

Keywords: Attitude, Environmental hygiene, Knowledge, Practice, Sanitation, Urban slum, Women's health.

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INTRODUCTION

The United Nations introduced 17 sustainable development goals (SDGs) to improve global health, well-being, and living conditions by 2030, with a strong emphasis on addressing persistent global issues, including poverty, gender inequality, hunger, and inadequate infrastructure. Environmental health plays a central role in achieving these goals, particularly in under-resourced settings, including rural and urban slum areas. Improvements in ecological hygiene contribute significantly to multiple SDGs, highlighting the interconnectedness of sanitation, health, and sustainable development.^{1–4}

Hygiene and sanitation are fundamental determinants of health and nutrition. Inadequate sanitation, poor hygiene, and limited access to clean water all contribute directly to malnutrition and disease transmission, particularly among vulnerable populations. According to the World Health Organization, nearly 50% of malnutrition cases globally are linked to repeated infections such as diarrhea, often caused by unsafe water, poor sanitation, and inadequate hygiene practices. This creates a vicious cycle, wherein malnourishment leads to compromised immunity, making individuals more susceptible to infections—often with fatal consequences. In densely populated urban slums, open defecation, unclean water sources, and inadequate washing facilities increase the risk of fecal–oral transmission of pathogens, leading to parasitic infections, including hookworms, roundworms, and whipworms. The existing status of urban slum households on environmental hygiene, with the following objectives:

Objectives

- To assess the level of knowledge among women in urban slums regarding environmental hygiene, sanitation practices, and their impact on health.

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- To evaluate the attitudes of women in urban slums towards environmental hygiene, including their perception of its importance for health and well-being.
- To examine the practices related to hygiene and sanitation within households in selected urban slum areas, focusing on areas such as waste management, water, sanitation, and personal hygiene.
- To investigate the relationship between demographic factors (such as age, education, and socioeconomic status) and the knowledge, attitudes, and practices (KAP) related to environmental hygiene.
- To identify barriers to effective hygiene practices among women in urban slums, including lack of resources, awareness, and infrastructure.
- To recommend targeted health education and intervention strategies that can enhance environmental hygiene knowledge and improve practices among women in urban slum areas.

Hypothesis

- H1: Women in urban slum areas have limited knowledge about environmental hygiene and its impact on health.
- H2: There is a significant relationship between the educational level of women in urban slums and their attitudes towards environmental hygiene.
- H3: The sanitation practices in urban slum households are significantly influenced by the availability of resources such as clean water, sanitation facilities, and waste management systems.
- H4: Women with higher levels of awareness and knowledge regarding environmental hygiene are more likely to implement better hygiene practices in their households.
- H5: Socioeconomic status (e.g., income and occupation) of women in urban slums has a significant effect on their access to and use of environmental hygiene practices.
- H6: Lack of proper sanitation facilities and infrastructure in urban slums is a significant barrier to the adoption of effective hygiene practices among women.

MATERIALS AND METHODS

The study was conducted in a selected urban slum area, comprising a total of 1,822 households that housed a population of 6,571 individuals, including 1,999 men, 2,010 women, and 2,562 children. Preliminary observations during the investigator's visit revealed unsatisfactory sanitary conditions in the area, indicating a significant need for improvement. The investigator approached the local panchayat leader to gather essential information and to encourage the implementation of action-oriented programs aimed at addressing the prevailing sanitation issues.

Several factors were considered in selecting the area for the study, including the severity of the sanitation problem, proximity, availability of transportation, the local community's cooperation, and a pre-existing rapport with the residents. Additionally, the need for community education on hygiene practices played a crucial role in this decision.³

Women, who are key agents of change in their households and communities, were selected as the primary respondents for this study. Educating women on environmental hygiene is crucial, as they play a vital role in maintaining better living conditions and safeguarding their families and surroundings from ecological degradation. By enhancing their knowledge and practices, women can make significant contributions to improving the health and well-being of their families and the broader community.

Data Collection Methodology

To collect comprehensive data on environmental hygiene, a mixed-method approach was adopted, combining interviews and direct observations. A structured interview schedule was used as the primary data collection tool. This enabled the collection of standardized and reliable information on the KAP of women regarding environmental hygiene. The interview-cum-observation method enabled the investigator to capture both self-reported data and direct observations of hygiene practices in the households, providing a more holistic view of the existing conditions and the effectiveness of the practices.

Major Findings

The significant findings include the relationship between the demographic profile and the prevailing environmental hygiene of

Table 1: Age, educational qualification, and occupational status of selected rural households

<i>(N = 500)</i>				
<i>S. No.</i>	<i>Category</i>	<i>Classification</i>	<i>Frequency</i>	<i>%</i>
1.	Age (in years)	21–25	4	1
		26–30	67	13
		31 and above	429	86
2.	Education	Illiterate	189	38
		Primary	30	6
		Secondary	181	36
		High secondary	23	5
		Graduate	40	8
		Post graduate	31	6
3.	Occupational status	Diploma	6	1
		Agriculture	49	10
		Daily laborer	344	69
		Maid/cook	32	6
		Self-employed	75	15
4.	Monthly income	Rs. ≤5,000	103	21
		Rs. 5,001–10,000	283	57
		Rs. 10,001–Rs. 15,000	56	11
		Rs. 15,001–Rs. 20,000	27	5
		Rs. >20,001	31	6

N, number of respondents

the selected urban area, as well as the level of knowledge, attitude, and practice among slum women regarding ecological hygiene.

A. Relationship between demographic profiles and the prevailing environmental hygienic practices.

It includes a socio-demographic profile of the selected households, prevailing environmental conditions, and the relationship between the socio-demographic profile and prevailing environmental conditions.

Socio-demographic Profile of the Selected Households

Under the socio-demographic profile of the selected households, the age, educational qualification, and occupational status are presented in Table 1.

Among the selected households, the majority of respondents, 86%, belonged to the age-group of 31 and above. Educational backgrounds have a significant impact on an individual's economic status and lifestyle. Lifestyle changes have effects on health.⁵ The analysis of the respondents' educational status shows that the majority, 38%, were illiterate, and 36% had completed their secondary education. It was clearly stated that only 8% of respondents were graduates, and 6% of respondents were postgraduates. Regarding occupation, the majority, 69% of the respondents, were working as daily laborers.

Regarding family income, 57% of the respondents' family income was between Rs. 5,000 and Rs. 10,000. Twenty-one percent of respondents had a family income less than or equal to Rs. 5,000, 11% had a family income in the range of Rs. 10,001–15,000. Only 6% had a family income above Rs. 20,001.

Prevailing Environmental Condition

A good environment is, thus, the most relevant for human well-being. However, especially in rural communities, environmental health conditions are not satisfactory. Neither the natural nor



Table 2: Environmental hygienic practices by the selected households

<i>Environmental hygienic practices</i>	<i>N = 500</i>							
	<i>Never</i>		<i>Sometimes</i>		<i>Most of the time</i>		<i>All the time</i>	
	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>
Burn waste in an open area	108	22	140	28	82	16	170	34
Dispose of the waste in an open area	215	43	170	34	75	15	40	8
Dispose of the waste in a community dustbin	180	36	100	20	100	20	120	24
Separates waste into recyclable and non-recyclable waste	320	64	80	16	60	12	40	8
Difficulties in procuring clean water access	120	24	80	16	135	27	165	33
Access to clean drinking water	160	32	120	24	100	20	120	24
Washing hands before eating	250	50	140	28	50	10	60	12
Access to a toilet at home	80	16	40	8	160	32	220	44
The toilets in the house are clean	190	38	100	20	160	32	50	10
Access to water in the toilets	190	38	100	20	160	32	50	10
Defecate or urinate in public spaces	80	16	40	8	160	32	220	44
Washing hands after using the toilet	180	36	100	20	100	20	120	24
Washing hands after coming back home	250	50	140	28	50	10	60	12
Lack of adequate infrastructure facilities leads to crowded living conditions	26	5	47	9	164	33	263	53
Disease prevalence increases due to unclean environments	72	14	96	19	149	30	183	37

N, number of respondents

Table 3: Relationship between age, education, occupation, monthly income, and prevailing environmental conditions

<i>Variables</i>	<i>Age</i>	<i>Education</i>	<i>Occupation</i>	<i>Monthly income</i>	<i>Prevailing environmental conditions</i>
Age	1	0.010	0.012	0.015	0.003
	–	(0.626)	(0.548)	(0.461)	(0.899)
Education	–	1	0.309**	0.265**	0.266**
	–	–	(0.000)	(0.000)	(0.000)
Occupation	–	–	1	0.428**	0.008
	–	–	–	(0.000)	(0.684)
Monthly income	–	–	–	1	0.015
	–	–	–	–	(0.461)
Prevailing environmental condition	–	–	–	–	1

**Significance @ 0.01 level

the built environment is free from undue hazards. In many cases, essential ecological services, such as adequate sanitation facilities, a reliable water supply, and effective solid waste management, are not provided to households and communities.⁶ Table 2 describes the prevailing environmental hygienic practices as expressed by the selected respondents.

Out of 500 households surveyed, 34% of respondents reported burning waste in open areas all the time, while 8% disposed of waste openly, and 24% used only community dustbins. Despite government programs and training initiatives, 64% of households still fail to segregate waste into recyclable and non-recyclable materials. Additionally, 33% of respondents faced difficulties accessing clean water, and 24% lacked access to safe drinking water. Handwashing before eating was practiced regularly by only 12%, while 50% admitted they did not wash their hands before meals. Access to toilets at home was available to 44% of households, with only 10% maintaining clean facilities. Public defecation or urination at all times was reported by 44%, and consistent handwashing after using the toilet or returning home was reported by 24 and 12%, respectively. Overcrowded living conditions and unclean environments were reported by 53 and 37%, contributing to higher disease prevalence among slum

populations compared to non-slum areas, consistent with studies in Nepal.²

Relationship between Socio-demographic Profile and Prevailing Environmental Conditions

The independent variables, age and education, and the dependent variables, occupation and monthly income, are related using Karl Pearson's correlation analysis. The obtained Pearson Correlation value helps to know the strength and direction of the relationship between the variables. Correlation coefficients are the indicators of the strength of the linear relationship between two different variables. The correlation coefficient is measured on a scale that varies from +1 to –1. The interrelationship between age, education, occupation, monthly income, and prevailing environmental conditions is presented in Table 3.

Hypothesis 1: There is no Significant Relationship between Age, Education, Occupation, Monthly Income, and Prevailing Environmental Conditions

Among various socio-demographic profiles, only education has been found to have a positive and significant relationship with prevailing environmental conditions ($r = 0.266$, $p < 0.05$). This indicates that

Table 4: Knowledge of environmental hygiene by the selected women

<i>Knowledge of environmental hygiene</i>	<i>N = 500</i>			
	<i>Yes</i>		<i>No</i>	
	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>
Harmful effects of incorrectly disposing of the waste on the environment and health	155	31	345	69
Burning garbage has harmful effects on the environment	485	97	15	3
It is not a good practice to bury waste such as plastic, glass, and paper outside	454	91	46	9
There are natural ways of promoting food waste decomposition	500	100	–	–
Waste materials should be segregated into wet waste (including food items) and dry waste (such as plastic, metal, and paper materials)	484	97	16	3
The quality of your water affects your health	484	97	16	3
The importance of washing your hands	152	30	348	70
Washing hands without soap after using the toilet is not good	155	31	345	70
It is not good to let water stagnate in areas around and outside the house	333	67	167	33
It is essential to store drinking water in covered containers	151	30	349	70
Public defecation and urination have adverse effects on those living in and around the area	151	30	349	70
Animal dung results in diseases	426	85	74	15

N, number; %, percentage

environmental conditions will improve when education is better. Hence, the null hypothesis is rejected, indicating a significant relationship between education and prevailing environmental conditions. Furthermore, the prevailing environmental conditions do not have a substantial relationship with age ($r = 0.003, p > 0.05$), occupation ($r = 0.008, p > 0.05$), or monthly income ($r = 0.015, p > 0.05$). This states that age, occupation, and monthly income are not related to the prevailing environmental conditions. Henceforth, the null hypothesis, that there is no significant relationship between age, occupation, monthly income, and prevailing environmental conditions, is accepted. It is also concluded that the socioeconomic background of slum dwellers influences social and behavioral aspects, as well as ecological quality.⁷

Knowledge, Attitude, and Practice of Environmental Hygiene by the Selected Women

Health, in humans, refers to the extent to which an individual's ongoing physical, emotional, mental, and social abilities enable them to cope with their environment. Access to sufficient amounts of safe and nutritious food is key to sustaining life and promoting good health. Unsafe food containing harmful bacteria, viruses, parasites, or chemical substances causes more than 200 diseases, ranging from diarrhea to cancer. It also creates a vicious cycle of disease and malnutrition, particularly affecting infants, young children, the elderly, and the sick. Good collaboration between governments, producers, and consumers is needed to help ensure food safety and a stronger food system.⁸

Sanitation and hygiene are critical to health, survival, and development. Many countries face challenges in providing adequate sanitation for their entire populations, leaving people vulnerable to diseases related to water, sanitation, and hygiene. Hence, it is essential to understand the knowledge of the connectivity between health, food, and sanitation among the selected women. Tables 4 and 5 highlight the knowledge of environmental hygiene and health issues among selected women.

Knowledge of Environmental Hygiene among the Selected Women

Knowledge of environmental hygiene as pressed by the selected women is given in Table 4.

Table 5: Knowledge of health issues by the selected women

<i>Knowledge of health issues</i>	<i>N = 500</i>	
	<i>N</i>	<i>%</i>
Health issues caused by poor water quality		
Dysentery	325	65
Cholera	175	35
Health issues caused by fecal-to-oral and soil-to-oral contact		
Hepatitis A/E	459	92
Typhoid	41	8

N, number; %, percentage

Table 5 displays the respondents' understanding of health, food, and sanitation. Thirty-one percent stated that they were aware of the negative impacts of improper garbage disposal on the environment and health, while the remaining 69% expressed that they were not aware of these impacts. The majority of respondents (97%) believe that burning waste is damaging to the environment, whereas 15% are unaware of the harmful impacts of burning garbage. Burying waste such as plastic, glass, and paper outside was not a good practice, according to 91% of respondents, while 9% said they were not aware of it. One hundred percent of the respondents agreed that they were aware of natural methods of improving food waste decomposition.^{7,9,10}

The waste materials should be segregated into wet waste, such as food waste, and dry trash, including plastics, metals, and paper materials, according to 97% of respondents. However, 3% of the respondents admit that they were unaware of the segregation. Ninety-seven percent of respondents claim they were aware that water quality affects health. However, 30% of respondents were aware of the relevance of hand washing, while 70% were unaware of its significance. Thirty-one percent of respondents acknowledged that washing hands without soap after using the toilet was not recommended, while 69% disagreed.

Sixty-seven percent of respondents understand that water stagnation around the house creates health problems, while 33% of respondents do not accept the fact. Thirty-two percent of respondents understand the need to store drinking water in covered containers, and public feces and urination negatively affect individuals living in and around the area. Eighty-five percent of respondents agreed that animal feces cause diseases.



Table 6: Attitudes of environmental hygiene by the selected women

<i>Attitudes towards environmental hygiene</i>	<i>N = 500</i>					
	<i>Agree</i>		<i>Somewhat agree</i>		<i>Disagree</i>	
	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>
It is each individual's responsibility to dispose of waste in trash cans	158	32	326	65	16	3
Defecating or urinating in public is very convenient	–	–	321	64	179	36
Failing to clean utensils for several days is unhygienic	14	3	175	35	311	62
Washing hands before and after eating is a waste of time	456	91	27	5	17	4
Washing hands after using the toilet is not an effective way to prevent diseases	274	55	205	41	21	4
The actions of one person in environmental sanitation are not sufficient	–	–	227	45	273	55
Proper sanitation practices are expensive	340	68	159	31.8	1	0.2
It is essential to practice good sanitation and hygiene and be a role model for our children	–	–	167	33	333	67
Wastewater should be disposed of appropriately	217	43	237	48	46	9
Bathing is essential for both hygiene and beauty purposes	95	19	235	47	170	34
The hands of family members will not cause a problem, even if they are unhygienic	142	28	202	41	156	31
It is not proper to share drinking cups with others	95	19	235	47	170	34
Proper sanitary practices are essential for preventing many infections	30	6	362	72	108	22
Individual toilets are primarily crucial for privacy, rather than hygiene purposes	142	29	202	40	156	31
It is not necessary to wash hands with soap	140	28	204	41	156	31

N, number; %, percentage

Knowledge of Health Issues by the Selected Women

Globally, 2.3 billion people still lack access to basic sanitary facilities, including toilets and latrines. Of these 892 million, still defecate in the open, in street gutters, behind bushes, or into open water bodies.⁹ Poor sanitation is linked to transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and poliomyelitis. Inadequate sanitation is estimated to cause 2,80,000 diarrheal deaths annually and is a significant factor in several neglected tropical diseases, including intestinal worms, schistosomiasis, and trachoma. Table 5 explains the opinions of selected women regarding health issues related to environmental hygiene.

The table above indicates the respondents' understanding of the health risks associated with poor water quality, fecal-to-oral and soil-to-mouth contact, and the sources of information about sanitation and hygiene. Sixty-five percent of respondents believed that poor water quality causes dysentery, whereas 35% believed that poor water quality causes cholera. Ninety-two percent of the respondents expressed that hepatitis is caused by fecal-to-oral and soil-to-oral contact, whereas 8.2% opined that typhoid is caused by fecal-to-oral and soil-to-oral contact.

Attitudes of Environmental Hygiene by the Selected Women

Healthier environments could prevent almost one quarter of the global burden of disease. The COVID-19 pandemic serves as a poignant reminder of the delicate relationship between humans and our planet. Clean air, a stable climate, adequate water, sanitation, and hygiene, safe use of chemicals, protection from radiation, healthy and safe workplaces, sound agricultural practices, health-supportive cities and built environments, and a preserved natural environment are all prerequisites for good health. Therefore, it is essential to understand the attitudes of women on environmental hygiene before creating awareness. Table 6 emphasizes the attitude of women towards ecological hygiene.

Table 7 depicts the respondents' attitudes towards environmental hygiene. Out of 500 respondents, 32% agreed, 65% somewhat agreed, and 3% disagreed that it is each individual's

responsibility to dispose of waste in dustbins. In terms of whether defecating in public is convenient, 64% of respondents agree, and 36% disagree.

Not cleaning utensils for many days is unhygienic, which was disagreed with by 62% of the selected respondents. Ninety-one percent of respondents agreed that washing hands before and after eating is a waste of time. Fifty-five percent and 41% of the respondents agreed and somewhat agreed, respectively, that washing hands after using the toilet is not effective in preventing diseases.

Forty-five percent somewhat agreed, and 55% disagreed that the action of one person in environmental sanitation is not sufficient. Sixty-eight percent of respondents agreed, while 32% agreed somewhat that proper sanitation practices are costly. Thirty-three percent somewhat agreed, and 67% disagreed that it is essential to practice good sanitation and hygiene and be a role model to our children.

Wastewater should be disposed of in an appropriate manner, which was agreed upon by 43% of the selected respondents. Forty-seven percent of the respondents somewhat agreed that bathing is essential for hygiene purposes, not just for beauty purposes. It is noted that 31% of the selected respondents disagreed that the hands of family members would cause a problem even if they were unhygienic.

Nineteen percent agreed that no hams share drinking cups with others. Regarding sanitary practices, 72% somewhat agreed that proper hygienic practices are the way to prevent many infections. Thirty-one percent of respondents disagree that individual toilets are only crucial for privacy and not hygiene purposes. Forty-one percent of respondents somewhat agreed that it is not necessary to wash hands with soap.

Practices of Environmental Hygiene by the Selected Women

To effectively achieve sustainable behavior change, it is necessary to understand how people value and perceive environmental change. It is for this reason that practices and knowledge assessment are

Table 7: Practices of environmental hygiene by the selected women

	<i>N = 500</i>							
	<i>Never</i>		<i>Sometimes</i>		<i>Most of the time</i>		<i>All the time</i>	
	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>
<i>Practices about health, food, and sanitation</i>								
Burn waste in an open area to dispose of it	108	22	140	28	82	16	170	34
Dispose of the waste in an open area	215	43	170	34	75	15	40	8
Dispose of the waste in a community dustbin	180	36	100	20	100	20	120	24
Separates waste into recyclable and non-recyclable products	320	64	80	16	60	12	40	8
Difficulties in procuring clean water access	120	24	80	16	135	27	165	33
Access to clean drinking water and washing	160	32	120	24	100	20	120	24
Washing hands before and after eating	250	50	140	28	50	10	60	12
Access to a toilet at home	80	16	40	8	160	32	220	44
Access to public toilets in the area	0	–	0	–	0	–	0	–
The toilets in the house are clean	190	38	100	20	160	32	50	10
Toilets are clean in public restrooms	0	–	0	–	0	–	0	–
Access to water in the toilets	190	38	100	20	160	32	50	10
Defecate or urinate in public spaces	80	16	40	8	160	32	220	44
Washing hands after using the toilet	180	36	100	20	100	20	120	24
Washing hands after coming back home	250	50	140	28	50	10	60	12

N, number; %, percentage

beneficial for this research. Knowledge and practice research approaches are used to understand what people know, believe, and do in relation to specific topics.¹⁰ Baseline data on current practices and knowledge about environmental hygiene are presented in Table 7.

Table 8 describes the respondents' practices on environmental hygiene. Out of 500 respondents, 34% burned the waste all the time in the open area. And 8% of the selected households disposed of the waste in an open area. It is interesting to note that 24% of the selected households disposed of the waste only in a community dustbin.

Despite numerous government programs and training initiatives, 64% of respondents still fail to separate waste into recyclable and non-recyclable products. Despite multiple government programs aimed at addressing water scarcity, 33% of the selected households still face difficulties in procuring clean water. Even among 500 families, 24% of households were not receiving pure drinking water.

Regarding handwashing before eating, only 12% are regular. It is heartening to note that 50% of the respondents reported not washing their hands before eating. Regarding access to toilets at home, 44% have this facility all the time. The cleanliness of the bathroom is a concern, as only 10% of the selected households keep the toilet clean and neat, mainly due to water availability issues.

Forty-four percent of the respondents say they defecate or urinate in public spaces all the time. Twenty-four percent say they always wash their hands after using the toilet. And only 12% say they always wash their hands after coming back home.

Relationship of Knowledge Scores with Attitudes and Practices on Environmental Hygiene is Presented in Table 8

Hypothesis 2: There is no Significant Difference in Knowledge, Attitude, and Practice among Women on Environmental Hygiene

Regarding the relationship between knowledge and attitude, the null hypothesis is rejected because a significant positive correlation

Table 8: Relationship of knowledge scores with attitude and practices on environmental hygiene

<i>Variables</i>	<i>Knowledge</i>	<i>Attitude</i>	<i>Practice</i>
Knowledge	1	0.183**	–0.002
Attitude	0.183**	1	–0.045
Practice	–0.002	–0.045	1

**Correlation is significant at the 0.01 level

exists between knowledge and attitude ($r = 0.183$). In contrast, there is no significant correlation between knowledge and practice or between knowledge and attitude. Therefore, the relationship between attitude and practice is framed by the null hypothesis.

SUMMARY AND CONCLUSION

A nation's progress extends beyond mere economic growth; it requires balanced development across all sectors, with a particular focus on health and wellness. When the population faces health challenges due to insufficient resources, it hampers their ability to fulfil daily responsibilities, which ultimately affects economic advancement. From the data gathered, it is evident that a lack of basic facilities and resources has led to various health issues, significantly impacting the physical and mental well-being of the population. Those living in suburban and urban slum areas are particularly vulnerable to these challenges.

In this context, it is crucial that residents, especially those in urban slums, take proactive steps to improve healthcare access and sanitation facilities. A comprehensive approach to urban development must involve enhancing public health infrastructure and hygiene practices for sustained growth. The study highlights that a focused awareness program, along with educational services on proper sanitation and hygiene, is urgently needed to improve living conditions in urban slum areas and promote a healthier environment.

DISCUSSION

The present study clearly demonstrates that targeted educational interventions can significantly enhance knowledge, attitudes, and



practices related to environmental hygiene in urban slum settings. Pre-intervention assessment revealed inadequate sanitation facilities, overcrowding, stagnant water accumulation, and limited awareness regarding hygiene and disease transmission among the households of Kallukuttai. Over the course of the intervention, which included health education, awareness materials, and mentoring support, gradual improvements were observed, and post-intervention results confirmed marked gains in hygiene knowledge, positive attitudes toward sanitation, and adoption of safer personal and environmental practices such as handwashing, waste segregation, and safe water handling. These findings affirm that behavior change in vulnerable communities is achievable when educational strategies are sustained, community-focused, and supported by local health workers. The study also suggests that strengthening sanitation infrastructure and integrating participatory community involvement may further reinforce and sustain the improved hygiene practices. Overall, the intervention proved effective in transforming household-level hygiene behavior and reducing environmental health risks in the slum context.

Study Design

This study was a descriptive cross-sectional study conducted among women residing in selected urban slum areas.

Study Duration

The study was carried out from January 2025 to June 2025.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Artificial Intelligence (AI) Disclosure

Generative AI tools were used only for language refinement and manuscript preparation support. All scientific content, data interpretation, analysis, and conclusions were developed, verified, reviewed, and approved by the author, who takes full responsibility for the content of this article.

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AUTHOR CONTRIBUTIONS

Dr Vidhya Jayakumar conceptualised and designed the study, conducted data collection, performed data analysis, interpreted the findings, and prepared the manuscript. The author reviewed and approved the final version of the manuscript.

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A Comparative Study on the Effects of Shift Work and Circadian Disruption on Nurses' Sleep, Fatigue, and Cognitive Function

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ABSTRACT

Background: Continuous patient care requires nurses to work in rotating and night-shifts, which may disrupt circadian rhythms and adversely affect sleep, fatigue levels, and cognitive functioning. This study aimed to compare the effects of shift-related circadian disruption on sleep quality, fatigue, and cognitive function among night-shift and morning-shift nurses.

Materials and methods: A comparative cross-sectional study was conducted among 60 nurses (30 night-shift and 30 morning-shift) selected through purposive sampling. Validated instruments—including the sleep hygiene index, standard shift index, Epworth Sleepiness scale, and Montreal cognitive assessment—were administered on day 1 and day 4 of the shift cycle. Data were analyzed using independent and paired *t*-tests at a 0.05 level of significance.

Results: By day 4, 80% of night-shift nurses reported moderate sleep disturbances, whereas 83% of morning-shift nurses reported no disturbances. Night-shift nurses demonstrated significantly higher daytime sleepiness scores (15.53 ± 2.20 ; $p = 0.01$) and poorer sleep hygiene (36.2 ± 2.63). Poor sleep hygiene showed a strong positive correlation with reduced sleep quality and was associated with a notably higher likelihood of daytime somnolence. Fatigue levels were also significantly higher among night-shift nurses. No significant between-group differences were observed in cognitive function.

Conclusion: Shift-related circadian disruption is associated with poorer sleep quality, elevated fatigue, and increased daytime sleepiness among night-shift nurses compared with their morning-shift counterparts. These findings highlight the need for institutional strategies to mitigate circadian misalignment and support nurse wellbeing while maintaining quality patient care.

Keywords: Circadian disruption, Cognitive function, Comparative study, Daytime somnolence, Fatigue, Shift work, Sleep quality, Nurses.

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INTRODUCTION

The human body is biologically programmed to remain awake during daylight hours and rest at night, a pattern regulated by the circadian rhythm that coordinates sleep–wake cycles and numerous physiological processes. Night-shift work requires healthcare professionals—particularly nurses—to override this innate rhythm, making adaptation difficult and often physiologically disruptive.¹ Extensive evidence demonstrates that night-shift schedules can significantly disturb circadian regulation, leading to sleep disruption, heightened oxidative stress, and a range of adverse health outcomes.^{2,3}

Globally, shift work is a prevalent occupational requirement. The European Working Conditions Survey (2015) reported that approximately 21% of the workforce engages in some form of shift work, reflecting its broad impact.⁴ Studies from Malaysia and China similarly report a high prevalence of sleep disturbances among nurses, with rates of 57.8 and 75.8%, respectively, underscoring the widespread vulnerability of nursing personnel to circadian disruption.^{5,6}

Circadian rhythm disturbances manifest in several domains, including impaired sleep, altered cognitive performance, and increased fatigue.^{7,8} Night-shift work is a major contributor to circadian misalignment, often resulting in difficulty initiating sleep, fragmented sleep, reduced total sleep duration, and increased daytime somnolence.^{9,10} These disturbances are so consistent that they form the basis of a recognized clinical condition termed

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Shift Work Disorder.¹¹ Among nurses, poor sleep quality can impair physical health, reduce psychomotor efficiency, and increase the likelihood of errors and occupational accidents, ultimately compromising patient safety.^{12,13}

Fatigue—characterized by overwhelming tiredness and diminished physical and cognitive capacity—is another frequent consequence of irregular and prolonged shift schedules. Extended working hours and misaligned sleep–wake cycles can impair attention, working memory, decision-making, and psychomotor vigilance.¹⁴ Both individual factors (such as age and baseline sleep quality) and workplace conditions (including shift duration and rotation frequency) contribute to fatigue-related cognitive decline

among nurses.¹⁴ Insufficient sleep further exacerbates daytime somnolence, decreases productivity, and heightens psychological stress.^{15,16} Evidence from China also suggests that chronic circadian disruptions may be associated with mood disturbances, including depressive symptoms among nursing professionals.¹⁷

Chronic sleep deprivation is known to affect multiple cognitive domains, including learning, working memory, motor coordination, and emotional regulation, thereby increasing the risk of impaired clinical decision-making and reduced patient safety.^{18–20} Considering the essential role nurses play in delivering continuous patient care, understanding the extent to which shift work affects sleep, fatigue, and cognitive function is crucial.

Although previous studies have explored various aspects of shift-related health effects, there remains limited comprehensive evidence comparing the combined influence of shift work–related circadian disruption on sleep quality, fatigue, and cognitive performance among nurses. Therefore, this study aims to compare the effects of shift work on circadian disruption—specifically sleep quality, fatigue, and cognitive function—between night-shift and morning-shift nurses.^{21–24}

Objectives

The overall aim of the study was to compare the effect of disruption in circadian rhythm during shift work on sleep quality, fatigue, and cognitive functions.

The specific objectives assessed at baseline (day 1) and day 4 were:

1. To compare sleep quality, daytime somnolence, fatigue, and cognitive functions between night-shift and morning-shift nurses.
2. To determine the correlation between sleep hygiene practices and sleep quality scores among night-shift nurses.
3. To estimate the likelihood (risk ratio and odds ratio) of daytime somnolence among night-shift compared with morning-shift nurses.

MATERIALS AND METHODS

Study Design and Setting

This study employed a quantitative, comparative cross-sectional design to evaluate the effects of shift work on circadian rhythm–related outcomes among nurses. The study was conducted at a tertiary-care hepatobiliary hospital in Delhi between November and December 2023.

A total of 60 nurses were enrolled using purposive sampling, with 30 night-shift nurses and 30 morning-shift nurses. The sample size was calculated using a standard deviation of 0.5 and a margin of error of 10%, yielding a required size of 66; the final sample was rounded to 30 participants per group.

Description of Study Groups: Night-shift Group

Nurses posted in selected Intensive Care Units working 12-hour night-shifts (8:00 p.m.–8:00 a.m.).

Morning-shift Group

Nurses work routine 8-hour morning shifts (8:00 a.m.–4:00 p.m.).

The ICU setting was selected because its demanding, high-acuity environment increases susceptibility to sleep disruption, fatigue, and cognitive strain—making it an ideal context for examining circadian misalignment. The study was based on existing

evidence suggesting that four consecutive night-shifts can lead to substantial disturbances in circadian rhythm, affecting sleep quality, fatigue, daytime somnolence, and cognitive performance.

Eligibility Criteria

The inclusion criteria included Registered nurses aged 18–42 years, currently working either night-shifts (case group) or morning shifts (control group), willing to provide informed consent. The exclusion criteria included diagnosed endocrine disorders (e.g., thyroid disease, diabetes mellitus), on medications affecting sleep or cognition, acute illness (e.g., fever) during data collection, diagnosed psychological stress disorders, or experiencing major family or personal stressors that could influence sleep or mental health.

Data Collection Procedure

Data were collected using self-administered questionnaires. Each participant received a participant information sheet outlining the study purpose, procedures, and instructions. Demographic information and sleep hygiene practices were recorded once at baseline (day 1). Sleep quality, fatigue, daytime somnolence, and cognitive function were assessed at two time points: Baseline (day 1), during daytime hours before the start of the duty cycle, and day 4. For night-shift nurses, day 4 assessments were conducted in the morning immediately after completing the night-shift, while for morning-shift nurses, assessments were completed during their routine morning duty hours.

Tools Used

The Standard Shift Work Index (SSI) included two subscales: the Sleep Questionnaire (11 items rated on a 5-point Likert scale; total score 160) and the Fatigue Scale (10 items; total score 50). The tool has demonstrated good reliability, with a reported Cronbach's alpha of 0.77, and is widely used in shift-work research.

The sleep hygiene index (SHI) consists of 13 items rated on a 5-point Likert scale. Scores are interpreted as follows: <26 = good sleep hygiene, 27–34 = normal sleep hygiene, and ≥35 = poor sleep hygiene. The reported reliability of the tool is Cronbach's $\alpha = 0.77$.

The Epworth Sleepiness Scale (ESS) comprises 8 items rated on a 0–3 Likert scale, yielding a maximum score of 24, with higher scores indicating greater daytime somnolence. The tool demonstrates excellent reliability, with a reported Cronbach's $\alpha = 0.95$.

Cognitive function was assessed using the Montreal Cognitive Assessment (MoCA), a 30-item tool covering eight cognitive domains. Scores ≥ 26 indicate normal cognition, whereas scores <10 denote severe impairment. The MoCA has a reported reliability coefficient of 0.82.

Ethical Considerations

Ethical clearance was obtained from the Institutional Ethics Committee of the College of Nursing, ILBS (M.Sc.(N)/30008/ILBS/CON/2085). All ethical principles as outlined in the Declaration of Helsinki were followed. Participation was voluntary, and both verbal and written informed consent were obtained.

RESULTS

Data Analysis

SPSS Statistics 20.0 was used for data analysis. Normality was assessed using the Shapiro–Wilk test, and the data met assumptions for parametric testing. Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to summarize the

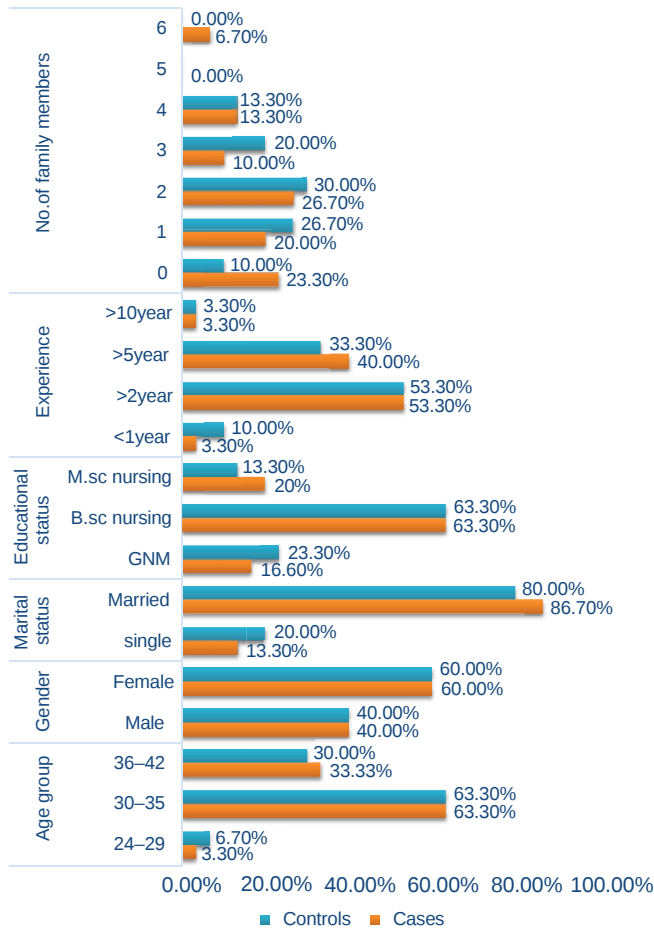


Fig. 1: Cluster bar graph showing the frequency percentage distribution of nurses based on their sociodemographic characteristics among cases and controls

variables. Independent *t*-tests were applied for between-group comparisons (night-shift vs morning-shift), and paired *t*-tests were used for within-group comparisons from day 1 to day 4. Chi-square tests were used for categorical variables. A *p*-value < 0.05 was considered statistically significant.

The two groups were comparable at baseline. Sixty percent of nurses in both groups were aged 30–35 years. Most participants were married (80% in the night-shift group and 60% in the morning-shift group), and the majority of night-shift nurses were female (80%). Educational status was similar between groups, with 63% holding a graduate degree. More than half of the participants reported 2–5 years of work experience (53.3% in controls). Approximately one-third of night-shift nurses and one-fourth of controls had two family members requiring caregiving responsibilities. Chi-square analysis indicated no significant differences between the two groups in age ($\chi^2 = 0.38, p = 0.82$), gender ($\chi^2 = 1.20, p = 0.27$), marital status ($\chi^2 = 0.48, p = 0.40$), education ($\chi^2 = 4.5, p = 0.10$), work experience ($\chi^2 = 1.1, p = 0.40$), or family caregiving responsibilities ($\chi^2 = 4.9, p = 0.40$) (Fig. 1).

Sleep Disturbances and Domain-wise Sleep Quality and Fatigue

At baseline, 60% of night-shift nurses reported moderate sleep disturbances, which increased to 80% by day 4, indicating a deterioration in sleep quality over the four consecutive night-shifts.

Table 1: Depicting frequency percentage of sleep disturbances and domain-wise description of sleep quality among cases and controls at baseline and day 4
 $n_1 + n_2 = 30 + 30$

1. Category of sleep disturbance				
	Night-shift nurses f (%)		Day-shift nurses f (%)	
	Day 1	Day 4	Day 1	Day 4
No sleep disturbances (121–160)	–	–	27 (90%)	25 (83%)
Mild sleep disturbances (81–120)	12 (40%)	6 (20%)	3 (10%)	5 (17%)
Moderate sleep disturbances (41–80)	18 (60%)	24 (80%)	–	–
Severe sleep disturbances (<40)	–	–	–	–

2. Domain of sleep					
Items	No. of mean	Night-shift nurses/ day-shift nurses		MD	Rank
		Day 1	Day 4		
Sleep latency	1	10.6/6.1	12.2/6.3	–1.6/0.2	V/IV
Sleep quantity	1	7.3/8.2	4.1/7.2	3.2/1.0	IV/III
Sleep efficiency	1	12.6/8.0	9.0/8.0	3.6/0	II/I
Refreshed on awakening	1	11.4/8.1	9.2/8.0	2.2/0.1	VI/V
Sleep satisfaction	1	20.8/7.1	18.0/7.0	2.8/0.1	V/V
Sleep awakening	1	5.1/7.0	6.0/7.0	–0.9/0	VII/VI
Daytime somnolence	8	8.2/7.6	14.2/7.0	–6/0.6	I/II
Sleep hygiene Practice (assessed only at day 1)	15	15.0/11.0	–	–	–

Table 2: Comparison of mean, SD, *t*-value, and *p*-value of sleep quality at baseline between cases and controls at baseline and day 4
 $n_1 + n_2 = 30 + 30$

Groups	Mean $\pm$ SD	95% CI value	<i>t</i>	<i>p</i> -value
Baseline				
Cases	82.50 $\pm$ 4.9	28.0–33.4	4	0.01*
Controls	51.27 $\pm$ 5.60			
Day 4				
Cases	88.36 $\pm$ 5.93	30.7–35.5	2	0.01
Controls	51.05 $\pm$ 5.6			

p-value < 0.05*; significant

In contrast, the majority of morning-shift nurses (83%) reported no sleep disturbances at either time point, demonstrating relative stability in their sleep patterns. Domain-wise analysis of sleep quality further highlighted the adverse impact of night-shift work (Tables 1 and 2). Night-shift nurses showed pronounced declines



Table 3: Comparison of mean, SD, MD, *t*-value, and *p*-value of daytime somnolence among night-shift and day-shift nurses on day 1 and day 4
*n*₁ + *n*₂ = 30 + 30

Time point	Group	Mean ± SD	Mean difference (MD)	95% CI for MD	<i>t</i> -value	<i>p</i> -value
Day 1	Night-shift nurses (<i>n</i> = 30)	9.63 ± 2.41	2.2	0.83 – 3.6	3.20	0.06
	Day-shift nurses (<i>n</i> = 30)	7.40 ± 2.9				
Day 4	Night-shift nurses (<i>n</i> = 30)	15.53 ± 2.20	7.7	1.3 – 3.8	4.1	0.01*
	Day-shift nurses (<i>n</i> = 30)	7.97 ± 2.9				

p-value < 0.05* considered statistically significant; minimum possible score = 0; maximum possible score = 24

Table 4: Comparison of mean, SD, MD, *t*-value, and *p*-value of fatigue experienced by night-shift nurses and day-shift nurses at day 1 and day 4
*n*₁ + *n*₂ = 30 + 30

Time point	Group	Mean ± SD	Mean difference (MD)	95% CI for MD	<i>t</i> -value	<i>p</i> -value
Day 1	Night-shift nurses (<i>n</i> = 30)	23.77 ± 4.40	0.64	0.4 – 2.5	0.99	0.3
	Day-shift nurses (<i>n</i> = 30)	23.13 ± 2.60				
Day 4	Night-shift nurses (<i>n</i> = 30)	25.93 ± 4.80	2.83	0.83 – 3.6	3.2	0.02*
	Day-shift nurses (<i>n</i> = 30)	23.10 ± 2.40				

*Indicates a statistically significant difference in fatigue scores between night-shift nurses and day-shift nurses at *p*-value < 0.05 significant

Table 5: Comparison of Mean, SD, MD, *t*-value, and *p*-value of cognitive function experienced by night-shift nurses and day-shift nurses at day 1 and day 4
*n*₁ + *n*₂ = 30 + 30

Time point	Group	Mean ± SD	Mean difference (MD)	95% CI for MD	<i>t</i> -value	<i>p</i> -value
Day 1	Night-shift nurses (<i>n</i> = 30)	25.33 ± 2.2	−0.6	−0.3 to 1.0	1.33	0.18
	Day-shift nurses (<i>n</i> = 30)	25.93 ± 0.94				
Day 4	Night-shift nurses (<i>n</i> = 30)	25.67 ± 2.2	−0.5	−1.6 to 0.4	1.09	0.2
	Day-shift nurses (<i>n</i> = 30)	26.23 ± 1.6				

p-value < 0.05 = significant

Table 6: Correlation between sleep hygiene practices and sleep quality scores among night-shift nurses (*n* = 30)

Variables	Sleep hygiene practices <i>r</i> (<i>p</i>)	Sleep quality <i>r</i> (<i>p</i>)	Sleep hygiene practices <i>r</i> (<i>p</i>)	Sleep quality <i>r</i> (<i>p</i>)
Sleep hygiene practices	1	0.43 (0.005)*	1	−0.11 (0.55)
Sleep quality	0.43 (0.005)*	1	−0.11 (0.55)	1

*Indicates a statistically significant correlation between sleep hygiene practices and sleep quality scores among night-shift nurses at *p* < 0.05 level; *r* = 1 denotes a perfect positive correlation; *r* = −1 denotes a perfect negative correlation

in daytime somnolence, sleep efficiency, sleep quantity, and sleep latency, with mean differences of −6, −3.6, −3.2, and −1.6, respectively, from day 1 to day 4. Moderate reductions were also seen in feeling refreshed upon awakening (MD = −2.2) and sleep satisfaction (MD = −2.8), while sleep awakening patterns showed minimal change. Conversely, morning-shift nurses demonstrated only negligible fluctuations across all sleep domains, underscoring the stability of their sleep quality compared to their night-shift counterparts.

Between-group comparisons further supported these findings. Independent *t*-test results revealed that night-shift nurses had significantly poorer overall sleep quality than morning-shift nurses at both baseline and day 4. By day 4, night-shift nurses recorded a mean sleep quality score of 88.36 ± 5.93, which was significantly higher, indicating poorer sleep quality, compared with the morning-shift group (*t* = 26.32, *p* < 0.05) (Tables 1 and 2). Daytime somnolence also differed markedly between groups, with night-shift nurses demonstrating significantly higher sleepiness scores on day 4. The mean difference of 15.53 (95% CI: 1.3–3.8) and

a *t*-value of 4.10 (*p* < 0.05) reflect a substantial increase in sleepiness attributable to night-shift work (Table 3).

Fatigue levels did not differ significantly between the two groups at baseline or day 4. Although night-shift nurses reported slightly higher fatigue scores, the differences were not statistically significant (baseline *t* = 0.99, *p* = 0.30), indicating considerable individual variability (Table 4). Cognitive function scores were also comparable between night- and morning-shift nurses, with no significant differences detected at baseline (*t* = 1.33, *p* > 0.05), suggesting that short-term exposure to consecutive night-shifts did not significantly impair global cognitive performance in this sample (Table 5).

A strong positive correlation was observed between sleep hygiene practices and sleep quality among night-shift nurses, indicating that poorer sleep hygiene was associated with greater sleep disturbances (Table 6). Risk analysis further revealed that night-shift nurses were substantially more vulnerable to daytime somnolence, being six times more likely to experience increased sleepiness compared with morning-shift nurses (*p* = 0.012). They

Table 7: Odds ratio and relative risk ratio for daytime somnolence among night-shift and day-shift nurses ($N = 60$)

Group	Daytime somnolence		OR RR	95% CI		p-value
	Present	Absent		Lower	Upper	
Night-shift nurses ($n = 30$)	12	18	6	1.481	24.299	0.012*
Day-shift nurses ($n = 30$)	3	27	4	1.254	12.754	0.019*

*Indicates a statistically significant association of daytime somnolence between night-shift nurses and day-shift nurses at $p < 0.05$ level. OR, odds ratio; RR, relative risk ratio

also exhibited a fourfold greater risk of excessive daytime sleepiness ($p = 0.019$), highlighting the heightened susceptibility of night-shift workers to circadian rhythm disruption and its functional consequences (Table 7).

Mean baseline sleep hygiene scores showed significantly poorer sleep hygiene among night-shift nurses (36.2 ± 2.63) compared with morning-shift nurses (18.01 ± 2.73).

DISCUSSION

The study examined the effects of shift work (night-shift vs day-shift) over four consecutive days among nurses, focusing on sleep quality, fatigue, and cognitive performance. A significant difference in sleep quality was found between the case and control groups ($p = 0.01$). Among the cases, a majority (80%) experienced moderate sleep disturbances after four consecutive night-shifts, while 83% of the controls reported no sleep issues.

Similar findings were reported by Hacimusalar et al.²⁵ and Tur et al.,²⁵ where 72.4 and 83.3% of physicians working night-shifts experienced poor sleep quality, respectively. McDowall et al.²⁷ and a study conducted in Saudi Arabia also reported comparable outcomes among nurses.²⁸ Consistent findings were noted in a 2021 cohort study, where 79.9% of night-shift nurses reported low sleep quality, 63.4% experienced sleep deprivation, and 28.5% had difficulty falling asleep.²⁹

In the present study, a strong positive correlation was observed between sleep hygiene practices and sleep quality. Good sleep hygiene practices were reported by 70% of the controls, compared to 56.1% of the cases. These results align with the findings of Bisht et al.,³⁰ who noted that improved sleep hygiene practices significantly enhanced sleep quality. Similar conclusions were drawn by Yazdi et al.,³¹ who found a significant association between poor sleep hygiene and poor sleep quality among medical students.

The study also found that fatigue levels were significantly higher among cases (mean score = 30.13 ± 2.6) compared to controls (mean score = 23.10 ± 2.4), with a p -value of 0.02. Khan et al.³² similarly reported increased risks of insomnia, fatigue, anxiety, post-traumatic stress symptoms, and depression among Australian paramedics working night-shifts, with insomnia and fatigue being the primary contributing factors. However, contrasting results were reported by Benzo et al.,³³ where no statistically significant relationship was found between shift type and fatigue. This discrepancy may be attributed to other variables such as chronotype, personality traits, and the availability of support systems at home during the day.

Regarding daytime somnolence, the mean score among cases increased from 9.63 ± 2.41 at baseline to 11.53 ± 2.20 after the

night-shifts ($p = 0.02$), while the controls maintained relatively stable scores (from 7.40 to 7.97). Similar findings were reported by Westwell et al.,³⁴ who observed that 28% of NHS night-shift nurses and midwives experienced excessive daytime sleepiness, raising significant concerns about safety at work and while commuting.

No significant differences were found between cases and controls in terms of cognitive functioning. In contrast, another study assessing cognitive performance in night duty nurses over two shifts found that performance was lowest in the middle of the night and improved toward the end of the shift.³⁵ The differences in findings could be due to variations in methodology, chronotype, personality, and the presence of home support systems allowing for adequate rest.

Strengths and Limitations

A key strength of this study lies in its use of validated, standardized instruments to assess sleep quality, fatigue, and cognitive function, which enhances the reliability and comparability of findings. The prospective, case-control design allowed for comparison between night-shift and day-shift nurses, and two assessments at baseline and day, provided insights into the effects of shift work. However, the study has several limitations. It was conducted in a single institutional setting, which may limit the generalizability of the results. The relatively small sample size may also reduce the statistical power to detect subtle differences, particularly in cognitive outcomes. Additionally, the reliance on self-reported questionnaires introduces the possibility of reporting bias and subjective interpretation by participants. Factors such as age, gender, individual chronotype, workload intensity, and environmental conditions, support system at home, which could influence sleep and fatigue, were not controlled for and need further exploration in future research. There had been significant differences observed in sleep quality and fatigue, but it cannot be stated conclusively that the four consecutive night duties independently led to this. Hence, a similar study on a larger population is recommended.

CONCLUSION AND RECOMMENDATIONS

This study shows that nurses working four consecutive night-shifts experience significantly poorer sleep hygiene, increased daytime sleepiness, and greater fatigue compared to those on regular day-shifts. A strong positive correlation was observed between poor sleep hygiene practices and sleep disturbances, reinforcing the immediate adverse effects of night-shift work on sleep quality and alertness. However, no significant impairments in cognitive function were observed over the short term; the findings highlight a concerning trajectory that could contribute to long-term health consequences if sustained. It underscores the significance of institutional policies that limit the number of consecutive night duties and ensure adequate recovery periods between shifts to mitigate circadian disruption. The actionable recommendations include: Restricting night duties to a maximum of 2–3 consecutive shifts, implementing structured sleep hygiene education for shift workers, incorporating scheduled rest breaks and recovery time into duty rosters, and regular monitoring of fatigue and sleep-related complaints through wellness programs.

Future longitudinal research using objective measures such as actigraphy, including a larger, more diverse population to generalize findings, is recommended. Supporting nurses' sleep health is



essential not only for their well-being but also for ensuring safe and effective patient care.

Availability of data and materials

The dataset used and/or analyzed during the current study are available from the first author on reasonable request.

Artificial Intelligence (AI) Disclosure

No AI-assisted technologies were used.

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AUTHORS' CONTRIBUTIONS

Ms Mahima Chaudhary - conceptualization, data collection and analysis.

Sunita Srivastava - Conceptualization, Data Analysis, preparing first draft of the manuscript, revising and finalizing it.

Ms Mahima Chaudhary has full access to all the data in the study and take full responsibility for the integrity of the data and accuracy of the data analysis. All authors have read and approved the final version of the manuscript.

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Breast Cancer Classification, Face Recognition, and Face Verification for Diagnosis Continuity Tracking

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ABSTRACT

Breast cancer is a disease where breast cells grow abnormally out of control and eventually result in a tumour. Breast cancer can be fatal, and it claims one life out of every two newly detected cases in India. The cancer classification involves a complex pattern recognition task over diagnostic data. This paper presents an artificial intelligence (AI) and machine learning (ML) based approach for breast cancer classification, face recognition, and face verification. The proposed approach for breast cancer classification is based on a multi-layer perceptron (MLP) using the breast cancer Wisconsin (diagnostic) dataset. The face recognition task is considered a patient identification task and is achieved through the proposed convolutional neural network (CNN)-based model. The breast cancer classification and face recognition are also performed using multiple baseline classifiers. The face verification-based continuity tracking task is achieved using the proposed Siamese network. This paper serves as a foundation and a road map for future works towards breast cancer classification and face verification-based continuity tracking for visits, diagnosis, and risks.

Keywords: Breast cancer, Diagnostic features, Machine learning, Women's health.

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INTRODUCTION

Breast cancer is a disease in which the abnormal growth of breast cells results in a mass called a tumor. In India, breast cancer is the most common cancer in women and one out of every two newly diagnosed women dies.¹⁻⁴ This presents a requirement for urgent attention towards early detection and timely diagnosis. The availability of artificial intelligence (AI) based models has shown great potential for medical and family welfare applications. The medical data requires extensive pattern identification to classify breast cancer in a patient. The pattern recognition involves analysing multiple features. This complex task of pattern recognition, if done with high accuracy and in less prediction time, can be life-saving for the patient. In order to achieve faster and more accurate breast cancer classification, AI, machine learning (ML), and neural networks (NN) can be helpful.

This paper presents an AI and ML-based solution towards breast cancer classification, face recognition-based patient identification, and face verification-based patient continuity simulation. The objective of this work is to provide an accurate and faster classification for breast cancer and provide a roadmap to integrate face recognition-based patient identification and face verification-based continuity diagnosis tracking through demo simulations. The proposed work relies on a diagnostic features-based dataset for breast cancer classification and image-based face recognition and verification. This work presents novel approaches towards the above-defined three tasks. The breast cancer classification task is considered a binary classification; the face recognition is considered as a 1:N search or multi-class identification, and face verification is treated as a 1:1 search (binary classification).

There have been several research works focused on breast cancer classification. But some of these works rely on baseline models for breast cancer classification and could not explore the learned patterns by virtue of a multi-layered perceptron (MLP). Also, most of these works worked on the cancer classification task

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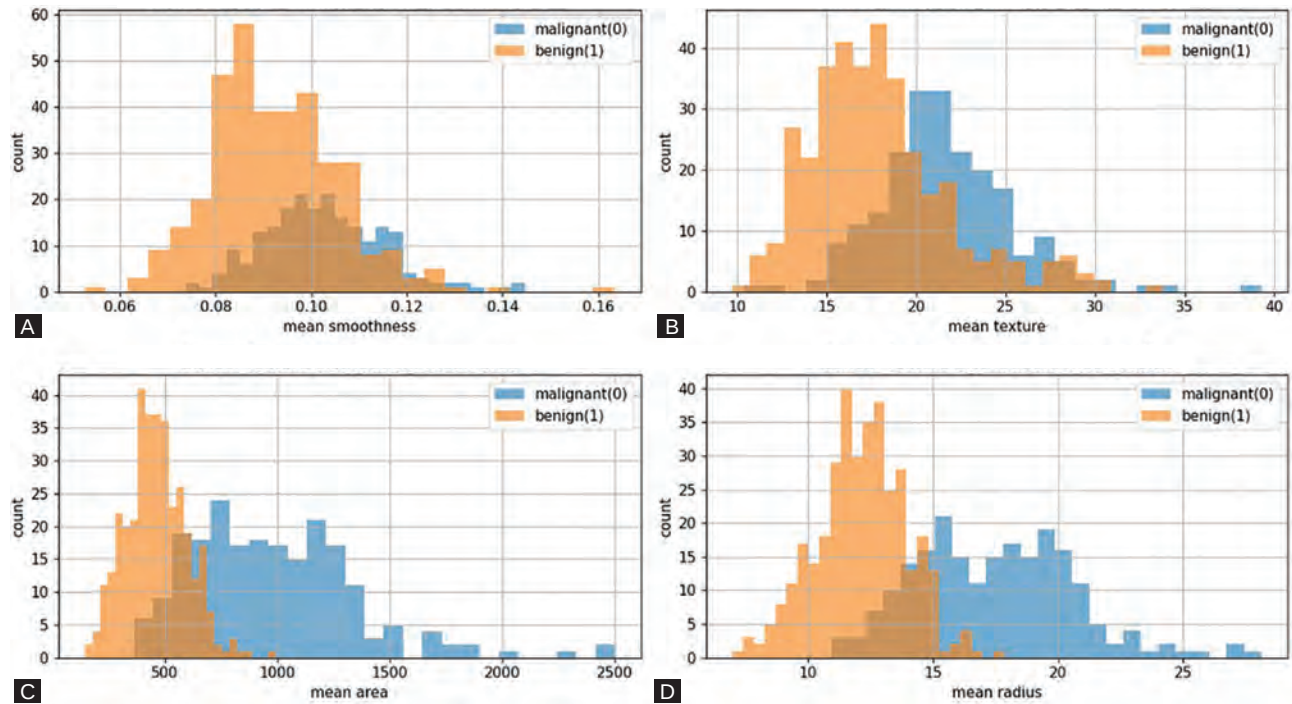
Conflict of interest: None

alone. On the contrary, this paper presents a patient identification technique based on face recognition using a convolutional neural network (CNN), face verification based on a Siamese Network, and patient continuity tracking simulation. This patient continuity tracking demo simulation establishes a futuristic insight to integrate patient diagnostic records along with biometric (face) data for effective patient diagnosis tracking.

The remainder of the paper is organized into multiple sections. The literature review section presents some related research works. The dataset used in this paper is presented in the dataset section. The proposed approach for three defined tasks is presented in the methodology section, followed by results and findings. The conclusive remarks of this paper are presented in the conclusion section, followed by future insights in the recommendations section.

Literature Review

Maanav et al.⁵ utilized a support vector machine (SVM) classifier with the Wisconsin diagnostic breast cancer (WDBC) dataset for



Figs 1A to D: Feature distribution breast cancer Wisconsin (Diagnostic) dataset. (A) Mean smoothness; (B) Mean texture; (C) Mean area; (D) Mean radius

breast cancer classification. Al-Khamees et al.⁶ used a supervised learning approach, specifically the k-nearest neighbors (KNN) algorithm, for the prediction of breast cancer and diabetes. Minnoor and Baths⁷ presented a random forest-based model for breast cancer classification. Jadhav et al.⁸ used deep neural networks with the WDBC dataset for breast cancer classification. Dhanya et al.⁹ proposed an ensemble model for breast cancer prediction using WDBC, Wisconsin, and microRNA datasets. Naji et al.¹⁰ used five algorithms to detect breast cancer by training on the WDBC dataset. Gupta¹¹ worked on predicting the recurrence of breast cancer tumour using ML techniques. This study specifically focused on breast cancer tumour recurrence through a time-based model. Nemade and Fegade¹² performed breast cancer prediction using multiple ML classifiers, namely logistic regression (LR), Naïve Bayes (NB), SVM, KNN, decision tree (DT), and an ensemble method. Naïve Bayes and KNN methods were also used by Amrane et al.¹³ for breast cancer classification. Ashraf et al.¹⁴ addressed missing values to improve breast cancer classification. Another KNN approach for breast cancer prediction was proposed by Pawlovsky and Nagahashi¹⁵ along with a parameter selection strategy.

Dataset

The breast cancer classification model uses the Breast Cancer Wisconsin (diagnostic) dataset, commonly referred to as the WDBC dataset.¹⁶

The dataset includes 569 samples and contains 30 features for breast cancer classification into two classes (malignant, benign).

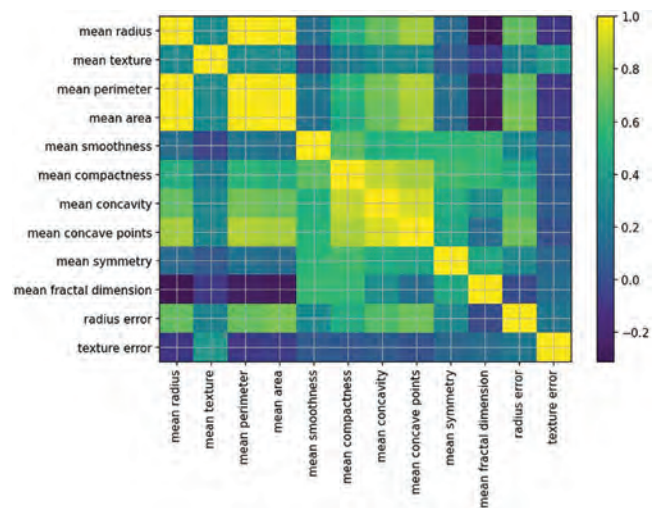


Fig. 2: Correlation heat map: WDBC dataset (first 12 features)

Figure 1 highlights the feature distribution of some features, including mean smoothness, mean texture, mean area, and mean radius.

Figure 2 presents a feature correlation heat map of the first 12 features from the WDBC dataset. The face recognition and face

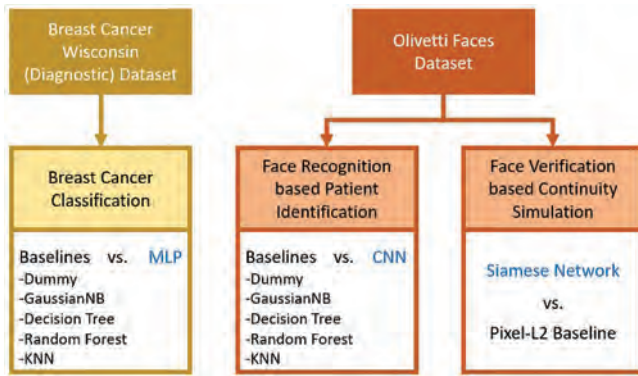


Fig. 3: Proposed approach methodology

verification module uses the Olivetti Faces dataset from AT&T Laboratories Cambridge (available through sklearn), which includes 400 images belonging to 40 classes.

MATERIALS AND METHODS

The study and experimentation with respect to this manuscript was done at the Department of Information Technology, Indira Gandhi Delhi Technical University for Women, New Delhi, India during November 2025. The proposed approach performs the breast cancer classification task on the Breast Cancer Wisconsin (diagnostic) dataset, as shown in Figure 3. The classification includes two classes (malignant = 0, benign = 1), making it a binary classification. The cancer classification was performed on multiple ML algorithms, and the proposed MLP was compared to the baseline algorithms. The baselines include Dummy (predicts the most frequent class), Gaussian features with Naïve Bayes (GaussianNB), DT (with depth = 3), random forest (60 trees), and KNN ($K = 15$ with scaled). Before the classification, the features are scaled so that unscaled features do not harm the optimization (as various features vary in scale). The proposed MLP architecture includes four dense layers, out of which the first three dense layers are activated by ReLU, and the last dense layer is the output layer, activated by sigmoid. The MLP is then trained using binary cross-entropy loss and Adam optimizer with 120 epochs and 32 batch size with early stopping capability. As a result, the training was stopped after 16 epochs, which reduced the model training time. The proposed MLP learned non-linear decision boundaries for the effective breast cancer classification task.

The patient identification task was accomplished by a face recognition model trained on the Olivetti Faces dataset. The classification was performed on the baselines and the proposed CNN from scratch. The internal CNN architecture includes 03 convolutional layers with ReLU activation function, followed by max pooling, a flattening layer, a dense layer activated by ReLU, followed by a dropout layer, and a final output dense layer with SoftMax activation. The proposed CNN was compiled with

Adam optimizer and sparse categorical cross-entropy loss. The hyperparameters involved 120 epochs, $1e-3$ as initial learning rate, $1e-5$ as min learning rate, with patience 10 early stopping, and ReduceLROnPlateau with patience set to 4 and factor set to 0.5. The proposed CNN learned spatial features and performed face recognition for 40 distinctive identities (assumed as patients).

The face verification task is done to maintain patient continuity and keep track of the diagnosis of a patient in a non-redundant way, with unique (face features) and faster verification. The face verification relies on a Siamese network-based model. The faces from the Olivetti Faces dataset are generated into pairs with the same identity representing positive pairs and different identities representing negative pairs. The generated pairs are referred to as Siamese pairs for face verification.

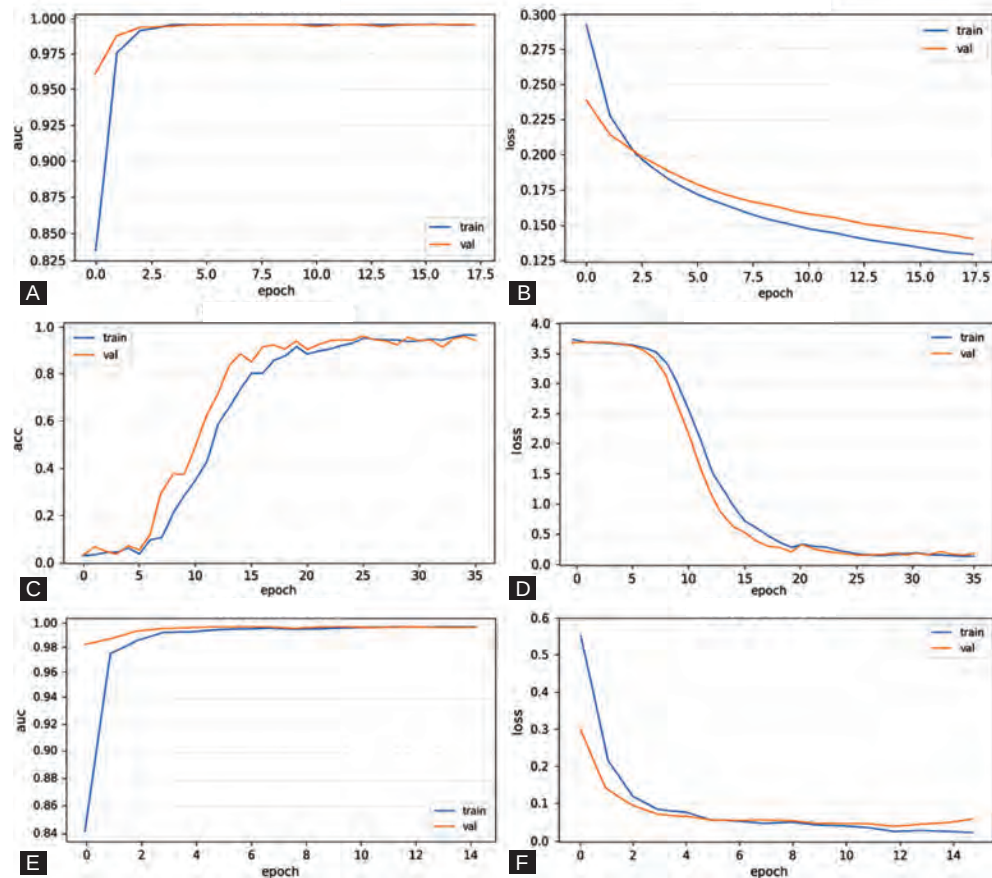
The proposed Siamese network builds an encoder entailing 03 convolutional layers activated by ReLU, followed by max pooling, a flattening layer, a dense layer, and L2 normalization. The CNN extractor outputs a 64-dimensional embedding vector, which is then normalized using L2 normalization to help with distance consistency. The Siamese network then builds a Siamese head to calculate Euclidean distance between embeddings, and then passes these distances through a dense layer and finally with a sigmoid. The verification is then accepted or rejected based on the threshold and Siamese score. The face verification is also performed with the Pixel L2 baseline. In order to generate a patient continuity simulation based on face verification, a synthetic longitudinal demo was considered. For each identity belonging to the Olivetti Faces dataset, one image was stored as a gallery template. A probe image from the TEST set was then considered, and the claimed identity was checked against the enrolled template (gallery) to verify, along with some imposter simulation (wrong identity claim). This simulation proved that face verification can be an ideal way to track patient records, diagnoses, and health scores over time per identity.

FINDINGS AND DISCUSSION

The training graphs representing accuracy and loss over epochs for the MLP breast cancer model, CNN face recognition model, and Siamese face verification model are highlighted in Figure 4. The corresponding confusion matrix heat maps generated for these three models are presented in Figure 5.

The first graph in Figure 6 (top) provides a Siamese similarity score across visits for multiple identities. The second graph in Figure 6 (bottom) presents a continuity acceptance matrix (with 1 = accepted and 0 = rejected). The graphs presented in Figure 7 denote a demo simulation only (not created on a real dataset). This gives a simulation and roadmap to future research that face verification can be integrated with patient records (visits, risks, diagnosis) for continuity tracking.

The proposed MLP-based breast cancer classification model achieved 95.83% accuracy, 97.72% precision, 95.55% recall, and 96.62% $F1$ -score. The comparative quantitative results of the proposed MLP against baselines for breast cancer classification are



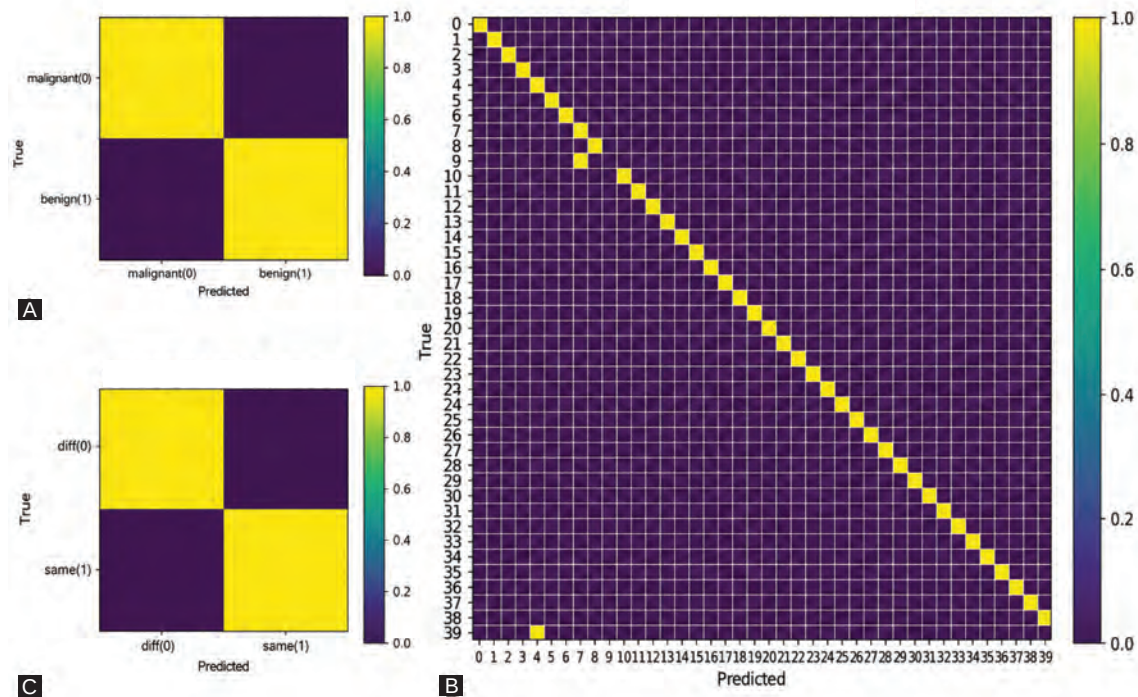
Figs 4A to F: Training graphs (left-right-top-bottom). (A) Siamese accuracy; (B) Siamese loss; (C) Face CNN accuracy; (D) Face CNN loss; (E) Cancer MLP accuracy; (F) Cancer MLP loss

presented in Table 1. The proposed CNN-based face recognition model achieved 96% accuracy, 92.91% precision, 95% recall, and 93.66% *F1*-score. The comparative quantitative results of the proposed CNN against baselines for face recognition are presented in Table 2. The Pixel-L2 baseline model for face verification achieved 80.69% accuracy, 12.81% precision, 90% recall, 22.42% *F1*-score, and 92% AUC. The proposed Siamese network model for face verification achieved 99.57% accuracy, 87.91% precision, 100% recall, 93.56% *F1*-score, 99.94% AUC, and 0.0022 equal error rate (EER). This clearly highlights that our proposed models outperformed the baselines.

The comparative result analysis of the proposed CNN (face recognition task) and the proposed MLP (breast cancer classification task) is presented in Table 3. The results clearly validate the effectiveness of our proposed method towards breast cancer classification, face recognition, and face verification-based simulation-oriented continuity tracking.

CONCLUSION

This paper presents a breast cancer classification approach based on an MLP trained on the breast cancer Wisconsin (diagnostic)



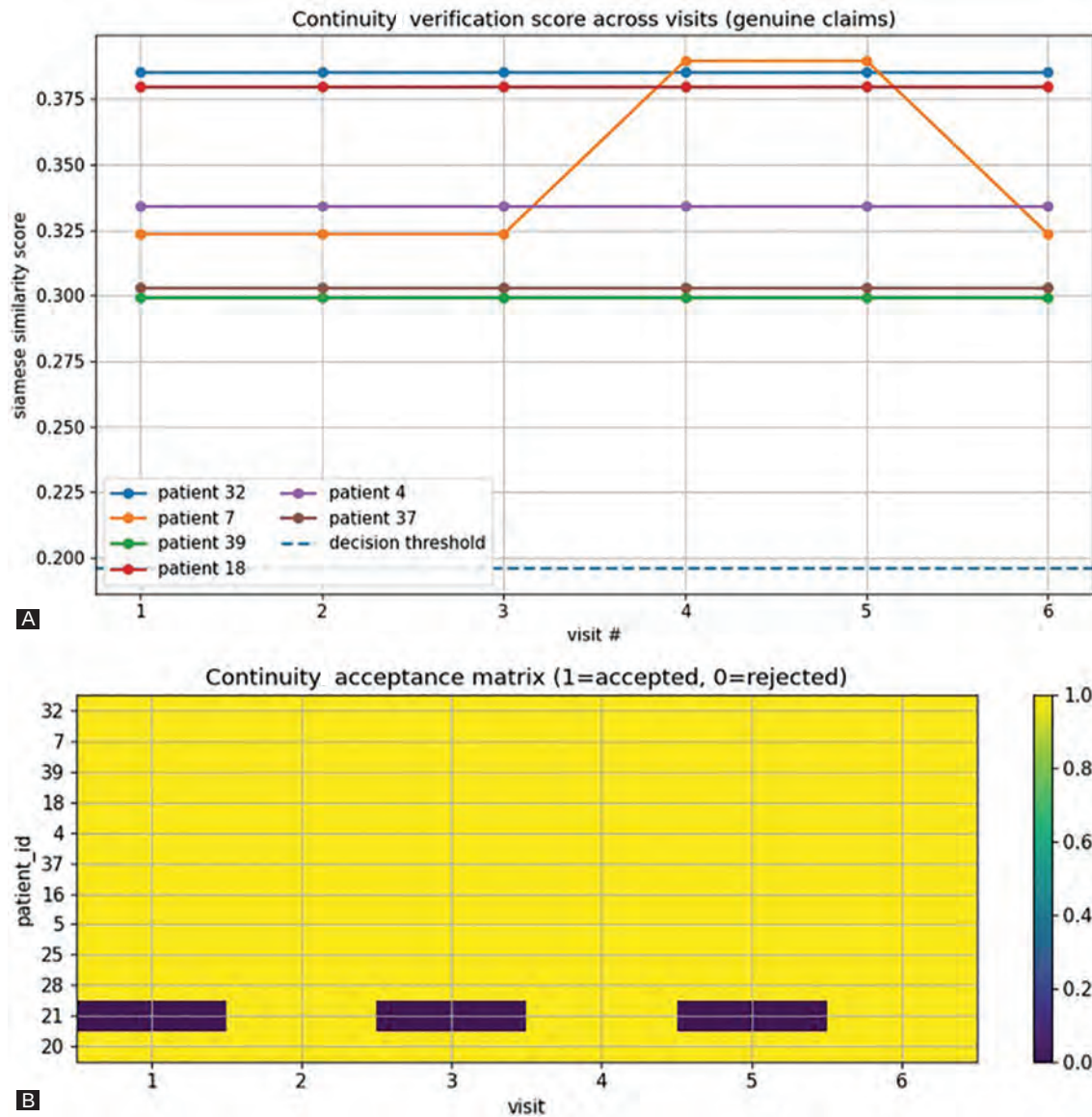
Figs 5A to C: Confusion matrix heat maps. (A) Cancer MLP Normalized; (B) Face CNN Normalized; (C) Siamese verification normalized

dataset. This work also proposes a face recognition-based patient identification insight. The face recognition model relies on a CNN model built from scratch using the Olivetti Faces dataset. The breast cancer classification task and face recognition task were also performed with baselines including dummy (most frequent), GaussianNB, DT, random forest, and KNN. The face verification task was performed to provide a patient continuity simulation. The face verification was achieved using the proposed Siamese Network. The Pixel-L2 baseline was considered for the face verification task. Moreover, several demo simulations were provided to help future works with insight that face verification can be an effective continuity tracking. The proposed MLP gave the best accuracy and precision and the second-best *F1*-score for the breast cancer classification task. The corresponding MLP gave an accuracy of 95.83%, 97.72% precision score, 95.55% recall, and 96.62 *F1* score. The proposed CNN model for the face recognition

task outperformed other baselines by providing an accuracy of 96%, precision of 92.91%, recall of 95%, and *F1* score of 93.66%. The proposed Siamese network for the face verification task gave an outstanding accuracy of 99.57%, *F1* score of 93.56%, and AUC of 99.94%. The results gave promising scores and established an insight for face verification-based continuity tracking and AI-based breast cancer classification.

Recommendations

The face verification based continuity tracking idea was performed as a stimulation demo with synthetic data in this paper. The demo stimulation clearly suggested that any future efforts with breast cancer classification, including medical data and biometric data, can be used for continuity tracking for patient visits, risks, and diagnosis. This effort would require creating a new breast cancer dataset involving facial images of the same patient included in



Figs 6A and B: Top-down. (A) Continuity verification score across visits; (B) Continuity acceptance matrix

the medical dataset. This would provide a real-time opportunity for patient continuity tracking corresponding to breast cancer classification by virtue of face recognition and face verification.

Ethical Statement

No patient data was used in this manuscript.

Data Availability

The data will be made available on request.

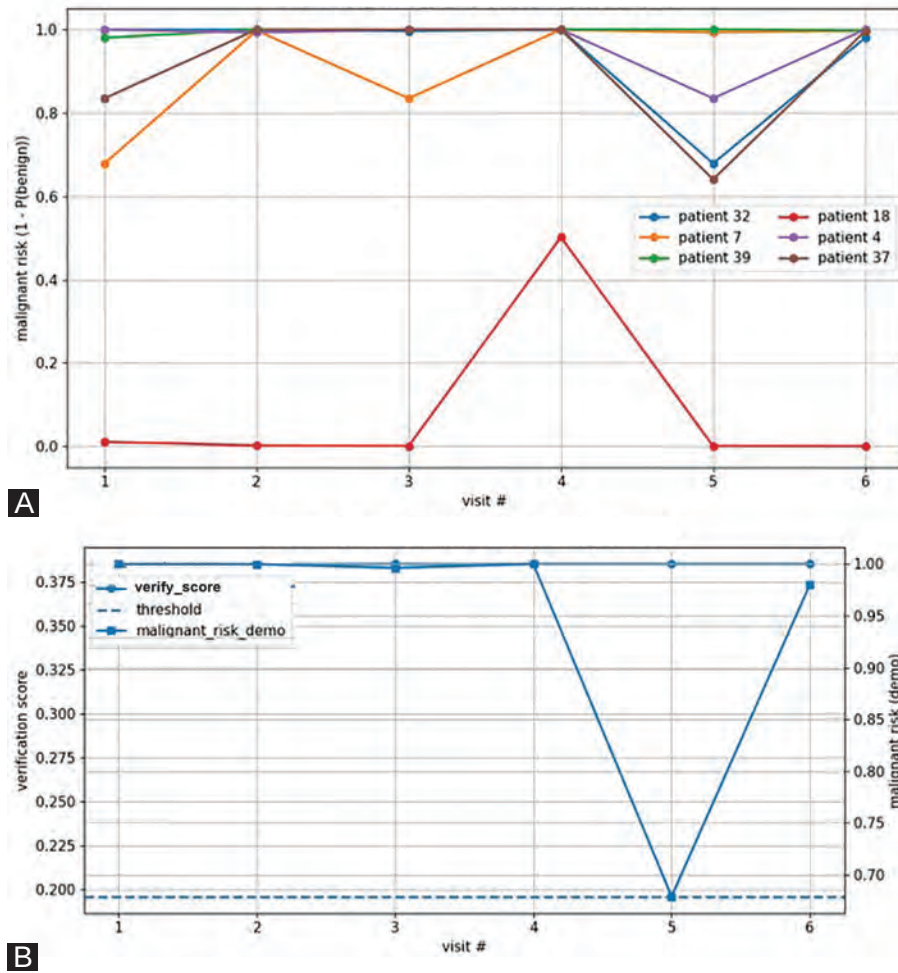
Artificial Intelligence (AI) Disclosure

No AI-assisted technologies were used in preparation of this work or manuscript.

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Figs 7A and B: (Top-down) demo simulation. (A) Continuity of malignant risk across visits; (B) Patient 32 verification, and continuity

Table 1: Breast cancer classification results on WDBC dataset (proposed MLP vs baselines)

Model	Accuracy	Precision	Recall	F1
Dummy (most_freq)	0.625000	0.625000	1.000000	0.769231
GaussianNB	0.930556	0.916667	0.977778	0.946237
DecisionTree ($d = 3$)	0.930556	0.934783	0.955556	0.945055
RandomForest	0.902778	0.913043	0.933333	0.923077
KNN (15)	0.958333	0.937500	1.000000	0.967742
MLP (our_model)	0.958333	0.977273	0.955556	0.966292

Bold represents the best performance

Table 2: Face recognition results on Olivetti faces dataset (proposed CNN vs baselines)

Model	Accuracy	Precision	Recall	F1
Dummy (most_freq)	0.02	0.000500	0.0250	0.000980
GaussianNB	0.88	0.845833	0.8750	0.845000
DecisionTree ($d = 6$)	0.16	0.100676	0.1625	0.114649
RandomForest	0.76	0.712500	0.7750	0.730833
KNN (pixels)	0.80	0.733333	0.8000	0.751667
CNN (our_model)	0.96	0.929167	0.9500	0.936667

Bold represents the best performance

Table 3: Result comparison of proposed method(s) against related works

Task and dataset	References	Performance (in %)
Face recognition (Olivetti dataset)	SSIM et al. ¹⁷	Accuracy: 89.50
	PCA-DWT Ayyad and Khalid ¹⁸	Accuracy: 94.75
	Improved PSO Zhang and Yan ¹⁹ TS3	Accuracy: 91.4286
	Khare et al. ²⁰	Accuracy: 87
	Annamalai et al. ²¹	Accuracy: 93
	Prasad et al. ²²	Accuracy: 91
	Nayak and Indiramma ²³	Accuracy: 83.01
	Proposed CNN (this work)	Accuracy: 96
Breast cancer classification (Breast Cancer Wisconsin diagnostic dataset)	Al-Khamees et al. ⁶	F-score: 92.5
	Dhanya et al. ⁹ SVM WDBC	Accuracy: 95.61
	Maanav et al. ⁵ SVM	F-score: 95.95
	Naji et al. ¹⁰ SVM	F-score: 96
	Proposed MLP (this work)	Accuracy: 95.83, F-score: 96.62

Bold values represent the best performance

AUTHORS' CONTRIBUTIONS

All the authors contributed equally in each phase of this work and manuscript.

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Temporal Analysis of Women's Health Indicators in Jammu Division: A Study Using National Family Health Survey Rounds 4 and 5

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ABSTRACT

This research investigates spatiotemporal variations in women's health and reproductive well-being across the Jammu division, using measures collected from the National Family Health Survey (NFHS-4, 2015–2016, and NFHS-5, 2019–2021), in Jammu division. The 14 measures used to represent variations in demographic and maternal, nutritional, and reproductive health include early marriage, female sterilization, institutional and cesarean deliveries, encephalitis, which were related to skilled professionals, antenatal care (ANC) coverage, unmet need for family planning (spacing and limiting), anemia prevalence, low body mass index (BMI), high blood glucose, and pregnant women suffered from anemia. All indicators were standardized using the Z-statistical method to produce a composite index, which was mapped using GIS to show variations at the district level. Results indicate extensive variation in health outcomes—Kathua, Jammu, and Samba consistently showed high values indicating better infrastructure and better service utilization. Notably Ramban, Reasi, Doda, and Poonch had low values indicating a lack of utilization, infrastructure, and remoteness. Between NFHS-4 and NFHS-5, there had been most improvements for modelled health outcomes for institutional deliveries, cesarean deliveries, and ANC coverage. However, there were high anemia prevalence, low BMI, and unmet need for family planning in numerous districts and locations. The results would support district-specific health planning for health service mitigation and health outcomes, especially in the remoter areas in the region. Continued encouragement of health care outreach, nutrition programs, and reproductive services will be critical to reduce inequalities in health, and meeting the expectations of Sustainable Development Goal (SDG)-3 (Good Health and Wellbeing), and improving socio-economic positions, quality of lives, and ultimately women health and wellbeing.

Keywords: Reproductive wellbeing, Spatial disparities, Women's health, Z-statistical composite index.

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INTRODUCTION

Women's health and reproductive rights are central to sustainable development, population stability, and equity in society, impacting the health not only of individual women but ultimately the health of future generations. Compared to three decades ago, global maternal and reproductive health have improved significantly through increased access to skilled birth attendants, antenatal care (ANC), and contraceptive services; nevertheless, inequality continues to affect women in low- and middle-income countries, especially among rural and marginalized communities.^{1,2} The Sustainable Development Goals (SDGs)—particularly SDG 3 (Good Health and Well-being) and SDG 5 (Gender Equality)—acknowledge the vital link between reproductive health services, prohibiting harmful practices like child marriage, and reducing maternal mortality to fewer than 70 per 1,00,000 live births by 2030.^{3–5} Despite commitments to policies and work plans, many women across the world still experience unmet family planning needs, under nutrition, high rates of anemia, and limited access to safe delivery services, suggesting complex, interrelated social, economic, cultural, and institutional barriers.^{6,7} Evidence from National Family Health Survey (NFHS)-5 showed that 689.56 million women live in India, which has made rhetorical progress to improve maternal and reproductive health indicators, but challenges still remain, especially in states with weak and disorganized health services, difficult terrains, and socio-economically marginalized regions.⁸ The NFHS is the most comprehensive source of data for nationally representative and district level health data that can robustly describe women's health outcomes spatially and temporally in India. Analysis of NFHS-4

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(2015–2016) and NFHS-5 (2019–2021), for example, indicates that India demonstrated promising improvements in institutional deliveries, cesarean sections, and ANC uptake.^{8,9} However, over this same period, anemia rates among women aged 15–49 increased, and indicators of nutritional status such as low body mass index (BMI), remained stagnant. Moreover, female sterilization remained the most common method of contraception.^{10–14}

The Jammu division of the Union Territory of Jammu and Kashmir is an exceptional case for exploring intra-regional disparities in women's health because of the variation in topography, socio-cultural diversity, and extent of the political context. For instance, the plain districts like Jammu, Kathua, and Samba have better connectivity, a higher density of health facilities,

and greater service delivery capacity, while the hilly, remote districts like Ramban, Reasi, Doda, and Poonch have logistical and workforce limits along with limited health service utilization.^{15–17} Structural inequities are compounded by socio-cultural drivers of women's health, such as early marriage, lack of reproductive autonomy, and gender norms that affect health-seeking behavior.

When there is early marriage, which is still widespread in many rural, impoverished districts, the rate of early pregnancy, maternal morbidity, and poorly delivered neonatal outcomes significantly increase.^{18,19} Early marriage commonly truncates education attainment and opportunities for employment further entrenching impoverished and poor health outcomes.²⁰ In addition to early marriage, high reliance on female sterilization as a single contraceptive mode of action in many parts of India, including parts of Jammu division, is not only an iconic representation of the success of sterilization programming but also suggests that modern reversible contraceptives have not proliferated.^{21–24} While sterilization provides long-term protection, single method reliance can, limit the range of options and flexibility for reproductive health.

Institutional deliveries—seen as a pillar of safe motherhood—have risen sharply across India, aided by policy initiatives such as the Janani Suraksha Yojana (JSY) and Janani Shishu Suraksha Karyakram (JSSK).^{25–30} However, inequalities still exist across regions, with remote districts in Jammu division reporting lower uptake of institutional deliveries. This has been attributed by some key informants to a lack of transport, weather-related disruptions, and cultural preferences for home births.³¹ Cesarean deliveries, when medically indicated, could avert maternal and neonatal deaths, but their irregularity, with high rates in urban centers and low rates in the remotes, suggests opportunities for over-medicalization in some rural settings and unmet surgical need in others.^{32,33}

Home delivery with trained professionals is not completely absent from Indian maternal health policy; it is a safer alternative to having a home birth alone. However, home delivery with trained personnel is not a common practice in the country. Home delivery has been in practice for some time in remote locations of Jammu division where people have no access to institutional care and are not able to trust institutional care.^{1,34,35} There is an increased use of ANC in the country, but not everyone initiates ANC early, with a consistent finding of limited use of the recommended four or more visits, especially in hill and underserved areas.^{36–40}

The unmet need for family planning as a process and as a method of family planning (spacing and limiting) has reached epidemic proportions and is a continuing challenge that hampers maternal and children's health, economic security, and gender empowerment.^{7,41} There are many factors contributing to unmet need, including lack of understanding, lack of choice of methods, fear of side effects, and lack of outreach of services to women in rural settings. Additionally, nutritional deficiencies are a counter-uphill battle in relation to reproductive health. Anemia in young girls aged 15–19 negatively impacts their current health and education and is likely to harm their health if they become pregnant in the future especially if they are anemic.¹¹ Anemia in women aged 15–49 years contributes to maternal mortality, low birth weight, and productivity.¹⁰

A low BMI in women is indicative of chronic under-nutrition, which has implications for reproductive outcomes and work capacity.⁴² At the same time, high blood glucose levels, including gestational diabetes in women, are increasingly common, as are the burden of non-communicable diseases and maternal

health.^{43,44} The risk of complications (e.g., preterm birth, stillbirth, and postpartum hemorrhage) is particularly high among pregnant women with anemia, providing a sensitive indicator of ANC.^{45,46}

Given that multiple indicators require certain shifts in thinking, a composite index is appropriate when wanting to analyze and summarize multi-dimensional data into a concise, single measure. Composite indices that are constructed using Z-statistical standardization are very robust methodologies for measuring variables that use different units of measurement, and provide the ability to compare directly differences in geographic locations.⁴⁷ In the context of Jammu division, it will allow for the identification of districts that performed well overall and those that need targeted interventions. The added use of Geographic Information System techniques can assist in visualizing inequalities on a spatial scale, thereby empowering policymakers to tailor approach strategies dealing with targeted geography.⁴⁸

While there has been progress in both policies and programs, no holistic, district-level, multi-indicator analysis of women's health in Jammu division using the most recent NFHS has been undertaken. This study will use a Z-statistical composite index approach to create a composite index of 14 indicators, including early marriage, female sterilization, institutional deliveries, cesarean deliveries, skilled home deliveries, ANC coverage, unmet need for family planning (spacing and limiting), prevalence of anemia in women aged 15–19 and 15–49, low BMI, high blood sugar, and prevalence of anemia in pregnant women, to show the disparity within the Jammu division at two time points (NFHS-4 and NFHS-5). The benefit of this study is to be both academically relevant to the understanding of regional health inequalities and, provide useable information for district planning and resource identification and allocation, as well as program prioritization. Reducing intra-region variation, and disparate women's health outcomes is an important step toward achieving the SDG targets, improving quality of life, and overall equitable socio-economic development in Jammu division and similar contexts around the world.

STUDY AREA

The present study focuses on Jammu division, which is one of the two administrative divisions of the Union Territory of Jammu and Kashmir, India. The Jammu region is geographically located between 32°17'N to 34°12'N latitude and 74°26'E to 76°58'E longitude.⁴⁹ Jammu division encompasses a diverse range of physiographic zones, including the fertile plains in the south and rugged, mountainous terrain in the north. The Jammu division include 10 districts—Jammu, Samba, Kathua, Udhampur, Reasi, Rajouri, Poonch, Doda, Ramban, and Kishtwar; each of the districts include distinct socio-economic, cultural, and demographic factors. The climate of the Jammu division ranges from sub-tropical to temperate and alpine conditions with increasing altitude, which influences agricultural practices, livelihoods, and the ease of access to health services. In addition to the varied climate, Jammu division has physical diversity as well, with urban centers, such as Jammu city, situated in the low-lying plains, whereas remote, mountainous areas, such as Ramban, Reasi, and Doda, are not as well served in terms of infrastructure, transportation, and access to health services. These spatial inequalities have direct consequences for women's health and reproductive health. For all these reasons, Jammu division presents an appropriate case selection for assessing current disparities at the district level. In addition, the study area is also strategically located in an area that borders and engages with



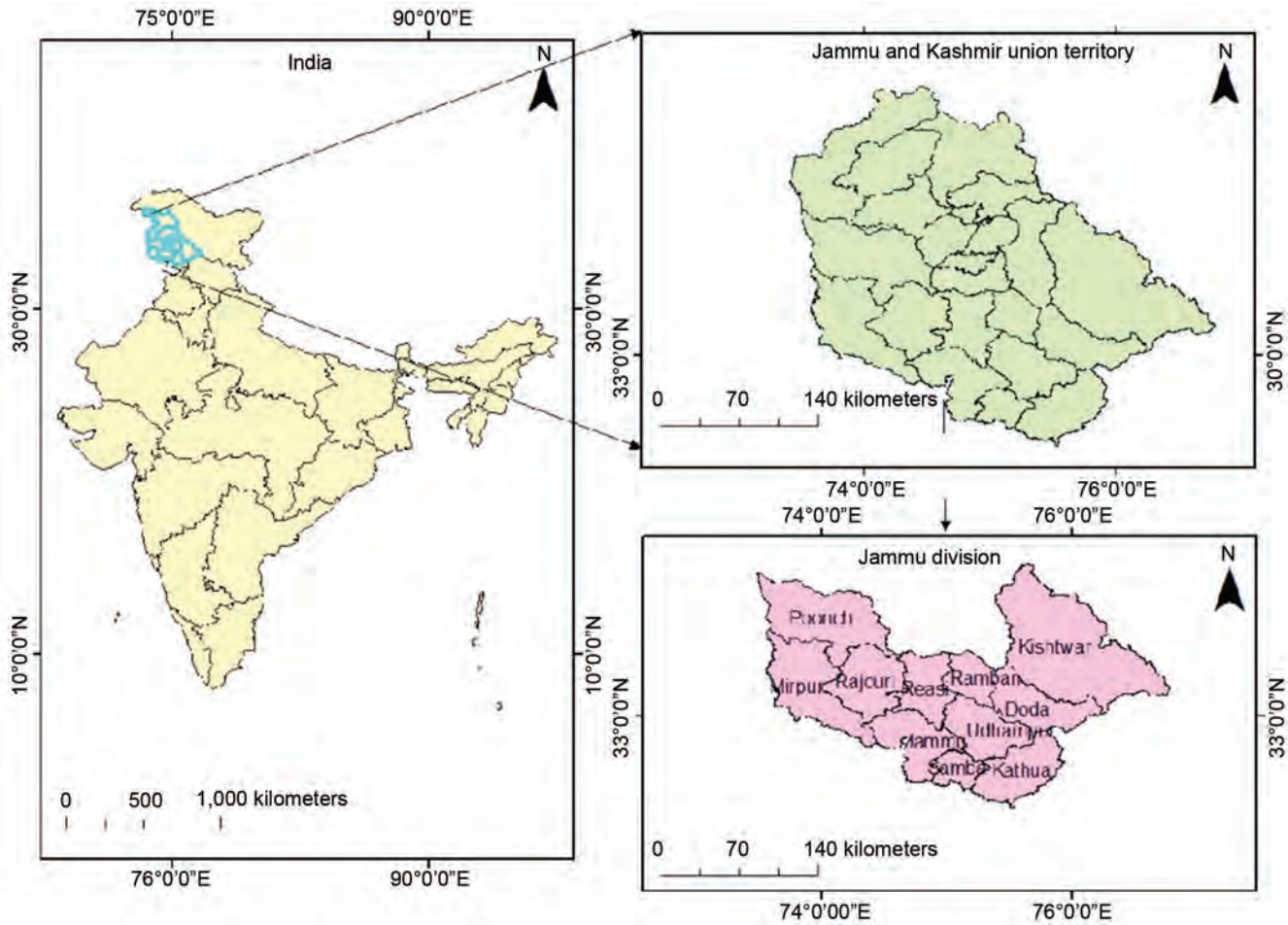


Fig. 1: Study area

multi-ethnic groups, and the educational attainment in the study area includes a varying range of literacy levels, which is an added complexity in assessing patterns of health service utilization. At this level, the study considers the 14 indicators from NFHS and will also provide valuable evidence that may be useful for health resource allocation.

DATABASE AND METHODOLOGY

The present study relies exclusively on secondary data obtained from the NFHS rounds 4 (2015–2016) and 5 (2019–2021), conducted by the Ministry of Health and Family Welfare (MoHFW), Government of India. The NFHS is India's largest household health survey, designed to provide high-quality, nationally and state-representative estimates on population health, nutrition, and socio-economic indicators, with a robust sampling framework that ensures comparability across time and space. District-level fact sheets for all ten districts of the Jammu division were extracted to collate data on 14 selected indicators (Fig. 1). These indicators are as:

To enable comparison across indicators with different measurement units, all selected variables were standardized using the Z-statistical method (Table 1). This approach transforms each indicator into a unit less scale, allowing their aggregation into a composite index for inter-district analysis. Composite score is calculated as:

Calculation of Q (Standard Normal Deviate)

For positive indicators:

$$Q_i = (Y_i - M)/S$$

Where, Y_i is the observed value of variable, M is the mean of the respective column, and S is the standard deviation of the respective column.

For negative indicators:

$$Q_i = (M - Y_i)/S$$

Where, M is the mean of the respective column, Y_i is the observed value of variable, and S is the standard deviation of respective column.

Calculation of C (Final Composite Score)

To calculate the value of C all the value of standard normal deviate for a particular district are summed up as

$$C = \sum_{i=1}^n Q_i$$

As the data sets here comprise of different years so to make the same map class interval is not possible in order to keep it simple the intervals of maps are calculated as:

Table 1: Indicators used in study

S. No.	Indicators	Remarks
1.	Marriage of women before 18 years	Negative
2.	Female sterilization	Positive
3.	Institutional deliveries	Positive
4.	Deliveries by cesarean	Negative
5.	Home deliveries by skilled personnel	Negative
6.	Currently married women with unmet need of family planning	Negative
7.	Unmet need of spacing	Negative
8.	Antenatal care visit in first trimester	Positive
9.	Anemia (age 15–19)	Negative
10.	Low BMI (age 15–49)	Negative
11.	Anemia (age 15–49)	Negative
12.	Blood sugar (age 15 above)	Negative
13.	Pregnant anemic women	Negative
14.	Women who are overweight	Negative

$$C.I. = (V_{\max} - V_{\min})/5$$

Where C.I. is the class interval, $V_{\max}$ is the highest value of indicator observed, and $V_{\min}$ is the lowest value of indicator observed.

Calculated value is divided by 5 because there are five classes in the map, it is important to mention that are value are calculated with the near whole number. To examine the interrelationships among the selected indicators, a correlation matrix was constructed using the standardized quotient (Z-score) values. The analysis was carried out in RStudio with Pearson's correlation, which enabled computation of pair wise correlation coefficients. Correlation was not applied directly on the raw values due to their large deviations and scale differences; instead, standardized values were used to ensure comparability. This step helped in identifying the strength and direction of associations between variables and in checking multicollinearity (Table 2).

RESULTS

To keep things simple here individual indicators values are not described. As described earlier Z-statistical method is applied to

Table 2: Calculation of composite score

	Jammu	Doda	Poonch	Reasi	Ramban	Kishtwar	Samba	Kathua	Rajouri	Udhampur
NFHS-4 (2015–2016)										
Q1	1.18	-0.93	-0.5	-0.41	0.53	-0.6	1.02	1.16	-1.79	0.34
Q2	0.62	-1.08	0.09	0.58	-1.08	-0.06	-0.94	1.43	-0.99	1.42
Q3	1.2	-1.72	0.36	-0.82	-0.95	-0.68	0.79	1.21	0.05	0.57
Q4	-1.4	1.32	-0.8	0.41	1.4	0.77	-1.25	-0.3	-0.45	0.31
Q5	1.14	-2.57	0.3	0.06	-0.22	0.11	0.95	0.15	-0.08	0.15
Q6	0.69	-1.5	0.46	0.13	-0.72	0.15	-0.91	1.14	-0.99	1.56
Q7	1.09	-0.62	-0.62	-0.89	-0.51	-0.96	0.13	1.46	-0.68	1.6
Q8	1.31	-1.82	0.29	-0.91	-0.31	-0.18	0.39	1.18	-0.81	0.86
Q9	0.83	1.03	0.64	-1.38	0.13	-1.38	1.06	0.27	0.14	-1.34
Q10	0.65	0.42	0.55	0.83	0.37	1.19	-0.49	-0.17	-1.67	-1.67
Q11	0.81	0.82	0.93	-0.33	-0.41	-1.66	0.65	0.33	0.57	-1.71
Q12	-2	0.54	0.43	0.49	0.84	0.9	-1.64	-0.11	0.31	0.25
Q13	0.42	0.68	1.44	0.96	-0.98	-0.91	0.34	0.31	-0.49	-1.78
Q14	-1.87	0.52	0.21	0.81	0.64	1.08	-1.66	-0.25	0.22	0.31
C	4.67	-4.91	3.78	-0.47	-1.27	-2.23	-1.56	7.81	-6.66	0.87
NFHS-5 (2019–2021)										
Q1	0.54	-1.27	0.51	-0.82	0.47	-0.06	0.22	1.77	-1.65	0.28
Q2	-0.49	-0.1	-1.47	-0.21	-0.88	0.33	-0.31	2.21	0.11	0.82
Q3	1.01	-1.3	-0.09	-1.8	-0.69	0.51	1.11	1.01	0.21	0.01
Q4	-1.57	1.27	-0.09	0.85	1.57	-0.5	-0.88	0.03	0.14	-0.82
Q5	1.08	0.74	-1.24	-0.12	-2.08	0.18	0.88	0.69	-0.35	0.21
Q6	0.44	0.18	-0.45	0.02	-1.44	-1.07	-1.02	1.74	0.96	0.65
Q7	1.2	-1.09	-1.52	-0.11	-0.11	-0.65	-0.22	0.43	0.22	1.85
Q8	2.31	0.56	-0.9	-0.17	0.13	-0.95	0.64	-0.22	-0.4	-1
Q9	0.4	0.14	0.08	0.06	-0.22	-2.69	0.28	0.5	0.47	1
Q10	0.61	-0.01	-1.4	0.53	-2.02	-0.09	1.08	-0.24	0.77	0.77
Q11	0.75	0.22	1.15	0.35	-0.71	1.22	-0.05	-2.05	0.02	-0.91
Q12	0.75	0.22	1.15	0.35	-0.71	1.22	-0.05	-2.05	0.02	-0.91
Q13	-0.05	-0.6	1.48	0.08	0.47	-2.19	-0.05	1.16	-0.06	-0.31
Q14	1.26	-0.44	1.34	0.58	1.39	0.32	-1.05	-1.25	0.58	-0.2
C	5.72	-1.48	-1.45	-0.41	-4.83	-4.42	0.63	3.73	1.04	1.44

The bold values in Table 2 indicate extreme Z-scores. Positive bold values (+) → Much better than average performance. Negative bold values (–) → Much worse than average performance

Source: Calculated by Author



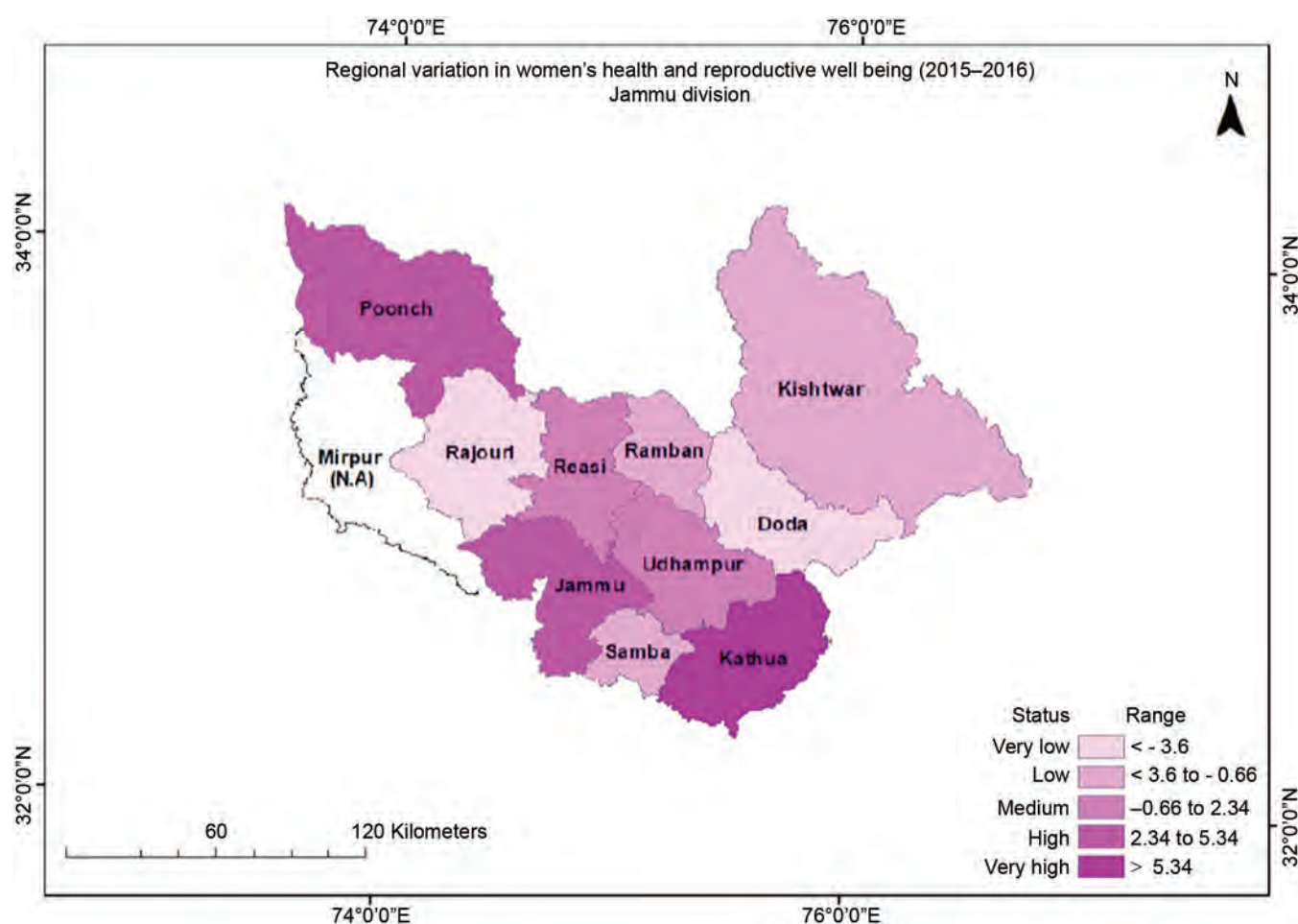


Fig. 2: Regional variation in women's health and reproductive well-being (2015–2016) Jammu division

calculate the composite score, calculation for different indicators based on NFHS-4 and NFHS-5 as:

Q1 is the simple quotient according to marriage of women before 18 years, Q2 is the simple quotient according to female sterilization, Q3 is the simple quotient according to institutional deliveries, Q4 is the simple quotient according to deliveries by cesarean, Q5 is the simple quotient according to home deliveries by skilled personnel, Q6 is the simple quotient according to currently married women with unmet need of family planning, Q7 is the simple quotient according to unmet need of spacing, Q8 is the simple quotient according to anti-natal care visit in first trimester, Q9 is the simple quotient according to anemia among women aged 15–19 years, Q10 is the simple quotient according to low BMI among women aged 15–49 years, Q11 is the simple quotient according to anemia among women aged 15–49 years, Q12 is the simple quotient according to blood sugar among women aged 15 years and above, Q13 is the simple quotient according to pregnant anemic women, and Q14 is the simple quotient according to women who are overweight.

Finally, *C* is the composite index derived from these 14 indicators using the Z-statistical method.

Interpretation of Regional Variation in Women's Health and Reproductive Well-being (NFHS-4, 2015–2016)—Jammu Division

The composite index map of women's health and reproductive well-being for NFHS-4 (2015–2016) in Jammu division reveals sharp

intra-regional disparities, underscoring the divide between the urbanized plains and the mountainous districts in terms of socio-economic conditions, infrastructure, and access to healthcare services (Fig. 2).

Very High Status

Kathua (7.81) and Jammu (4.67) emerge as the best-performing districts, reflecting stronger health infrastructure, higher female literacy, urbanization, and better socio-economic conditions. These districts report higher rates of institutional deliveries, improved ANC coverage, lower unmet need for family planning, and greater adoption of modern contraceptive methods. Jammu benefits from its urban health facilities, while Kathua's proximity to Punjab connectivity and service utilization.

High Status

Poonch (3.78) records moderate achievements despite its border location and geographical challenges. Improvements in female literacy and maternal health indicators suggest that state and central interventions in border areas have yielded results, though accessibility remains a constraint.

Medium Status

Udhampur (0.87) reflects an intermediate position, with progress in institutional deliveries and ANC but setbacks in rural female literacy, early marriage, and unmet need for family planning.

Its mixed geography (plains and hills) translates into uneven health outcomes.

Low Status

Reasi (−0.47) and Ramban (−1.27) fall in the low category due to poor female literacy, high prevalence of anemia and low BMI, delayed ANC, and early marriages. Being mountainous, both districts suffer from weak accessibility and limited adoption of spacing methods in family planning.

Very Low Status

Doda (−4.91), Rajouri (−6.66), and Kishtwar (−2.23) perform the worst, characterized by very low female literacy, high unmet need for family planning, widespread anemia, and weak health infrastructure. Doda and Kishtwar face geographical remoteness, while Rajouri's high population density and socio-cultural constraints further restrict maternal healthcare utilization.

Overall, the NFHS-4 analysis highlights a clear divide between urban-plains districts (Jammu, Kathua, Samba), which fare better, and remote mountainous districts (Ramban, Reasi, Rajouri, Doda, Kishtwar), which lag behind. The findings emphasize the critical role of geography, socio-economic development, education, and infrastructure in shaping women's health and reproductive well-being in Jammu division.

Relationship among Selected Indicators for NFHS-4

Correlation matrices are widely used in social and health research to examine the strength and direction of relationships between different variables, helping to identify patterns that may not be visible through individual indicators alone. The correlation matrix of NFHS-4 indicators provides a multi-dimensional picture of how social, demographic, and health factors affecting women in India are interconnected.

The correlation matrix of NFHS-4 indicators provides a multi-dimensional picture of how social, demographic, and health factors affecting women in India are interconnected. Looking at the association between early marriage and other indicators, it is evident that marriage before the age of 18 years (Q1) is linked with higher prevalence of sterilization (Q2) as well as greater unmet need for family planning (Q6). This indicates that in regions where child marriage is common, women tend to rely on sterilization later as a fertility control method while simultaneously facing gaps in contraceptive access during their reproductive years. Such patterns also connect to unmet need of spacing (Q7), reinforcing the idea that women who marry at a young age have less autonomy over their reproductive decisions, leading to challenges in planning the timing and number of children. These linkages highlight the persistent influence of social factors, particularly child marriage, on women's reproductive health outcomes (Fig. 3).

The maternal and child health indicators also reveal important relationships. Institutional deliveries (Q3) are negatively correlated with early marriage and positively associated with ANC visits in the first trimester (Q8). This shows that regions with stronger maternal health systems, where women access ANC services early, are also those where institutional deliveries are more common, contributing to safer childbirth. On the other hand, the negative relationship between institutional deliveries and home deliveries by skilled personnel (Q5) suggests a substitution effect, where reliance on trained attendants at home is higher when hospital-based delivery is lower. Deliveries by cesarean section (Q4) are strongly

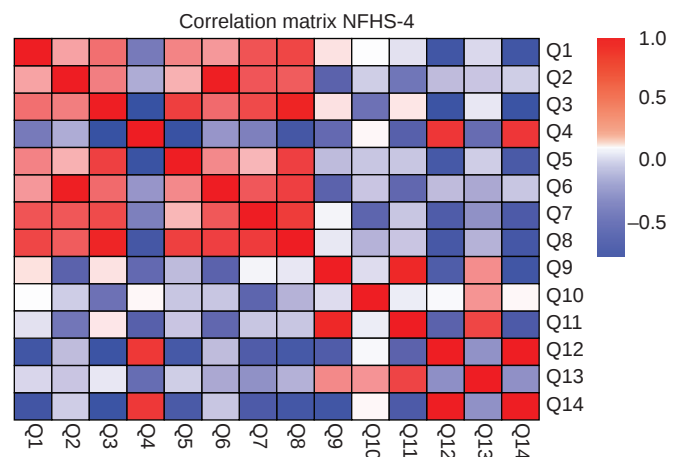


Fig. 3: Correlation matrix for NFHS-4 indicators

associated with institutional deliveries, which is consistent with medical practice since cesareans can only take place in facilities. Taken together, these associations point to the uneven distribution of healthcare access across regions, where women's social circumstances, such as early marriage, directly affect their ability to benefit from modern health services.

Nutritional and health indicators present another critical set of patterns. Anemia among adolescent girls (Q9) and among women aged 15–49 (Q11) are strongly correlated, reflecting the high and widespread prevalence of anemia across all age groups of women. Pregnant women with anemia (Q13) also show a strong association with these indicators, suggesting that poor nutritional status is not adequately addressed during pregnancy and continues to affect maternal health. This persistence of anemia across age and reproductive stages reflects deep-rooted nutritional challenges. Meanwhile, body mass indicators show the coexistence of under-nutrition and over-nutrition. Women with low BMI (Q10) are negatively associated with women who are overweight (Q14), which is expected since these represent opposite nutritional conditions. However, what is striking is the strong positive association between overweight women and elevated blood sugar levels (Q12), illustrating the increasing burden of lifestyle-related diseases such as diabetes. These trends underline the “double burden of malnutrition,” where under-nutrition in the form of anemia and low BMI exists alongside rising overweight and metabolic disorders in the same population.

The broader interpretation of this correlation matrix is that women's health is shaped by an interwoven set of social, reproductive, and nutritional factors that cannot be viewed in isolation. The persistence of child marriage has cascading effects: it is tied not only to fertility outcomes such as sterilization and unmet need for contraception but also indirectly to maternal health care utilization, since early marriage is often associated with lower educational attainment and reduced healthcare access. Similarly, maternal healthcare indicators reinforce each other, showing that women who enter the health system early during pregnancy are more likely to continue accessing institutional delivery and advanced care when required. On the nutritional front, the correlations reveal a dual challenge. On one hand, anemia and low BMI remain widespread, reflecting poverty, food insecurity, and gender-based nutritional disadvantage. On the other, the

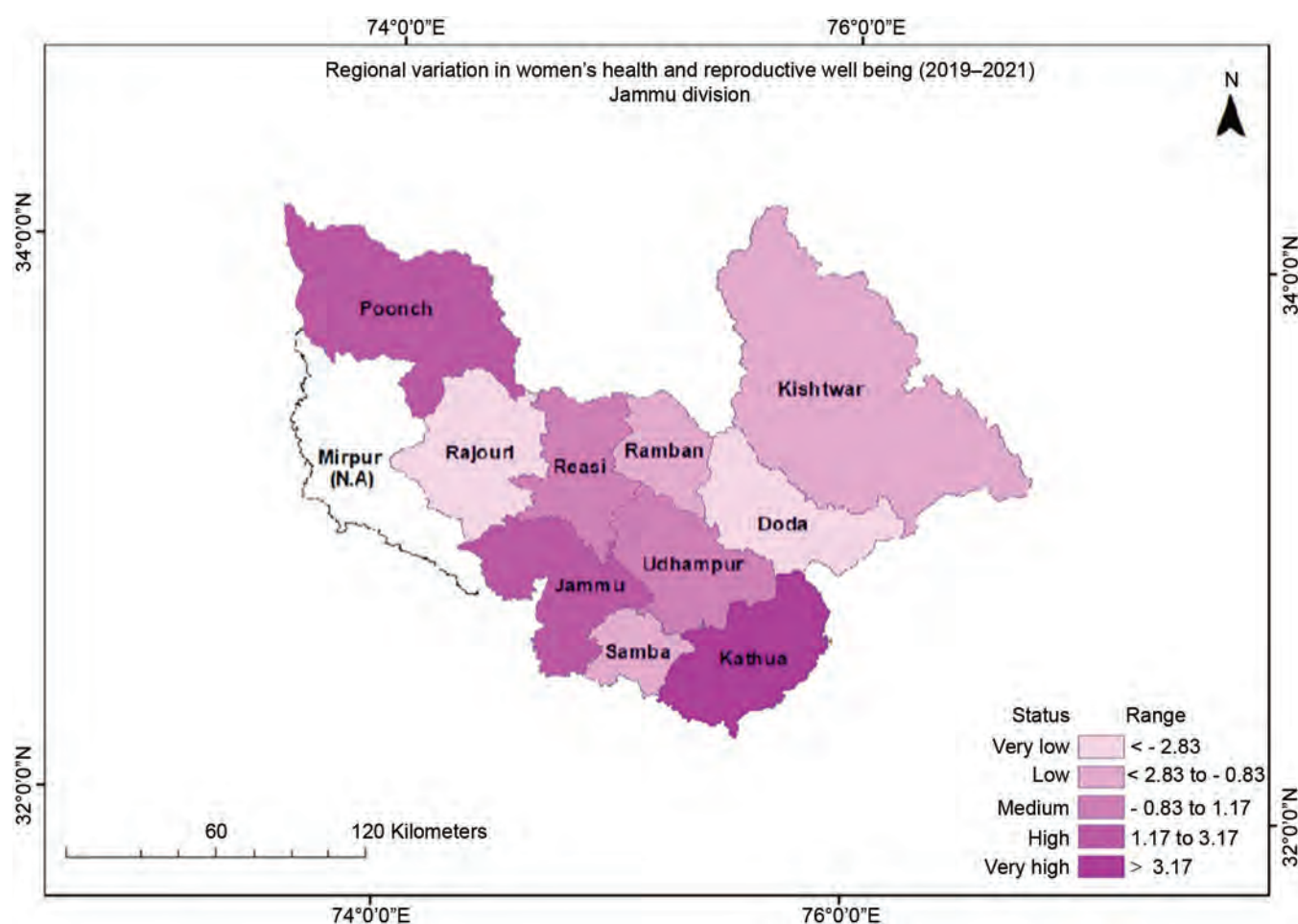


Fig. 4: Regional variation in women's health and reproductive well-being (2019–2021) Jammu division

rising burden of overweight and related conditions such as high blood sugar signals the epidemiological transition in India, where urbanization and lifestyle changes bring new health risks.

In conclusion, the NFHS-4 correlation matrix reveals that women's health in India is influenced by both traditional concerns such as child marriage, reproductive control, and anemia, as well as emerging risks like obesity and non-communicable diseases. The associations suggest that policies must adopt a holistic approach, simultaneously addressing the social determinants of health, ensuring access to family planning and maternal health services, and combating both under-nutrition and over-nutrition. Without integrated action, improvements in one domain may be undermined by persistent weaknesses in another. The findings clearly show that women's health challenges are interconnected, and effective policy responses must therefore be equally comprehensive, targeting reproductive health, nutrition, and chronic disease prevention together.

Interpretation of Regional Variation in Women's Health and Reproductive Well-being (NFHS-5, 2019–2021)—Jammu Division

The composite index map of women's health and reproductive well-being for NFHS-5 (2019–2021) presents an updated picture of progress and continuing disparities in Jammu division. While some districts recorded improvements compared to NFHS-4, a persistent

rural–urban divide and terrain-related challenges continue to influence outcomes (Fig. 4).

Very High Status

Jammu (5.72) and Kathua (3.73) again top the chart, consolidating their position as the best-performing districts. These districts enjoy high levels of institutional deliveries, ANC in the first trimester, and high levels of female literacy. They also report lower levels of unmet need for family planning and improved nutritional status of women (e.g., reduced prevalence of low BMI). Being urban and semi-urban, these districts benefit from higher awareness levels, better access to health services, and continuous implementation of schemes such as JSY and JSSK. The higher presence of private healthcare facilities also supplements public service delivery.

High Status

Districts like Rajouri (1.04) and Udhampur (1.44) showed marked improvements from NFHS-4 to NFHS-5, moving into the high and medium status categories. This shift can be attributed to increased coverage of institutional deliveries, rising literacy among women, and improved ANC utilization. Rajouri's improvement is particularly significant, as it had previously fallen in the very low category, suggesting the impact of targeted interventions. Udhampur, benefitting from better road connectivity and semi-urbanized population centers, shows steady progress in maternal health care and service utilization.

Medium Status

Samba (0.63) reflects a moderate level of achievement. Despite being geographically closer to Jammu, Samba did not show as strong an improvement as its neighboring districts. This may be due to persistent nutritional challenges, high rely on sterilization for family planning, and moderate levels of unmet need. Similarly, Reasi (−0.41) lies in the lower-medium category, reflecting improvements in institutional deliveries and anti-natal care coverage but continuing weaknesses in literacy levels and nutritional indicators such as anemia.

Low Status

Poonch (−1.45) reflects stagnation in several indicators. Despite improvements in anti-natal care coverage, the district lags behind in literacy, unmet need for family planning, and nutritional indicators, which continue to depress its composite score. Border location, remoteness, and socio-economic vulnerabilities contribute to its low perform anti-natal care.

Very Low Status

Ramban (−4.83) and Kishtwar (−4.42) remain at the bottom of the ranking, along with Doda (−1.48). These districts are marked by poor infrastructural facilities, weak accessibility, and a high burden of nutritional deficiencies such as anemia and low BMI. Ramban, in particular, has the highest prevalence of home deliveries by skilled personnel, reflecting weak trust in institutional facilities. Kishtwar faces the compounded disadvantages of terrain, low literacy, and poor socio-economic conditions. Despite national and state-level schemes, the penetration of health services remains limited in these areas.

Overall, NFHS-5 indicates progress in institutional delivery, ANC coverage, and improved contraceptive use, particularly in Jammu, Kathua, Rajouri, and Udhampur. However, nutritional challenges such as anemia and low BMI persist across the division, while remoteness and terrain continue to depress the scores of mountainous districts. The map thus underlines the dual reality: while urban and semi-urban districts are improving steadily, hilly and remote districts remain marginalized, requiring sustained interventions in literacy, nutrition, and health infrastructure to reduce inequalities.

Relationship among Selected Indicators for NFHS-5

Same method is used to calculate the correlation among selected indicators of NFHS-5 as used earlier.

The correlation matrix from NFHS-5 (2019–2021) presents a complex picture of women's health and social conditions in India, reflecting both enduring challenges such as child marriage and anemia, and new concerns such as overweight and non-communicable diseases. Compared with NFHS-4, the NFHS-5 results reveal areas of improvement, persistence, and change, making it a critical resource for understanding the shifting health landscape (Fig. 5).

The first set of associations concerns early marriage and fertility-related behaviors. Marriage before 18 years (Q1) continues to be positively correlated with female sterilization (Q2) and unmet need for family planning (Q6). This suggests that in states or regions where early marriage is common, sterilization remains the dominant method of fertility limitation, often adopted after childbearing is largely complete. At the same time, these areas are characterized by gaps in access to temporary contraceptive methods, reflected

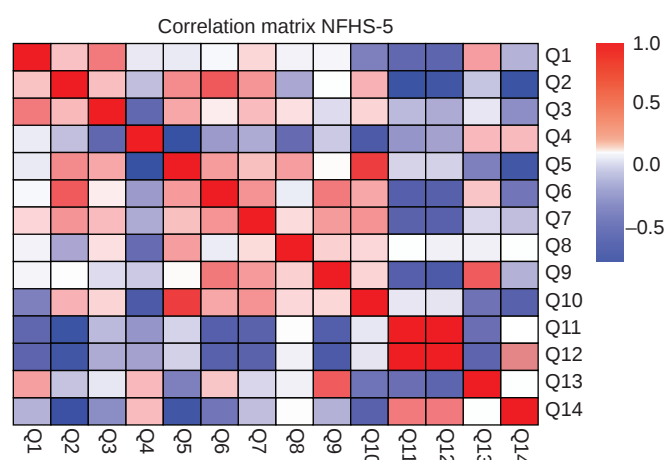


Fig. 5: Correlation matrix for NFHS-5 indicators

in the higher unmet need for family planning. Q1 also shows a relationship with unmet need of spacing (Q7), reinforcing that women who marry young have limited ability to plan and space births. Interestingly, the negative correlation of Q1 with institutional deliveries (Q3) and ANC visits in the first trimester (Q8) is still visible but somewhat weaker than in NFHS-4. This indicates that even in contexts where early marriage persists, there have been improvements in maternal health service utilization, likely due to stronger policy interventions promoting hospital births and ANC.

Maternal health indicators display the expected reinforcing relationships. Institutional deliveries (Q3) are positively correlated with deliveries by cesarean section (Q4) and ANC in the first trimester (Q8). These associations are logical, since institutional settings provide both surgical delivery options and encourage early maternal health visits. Conversely, institutional deliveries are negatively correlated with home deliveries by skilled personnel (Q5), demonstrating a substitution effect: as more women shift to hospitals, reliance on community-based delivery declines. Compared with NFHS-4, the link between ANC in the first trimester and institutional delivery appears slightly stronger in NFHS-5, reflecting progress in early health-seeking behavior among pregnant women. This trend suggests that interventions such as conditional cash transfers and improved health infrastructure are starting to pay off, though gaps remain.

Nutritional and health status indicators present some of the most striking findings. Anemia among adolescent girls (Q9) continues to be strongly correlated with anemia among women of reproductive age (Q11) and pregnant women (Q13). This persistence underscores the systemic and life-cycle nature of anemia, which affects women from adolescence through pregnancy. Despite long-running supplementation and nutrition programs, the correlations suggest that progress has been limited, and anemia remains a deeply rooted challenge. Similarly, the clustering of anemia-related indicators shows that nutritional deficiencies are not isolated problems but spread across age and reproductive stages.

Body mass and metabolic indicators reveal the growing "double burden of malnutrition." Low BMI among women (Q10) is negatively correlated with overweight women (Q14), reflecting the coexistence of under-nutrition and over-nutrition within the same population. What is particularly concerning is the strong and positive correlation between overweight women (Q14) and women with high blood sugar (Q12). This link appears stronger

in NFHS-5 than in NFHS-4, reflecting the growing burden of non-communicable diseases, especially diabetes, among women. These trends highlight the changing epidemiological profile of India, where traditional concerns like anemia and undernutrition coexist with rising obesity and metabolic disorders. The patterns suggest that health interventions must now simultaneously address two very different challenges: persistent nutritional deficiencies and the rise of lifestyle-related conditions.

Another observation from the NFHS-5 matrix is the persistence of moderate correlations across multiple dimensions, suggesting that women's health outcomes are shaped by interlocking influences. For example, early marriage not only affects fertility behaviors but also indirectly influences maternal care utilization. Similarly, nutritional outcomes like anemia and BMI are linked with broader reproductive health indicators, showing that deficiencies in one domain often spill over into another. Compared with NFHS-4, the NFHS-5 correlations suggest some progress in maternal health service utilization but little structural change in nutrition-related conditions.

Overall, the NFHS-5 correlation matrix portrays a picture of continuity and transition. On one hand, child marriage, unmet need for family planning, and anemia remain persistent and influential, shaping multiple aspects of women's health. On the other, maternal health services show signs of improvement, with stronger correlations between early ANC and institutional deliveries.

Meanwhile, new challenges emerge with the rise of overweight and diabetes, reflected in the strengthened correlation between BMI and blood sugar. These shifts reflect India's demographic and epidemiological transition, where traditional maternal and nutritional concerns overlap with the growing burden of non-communicable diseases.

In conclusion, the NFHS-5 correlation matrix reinforces the understanding that women's health in India cannot be addressed through isolated interventions. Social determinants like age at marriage remain central to shaping reproductive and maternal outcomes. Health system interventions, particularly those expanding ANC and institutional delivery, show signs of effectiveness but require sustained attention. Nutritional interventions must be strengthened to address anemia, while at the same time new preventive strategies are needed to confront rising non-communicable diseases. The patterns highlight the urgent need for a holistic and integrated policy approach that simultaneously addresses reproductive health, maternal care, nutrition, and lifestyle-related risks. Only through such a comprehensive response can India achieve meaningful and sustained improvements in women's health outcomes.

Comparative Interpretation of NFHS-4 (2015–2016) and NFHS-5 (2019–2021)—Jammu Division

A comparative analysis of NFHS-4 and NFHS-5 composite indices for Jammu division highlights both progressive shifts and persistent disparities. The plains districts of Jammu and Kathua consistently maintained very high status across both rounds, reflecting their structural advantage in terms of urbanization, health infrastructure, literacy, and socio-economic conditions. Their sustained high scores confirm that urbanized centers continue to perform well on almost all indicators, including institutional deliveries, anti-natal care coverage, and contraceptive use.

Rajouri and Udhampur are notable cases of improvement. Rajouri, which was among the weakest performers in NFHS-4 with

a very low composite score (−6.66), made significant progress by NFHS-5, moving into the positive range (1.04). This reflects effective policy interventions in institutional deliveries, ANC, and family planning awareness. Udhampur also improved from a marginally positive score (0.87) in NFHS-4 to a stronger perform (1.44) in NFHS-5, suggesting that semi-urbanization and better connectivity are positively influencing women's health indicators.

Poonch and Reasi, however, represent stagnation. Both districts remained in the low to medium categories across NFHS rounds. Despite some gains in ANC coverage, they continue to lag behind in literacy, unmet need for family planning, and nutritional indicators, which prevent a significant upward shift.

The most concerning trend is observed in Ramban, Doda, and Kishtwar. All three districts remained entrenched in the very low categories, with minimal improvements across NFHS rounds. Ramban (−1.27 in NFHS-4, −4.83 in NFHS-5) and Kishtwar (−2.23 to −4.42) even worsened over time, underlining the persistent challenges of remoteness, infrastructural deficiency, and nutritional vulnerabilities. Doda improved slightly but still stayed in the low-performing group, highlighting its fragile health status.

Samba, despite being a plains district with geographical advantages, recorded only modest gains, reflecting structural weaknesses in reproductive health and nutritional outcomes.

In summary, the comparative interpretation underscores that while urban and semi-urban districts (Jammu, Kathua, Udhampur, Rajouri) have moved toward better health outcomes, remote mountainous districts (Ramban, Kishtwar, Doda, Reasi, Poonch) remain persistently disadvantaged. The divergence between plains and hills has not narrowed significantly, revealing that improvements are unevenly distributed and largely restricted to better-connected districts. This emphasizes the urgent need for geographically targeted health interventions, particularly in literacy, nutrition, and maternal health outreach, to bridge the intra-regional divide in women's health and reproductive well-being across Jammu division.

DISCUSSION

The analysis of women's health and reproductive well-being in Jammu and Kashmir based on NFHS-4 (2015–2016) and NFHS-5 (2019–2021) highlights important temporal shifts and spatial inequalities. The persistent divide between plains districts (such as Jammu, Kathua, and Samba) and hilly or remote districts (such as Doda, Kishtwar, Ramban, and Reasi) reflects the strong role of geography, accessibility, and socio-economic context in shaping health outcomes.

Urbanized plains districts consistently recorded higher levels of institutional deliveries, ANC in the first trimester, and use of family planning methods. This demonstrates the positive association of female literacy, health infrastructure, and urban accessibility with maternal and reproductive health outcomes.^{50,51} On the other hand, mountainous and border districts continued to struggle with high prevalence of anemia, nutritional deficiencies, and unmet need for family planning. These findings highlight a structural imbalance in health service delivery and awareness between regions.⁵²

The comparative analysis also shows that some districts, particularly Rajouri and Udhampur, have made notable improvements between NFHS-4 and NFHS-5, reflecting the effectiveness of targeted schemes such as JSY, JSSK, and outreach under National Health Mission (NHM). However, districts like Ramban and Kishtwar either stagnated or declined, suggesting

that universal schemes alone are insufficient in addressing localized barriers of terrain, socio-economic vulnerability, and cultural constraints.^{53–55}

From a policy perspective, the results underline the need for area-specific interventions. In mountainous and border districts, improving road connectivity, mobile health units, telemedicine facilities, and strengthening sub-centers and primary health centers is essential. Community-level awareness campaigns on nutrition, anemia, and family planning should be prioritized, especially for adolescent girls and newly married women.⁵⁶ Nutritional support under schemes such as POSHAN Abhiyaan must be expanded with special monitoring in high-anemia districts.⁵⁷

The findings also align with SDGs, particularly SDG 3 (Good Health and Well-being) and SDG 5 (Gender Equality). Reducing maternal mortality, improving reproductive health services, and addressing nutritional deficiencies directly contribute to these global commitments.⁵⁸ Furthermore, bridging intra-regional disparities will ensure that progress is inclusive and equitable. Policymakers must move beyond one-size-fits-all strategies and adopt differential planning, focusing more resources and innovations in the vulnerable hilly and remote districts. Strengthening education, women's empowerment, and healthcare accessibility together can accelerate progress toward equitable health and reproductive well-being for women across the Union Territory.

Key Limitations

Although this study provides important insights into spatial and temporal variations in women's health indicators across Jammu Division, some limitations should be acknowledged. The analysis is based on secondary NFHS datasets, and therefore depends on the accuracy and availability of reported survey data. The study is limited to district-level analysis, which may not capture smaller local variations at village or household levels. Future studies may incorporate primary surveys, finer spatial-scale datasets, and additional socio-economic variables to provide a more comprehensive understanding of women's health inequalities.

CONCLUSION

The analysis of women's health and reproductive well-being in Jammu and Kashmir using NFHS-4 (2015–2016) and NFHS-5 (2019–2021) highlights significant regional and temporal disparities. A clear divide is observed between the plains districts such as Jammu, Kathua, and Samba, which consistently performed better, and the mountainous districts like Doda, Kishtwar, Ramban, and Reasi, which lagged behind across most indicators. Urbanization, better socio-economic conditions, higher literacy, and improved access to health services contributed to the high performance of plains districts, while remoteness, poor infrastructure, and nutritional deficiencies restricted improvements in hilly and border areas.

The comparative assessment shows that certain districts, notably Rajouri and Udhampur, demonstrated substantial improvement between NFHS-4 and NFHS-5, reflecting the effectiveness of policy interventions and targeted maternal health programs. However, districts such as Ramban and Kishtwar either stagnated or worsened, underlining persistent gaps in healthcare delivery. Nutritional issues, especially anemia and low BMI among women, continue to be widespread and remain a critical challenge across the entire region.

Overall, the findings underscore that while progress has been achieved in institutional deliveries, ANC, and contraceptive

use, there remains a strong need for geographically focused interventions in remote mountainous districts. Strengthening health infrastructure, improving female literacy, reducing nutritional deficiencies, and enhancing awareness of reproductive health services are essential for bridging intra-regional disparities. The study thus emphasizes that achieving equity in women's health outcomes requires context-specific strategies that address both structural barriers and socio-economic determinants.

Ethical Approval

All the ethical standards of research publishing were taken care of during this study.

Data Availability Statement

The datasets used in this study are publicly available from the NFHS.

Artificial Intelligence (AI) Disclosure

Artificial intelligence-based tools were used only for improving the grammar and language clarity of the manuscript. No AI tool was used for data analysis, interpretation of results, or generation of scientific conclusions. The authors take full responsibility for the content of the manuscript.

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AUTHORS' CONTRIBUTIONS

Mandeep Singh: Conceptualization, methodology, data collection, data analysis, visualization, and writing—original draft preparation. Shashi Prabha: Supervision, validation, review, and editing. Naveed Ahmed Khan: Review, editing, and suggestions for manuscript improvement. All authors have read and approved the final manuscript.

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Challenges in Implementing the Ayushman Bharat Digital Mission in India: A Perspective from a Private Personal Health Record Implementer

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ABSTRACT

The Ayushman Bharat Digital Mission (ABDM) represents one of the world's most ambitious national digital health initiatives, aiming to create a federated, interoperable, and citizen-centric digital health ecosystem for India. While substantial progress has been made in building core digital infrastructure, including unique health identifiers, Ayushman Bharat Health Account (ABHA), registries, and consent-based health information exchange, translation of this infrastructure into meaningful health system impact remains limited. Drawing on policy analysis, emerging empirical evidence, and first-hand experience as a private personal health record (PHR) platform operating within the ABDM ecosystem, this perspective critically examines the sociotechnical, governance, and implementation challenges confronting ABDM. We argue that the current phase of ABDM is characterized by an "infrastructure–utilization gap," where account creation outpaces real-world use, record linkage, and clinical integration. Key challenges include digital inequities, low awareness and trust, provider-side integration burdens, workflow disruption, privacy anxieties, and misaligned incentive structures for private ecosystem players. We conclude with targeted, actionable recommendations for policymakers to move ABDM from a compliance-driven infrastructure program to a value-driven, citizen- and provider-embedded digital public good.

Keywords: Ayushman Bharat, Digital divide, Health record, Health-system outcomes, Infrastructure–utilization gap, Personal.

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INTRODUCTION: FROM DIGITAL INFRASTRUCTURE TO HEALTH-SYSTEM IMPACT

India's healthcare system has long been constrained by fragmentation, paper-based records, and weak continuity of care across public and private sectors.^{1–3} Ayushman Bharat Digital Mission (ABDM) was conceptualized to address these structural deficiencies by establishing a national, standards-based digital backbone capable of supporting longitudinal, portable, and patient-controlled health records.^{4–6} The creation of ~85 crore Ayushman Bharat Health Account (ABHA) IDs and the onboarding of ~7.8 Lakhs of providers reflect remarkable progress in digital public infrastructure.⁷ However, infrastructure alone does not guarantee transformation.

A personal health record (PHR) application under ABDM is a citizen-facing digital platform that enables individuals to securely store, access, and share their health records using ABHA-based, consent-driven interoperability. From the perspective of private PHR implementers, ABDM's current trajectory reveals a widening gap between digital readiness and digital usefulness. While compliance milestones are increasingly achieved, sustained utilization, routine clinical integration, and patient-perceived value remain uneven. This perspective explores why.

THE INFRASTRUCTURE–UTILIZATION PARADOX

Ayushman Bharat Digital Mission's early success has been measured largely through quantitative indicators such as ABHA creation, registry enrollment, and sandbox integrations. Yet evidence suggests that registration does not equate to engagement. As of February 2026, the ABDM has built substantial digital health infrastructure, with over 85 crore ABHA accounts, 86 crore linked

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health records, 7.8 lakh registered healthcare professionals, and 4.5 lakh health facilities in the ecosystem. However, utilization remains limited: Only ~26,000 facilities actively transact on the platform, predominantly government facilities (~21,000), while private-sector participation remains low (~4,000).⁷ Although ~2.5 lakh facilities possess ABDM-enabled software, only ~1.1 lakh facilities actively link health records to ABHA, indicating a major gap between technical readiness and real-world data exchange in routine care.⁷ Empirical evidence across India consistently shows low awareness of ABDM and ABHA among the public and healthcare stakeholders. For example, a survey in Bengaluru reported only 8% awareness of ABDM, although willingness to create ABHA increased to 92% after explanation, suggesting that lack of awareness rather than resistance is the key barrier.⁸ Similarly, a multi-city household study across six Indian cities found 14.8% awareness, 11% ABHA ownership, and nearly half of respondents expressing no interest in registration, indicating persistent

public disengagement.⁹ Awareness gaps are also seen among healthcare trainees and system actors; qualitative interviews with postgraduate health science students in coastal Karnataka revealed poor conceptual clarity, confusion between ABDM and AB-PMJAY, and privacy concerns affecting adoption.¹⁰ Even among National Health Authority personnel, only about half were aware of the functional benefits of ABHA, highlighting knowledge gaps within implementing institutions.¹¹ Moreover, registration rarely translates into meaningful utilization: A tertiary-care study in Northern Maharashtra reported 60.9% ABHA registration but only 4% active use, with barriers including lack of awareness (27.7%), non-use after registration (25.2%), and digital illiteracy (8.9%).¹² Similarly, a mixed-methods study in Chandigarh primary health centers found 78% ABHA registration, but 98% of patients still relied on paper-based records, demonstrating minimal integration of digital records into routine care.¹³

From a PHR platform standpoint, this paradox manifests daily: Users create accounts (often assisted), but fail to link records, revisit applications, or use consent flows meaningfully. The system risks becoming a static identity layer rather than a dynamic health-management tool. Figure 1 provides a detailed conceptual

framework on the infrastructure–utilization gap of ABDM from a private PHR perspective.

Beyond digital adoption metrics, underutilization of ABDM-enabled PHRs has direct implications for public health outcomes. Fragmented access to longitudinal records contributes to duplication of diagnostic testing, incomplete clinical histories during care transitions, missed follow-ups in chronic disease management, and delays in preventive or secondary care. At a system level, limited record exchange constrains population health analytics, weakens disease surveillance, and reduces the efficiency gains expected from a national digital health infrastructure. These downstream effects underscore why ABDM's utilization gap is not merely a technical concern but a health-system performance issue.

DIGITAL DIVIDE: BEYOND CONNECTIVITY METRICS

India's digital expansion is undeniable, yet access remains uneven. Rural populations, older adults, women, and low-income groups face persistent barriers related to device ownership, shared smartphones, language, and digital literacy.^{14–16} Personal

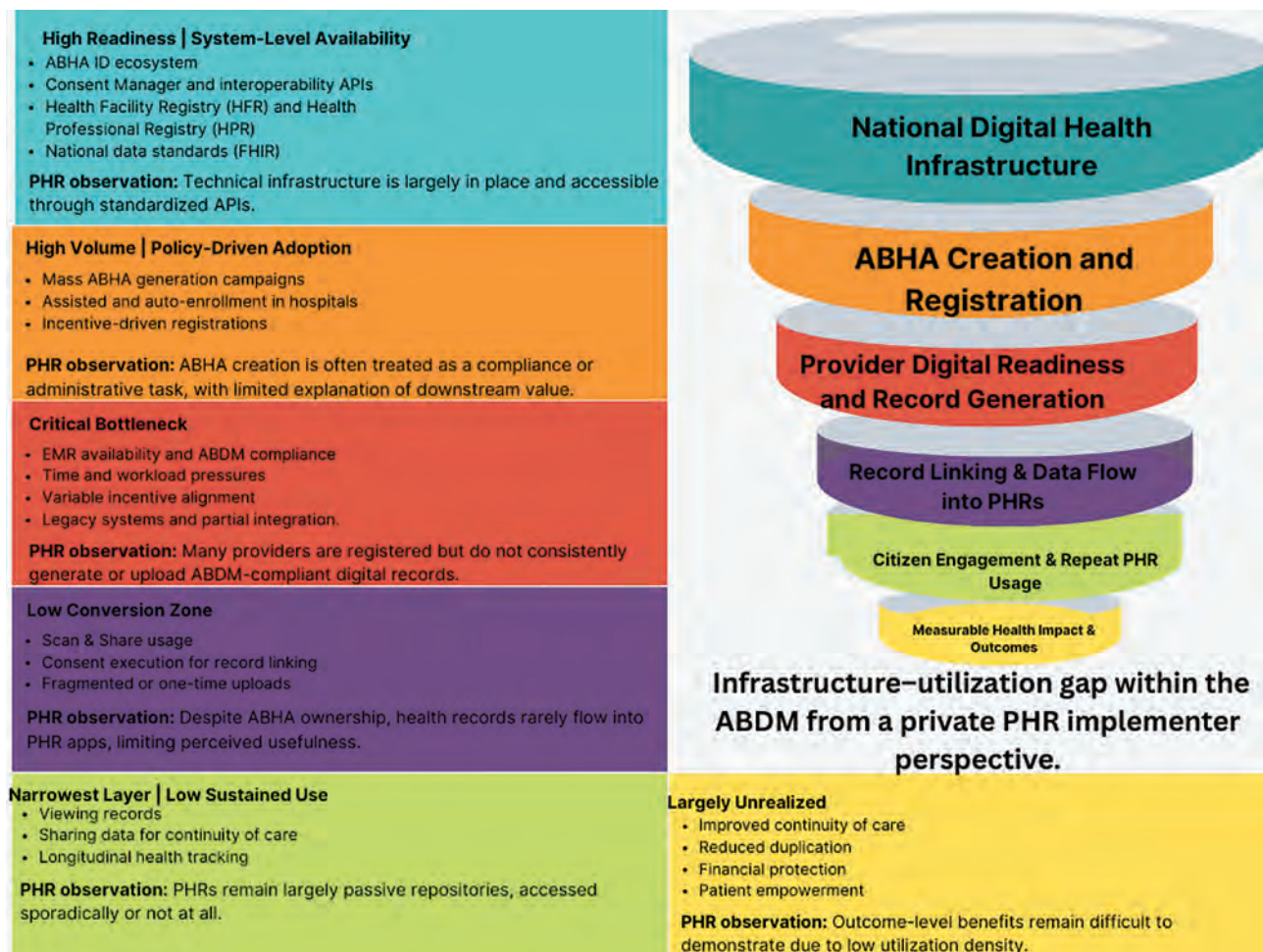


Fig. 1: Conceptual framework on infrastructure–utilization gap within the ABDM from a private PHR implementer perspective

health record applications, despite being technically compliant, often struggle to deliver equitable user experiences across such heterogeneous contexts.

From a private-sector perspective, building ABDM-compliant PHRs that are low-bandwidth, multilingual, offline-capable, and capable of delivering truly informed consent is technically complex and resource-intensive. While these features are essential for equitable adoption, they generate limited commercial returns and are insufficiently supported by current incentive structures. As a result, private PHR providers bear a disproportionate share of the cost of inclusive design, user education, and assisted workflows. Without systemic policy support and shared responsibility for inclusivity, ABDM-enabled PHRs risk primarily benefiting digitally advantaged populations, thereby reinforcing existing health and digital inequities rather than reducing them.

AWARENESS, TRUST, AND MISALIGNED PUBLIC COMMUNICATION

Multiple studies highlight poor public understanding of ABDM, with frequent confusion between ABDM and insurance schemes such as AB-PMJAY.^{12,17,18} Even among healthcare-adjacent populations, awareness of ABDM's purpose, benefits, and consent mechanisms remains superficial.

From a private PHR perspective, trust deficits represent a greater barrier than technical hurdles. Users frequently question:

- Why should I link my records?
- Who can see my data?
- What do I gain today?

Without clear, sustained, and citizen-facing communication strategies, ABDM adoption remains transactional rather than participatory.

PROVIDER-SIDE FRICTIONS AND WORKFLOW REALITIES

Private PHR adoption is deeply dependent on provider participation. However, many small clinics and diagnostic centers lack interoperable EMRs or the financial capacity to integrate ABDM workflows.^{19,20} For clinicians, digital documentation and consent-driven data sharing often compete with already overwhelming workloads.

While some evidence suggests digital records can improve efficiency once embedded, the transition costs, time, training, hardware, and cultural change are borne largely by providers and digital vendors, with limited systemic support.²¹

INCENTIVES, SUSTAINABILITY, AND THE PRIVATE ECOSYSTEM

Ayushman Bharat Digital Mission's incentive frameworks played a crucial role in early onboarding. However, recent tightening of eligibility thresholds and declining per-transaction incentives have created sustainability concerns for smaller PHR players and startups.²² For private platforms, long-term viability depends not only on compliance but on predictable policy signals, fair incentive structures, and pathways to value creation beyond ABHA issuance.

Without recalibration, ABDM risks becoming an ecosystem dominated by a few large integrators, limiting innovation and contextual solutions for underserved populations.

PRIVACY, CONSENT, AND THE PERCEPTION GAP

Although ABDM is architected around consent, sandboxing, and security audits,²³ public perception is shaped by broader cybersecurity anxieties. Rising reports of health-data breaches and cyber incidents amplify fear, particularly around sensitive health information.²⁴

From a PHR implementer's view, consent literacy is as important as consent architecture. Complex consent flows, legalistic language, and one-time authorizations undermine genuine user understanding. Trust cannot be engineered solely through policy; it must be experienced through transparent, respectful, and reversible data-sharing practices.

While some of these challenges may manifest differently in fully public or tertiary-care settings, where centralized EMRs and institutional workflows are more mature, the utilization gap described here is most visible at the primary-care and mixed public-private interface, where continuity failures are greatest.

Policy Suggestions from a Private PHR Perspective

To move ABDM from infrastructure to impact, we propose:

- Shift success metrics from ABHA creation to ABHA utilization, record exchange volumes, PHR usage frequency, providers and facilities participation. Add metrics that measure continuity of care and duplication of diagnostic tests. Figure 2 provides a detailed conceptual logic model of linking ABDM indicators to health-system outcomes.
- Institutionalize assisted digital health models, leveraging community health workers as ABDM navigators.
- Rebalance incentives to support small providers and PHR innovators, not just scale leaders.
- Mandate usability and inclusivity audits alongside technical compliance.
- Simplify consent communication, using regional languages, visual cues, and revocable permissions.
- Create formal feedback loops between policymakers and ecosystem implementers.

CONCLUSION

Ayushman Bharat Digital Mission is a landmark digital public good with transformative potential for India's health system. Yet its success will depend not on the number of accounts created, but on whether citizens, clinicians, and digital platforms experience real value in daily care delivery. From a private PHR perspective, the next phase of ABDM must prioritize trust, usability, provider integration, and ecosystem sustainability. Only then can ABDM transition from a national digital infrastructure to a lived, equitable, and impactful public health system.

DECLARATIONS

Declaration of Competing Interests

One or more authors are affiliated with a private PHR platform that is compliant with the ABDM. The perspectives expressed

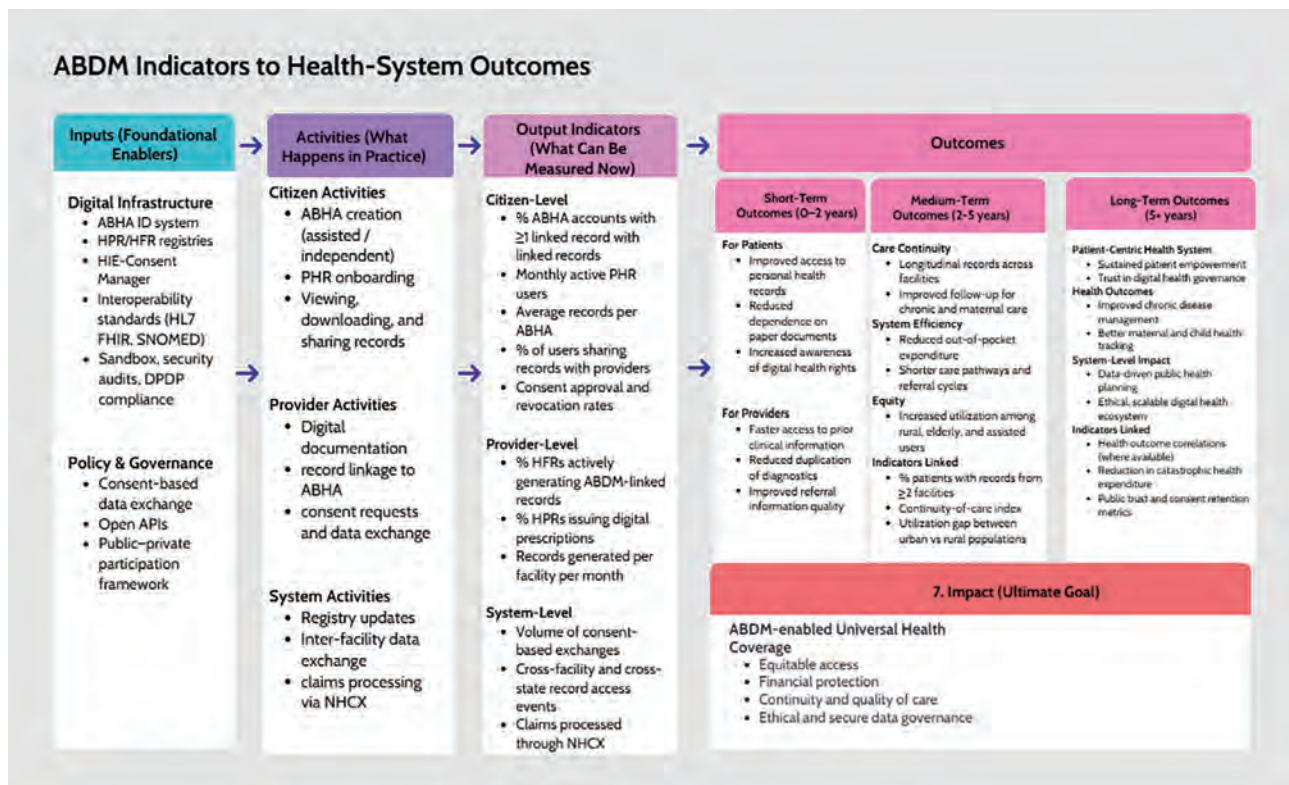


Fig. 2: Conceptual logic model linking ABDM indicators to health-system outcomes

are based on implementation experience and do not represent official positions of the Government of India or the National Health Authority.

Ethical Clearance

Not applicable.

Clinical Trial Registration

Not applicable.

Artificial Intelligence (AI) Declaration in Scientific Writing

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