EDITORIAL

Family Planning after Replacement Fertility: Repositioning India's Program for Choice, Spacing, and Equity

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India's family planning program stands at an important turning point. India was the first country in the world to launch a national family planning program. For many decades, the program worked in a difficult setting. The country had high fertility, high infant and child mortality, low female literacy, early marriage, limited access to health services, and deep social inequalities. The early policy concern was therefore understandable. India needed to reduce high fertility and improve maternal and child survival.

That phase has changed. National Family Health Survey (NFHS)-6 shows that India's total fertility rate remains at 2.0. This is a major achievement for public health, social development, women's education, child survival, and access to reproductive health services. It also shows that the family planning program has entered a more mature phase. Replacement-level fertility does not mean that the family planning agenda is complete. It means that the agenda must change. India must now move from a narrow concern with population control to a wider concern with reproductive autonomy, healthy timing and spacing of pregnancy, informed choice, gender equity, and quality of care.[1]

National Family Health Survey-6 gives a clear message. Any method used among currently married women has increased from 66.7% in NFHS-5 to 69.1% in NFHS-6. Total unmet need has declined from 9.4 to 8.5%. Early marriage among women aged 20–24 years has declined from 23.3% to 20.1%. These are encouraging changes. At the same time, modern contraceptive use has declined from 56.4 to 52.7%. Traditional method use has increased from 10.3 to 16.4%. Female sterilization remains the dominant method at 36.5%, while male sterilization remains extremely low at 0.5%. Unmet need for spacing has increased from 4.0 to 4.5%, even though unmet need for limiting has declined from 5.4 to 4.0%. These findings need careful reading. They do not suggest program failure. They suggest a program transition.[1]

India has succeeded in reducing fertility, but the method mix remains narrow. Women still carry most of the contraceptive burden. Young couples still do not receive enough support to delay the first pregnancy or space the second. Men remain largely absent from family planning responsibility. Many couples appear to be using traditional methods, which may indicate a gap in access, counseling, confidence, continuity, or acceptability of modern reversible methods. These gaps matter because family planning is not only about fertility. It is also about maternal health, newborn survival, child nutrition, women's agency, economic security, and dignity.

India's own policy framework provides the direction for this shift. The National Population Policy (NPP) 2000 did not frame population stabilization only as a question of contraception. It placed population stabilization within a wider reproductive and child health framework. Its immediate objective was to meet the unmet need for contraception, health infrastructure, and health personnel, and to provide integrated service delivery for basic reproductive and child health care. Its medium-term objective was to bring fertility to replacement level. Its long-term objective was to achieve a stable population by 2045, consistent with sustainable economic growth, social development, and environmental protection.[2]

This framing remains relevant. National Population Policy 2000 recognized that people choose smaller families when children survive, women are educated, health services are accessible, and couples have confidence in the future. This means family planning cannot be separated from maternal health, child health, adolescent health, nutrition, education, gender equality, and social development. The success of India's fertility transition confirms this. The decline in fertility has not happened only because contraceptives became available. It has happened because survival improved, women's education expanded, aspirations changed, and the health system reached more people.

The National Health Policy 2017 carried this thinking forward. It recognized that improved access, education, and empowerment form the basis of successful population stabilization. It also advised the system to move away from camp-based services, with their concerns of quality, safety, and dignity, toward services that are available on any day of the week or at least on fixed days. It also gave a clear policy direction to increase the proportion of male sterilization from less than 5% to at least 30%, and if possible, much higher.[3] This remains one of the most unfinished parts of India's family planning agenda.

The voluntary, rights-based nature of India's family welfare program must be upheld to ensure couples' freedom of choice and protect their dignity and confidentiality, fostering trust in the system.

State-level experiences offer important lessons. Some high-fertility States have had valid reasons to focus on fertility decline, maternal health, child survival, and contraception. Mission Parivar

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Vikas was designed for such contexts. It focused on improving access to contraceptives and family planning services in high-fertility districts of Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, and Assam. This district-focused approach remains relevant because national averages hide sharp local differences.[4]

At the same time, some State policies and draft laws have used two-child norms, incentives, and disincentives. Assam's Population and Women Empowerment Policy used a two-child norm in relation to eligibility for some public roles and benefits. The Uttar Pradesh draft Population Bill of 2021 also reflected a two-child norm approach through proposed incentives and disincentives. More recently, some low-fertility States have started to revisit old two-child restrictions. For example, Telangana's 2026 Bill proposed the deletion of the two-child disqualification for local body elections, citing declining fertility. These examples show that population policy in India is no longer moving in one uniform direction. It is becoming more differentiated across States.[5–7]

This differentiation is important. India is no longer a uniformly high-fertility country. Some districts and population groups still need focused support for fertility decline, delayed marriage, delayed first pregnancy, and birth spacing. Other States now face low fertility, population aging, migration, shrinking family size, and concerns about the future workforce. A single national message will not serve all regions equally. High-fertility districts need stronger access to spacing methods, postpartum family planning, adolescent counseling, girls' education, and male engagement. Low-fertility districts need a broader reproductive health approach that also includes infertility care, healthy aging, childcare support, women's workforce participation, and reproductive choice without pressure in either direction.

The most urgent programmatic need is to expand the method mix. Female sterilization should remain available for women and couples who have completed their families. Many women continue to prefer it, and the system must provide it safely and respectfully. However, sterilization should not remain the default method. A modern family planning program must offer condoms, pills, intra uterine contraceptive devices (IUCDs), injectables, emergency contraception, and other safe options, with correct counseling and follow-up. Couples need a real basket of choice, not a symbolic one. The increase in traditional method use in NFHS-6 should prompt the program to ask hard questions. Are modern methods available regularly? Do women receive complete information? Do providers explain side effects? Do couples know where to return for follow-up? Do young couples feel welcome at public facilities? These questions are now more important than simple coverage numbers.[1]

Spacing deserves special attention. Closely spaced pregnancies increase risks for mothers and children. Delaying the first pregnancy and spacing the second can improve maternal nutrition, support breastfeeding, reduce low birth weight, and improve child survival. Yet many young couples receive family planning advice only after the first child is born. This is too late. Counseling should begin earlier, through adolescent health platforms, newly married couple counseling, community outreach, school health, Ayushman Arogya Mandirs, and routine contacts with frontline workers. Family planning should not begin after a woman has completed her family. It should begin when a young person needs information, when a couple plans marriage, when a woman becomes pregnant, and when a family prepares for the next stage of life.

Postpartum family planning must become a stronger program priority. Institutional delivery has increased across India. This creates a valuable contact point. Every woman who delivers in a health facility should receive respectful counseling on return of fertility, lactational amenorrhea, birth spacing, available methods, and follow-up options. However, counseling must not become pressure. The woman must receive information, time, privacy, and choice. Post-abortion family planning also needs attention. Women who experience abortion, miscarriage, or pregnancy loss need sensitive care and counselling. They should not face stigma or neglect.

Male participation must move from slogan to service design. Men should not remain the only decision-makers while women become the users of contraception. Men must receive information, counseling, and services. Male sterilization must be normalized as a safe and simple option for couples who have completed their families. Condom use must be promoted not only as a contraceptive method but also as a sign of shared responsibility. Men must also support delayed first pregnancy, birth spacing, antenatal care, breastfeeding, nutrition, and postpartum contraception. Accredited social health activists (ASHAs), auxiliary nurse midwifes (ANMs), Community Health Officers, male health workers, peer educators, Panchayati Raj institutions, and community leaders can all support this change. The health system should create male-friendly counseling spaces without reducing women's autonomy.

Ayushman Arogya Mandirs can become a strong platform for this new phase. These facilities bring comprehensive primary healthcare closer to the community. They can provide family planning counseling across the life course. They can support adolescents, newly married couples, pregnant women, postpartum women, men, and older women. They can link family planning with anemia prevention, menstrual health, nutrition counseling, non communicable disease (NCD) screening, mental health, gender-based violence response, and referral care. This integrated approach can make family planning more acceptable and useful. It can also reduce the old perception that family planning is only about limiting births.

India's FP2030 vision supports this direction. It commits to high-quality, comprehensive family planning services for all people of reproductive age, including marginalized groups. It emphasizes equitable, affordable, and appropriate contraceptive choices, last-mile information, health systems strengthening, and community engagement within the universal health coverage framework.[8] This vision is well aligned with the needs emerging from NFHS-6. The next decade should therefore focus on access, quality, choice, and equity, not only on fertility decline.

Technology can support continuity. Digital tools can help track eligible couples, postpartum women, missed follow-up visits, contraceptive stocks, and service gaps. Teleconsultation can support counseling in remote areas. Digital platforms can provide reminders and information. Supply-chain tools can reduce stock-outs. However, technology must not replace human trust. Family planning decisions are personal. They involve fertility intentions, gender relations, privacy, fear of side effects, family pressure, and social norms. Digital systems can assist the frontline worker, but they cannot replace respectful counseling.

Quality of care must become the defining measure of success. Informed consent, method choice, privacy, side-effect management, and follow-up are not optional. They define the program. Frontline workers need simple tools to discuss fertility intention, available methods, benefits, side effects, return visits,

and warning signs. Providers must avoid bias against young women, women with no children, women with one child, migrants, unmarried adolescents, women with disabilities, and socially disadvantaged groups. A woman should not be pushed toward one method because it is easy for the system. She should choose a method that suits her life and health needs.

The program also needs a stronger equity lens. National averages can hide district-level and community-level gaps. Family planning needs differ by age, parity, education, caste, tribe, religion, income, migration status, disability, and place of residence. Urban poor women may live close to facilities but still face poor access, cost, stigma, and time barriers. Tribal communities may need culturally sensitive counseling and reliable outreach. Migrant families may miss follow-up because they move between work sites and villages. Adolescents and unmarried young people may need information but may fear judgment. The program must recognize these realities.

National Family Health Survey-6 also points to a wider demographic transition. The share of the population below 15 years has declined, while the share of the population aged 60 years and above has increased. Family planning policy must therefore connect with aging, social care, women's work, childcare, migration, and intergenerational support. In high-fertility areas, family planning will still support maternal and child health. In low-fertility areas, reproductive health policy must protect choice and avoid new forms of pressure to have more children. The common principle should remain the same: People must be able to make informed and dignified reproductive choices.

India's family planning program was a pioneer in the world. It now has the opportunity to become a model for the post-replacement fertility era. This model must be voluntary, evidence-based, equity-focused, and rooted in primary healthcare. It must move beyond demographic targets and place people at the center. It must protect choice in both high-fertility and low-fertility settings. It must treat women not as targets, but as rights-bearing citizens. It must bring men into responsibility without reducing women's agency.

The way forward is clear. India should reposition family planning as reproductive well-being. It should expand spacing choices. It should strengthen postpartum and post-abortion contraception. It should support adolescents and newly married couples. It should bring men into shared responsibility. It should use Ayushman Arogya Mandirs and digital tools for continuity of care. It should use district-level data for local planning. Above all, it should preserve dignity, choice, and trust.

National Family Health Survey-6 does not close India's family planning chapter. It opens a new one. The next generation of family planning should not be judged only by how low fertility falls. It should be judged by how well the health system helps individuals, couples, and families avoid unwanted pregnancies, plan wanted pregnancies, space births safely, choose suitable methods, and receive respectful care. India has achieved replacement-level fertility. It must now achieve reproductive well-being.[9,10]

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ORIGINAL ARTICLE

Impact of Climate Change and Heatwaves on Elderly Health: A Cross-sectional Study in Rural India

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Abstract

Background: Climate change has increased the frequency and intensity of heatwaves, disproportionately affecting elderly populations susceptible to heat-related illnesses.

Objectives: This study aimed to estimate heat-related morbidity, elucidate risk factors, and assess vulnerability among rural elderly in northern India using a validated Heat Vulnerability Assessment Questionnaire (HVAQ).

Materials and methods: A cross-sectional community-based study was conducted during a heatwave season (April–June 2025) among 356 residents aged ≥60 years in a rural district of northern India. The HVAQ, adapted from the Indian National Disaster Management Authority (NDMA) framework, assessed dimensions of exposure, sensitivity, and adaptive capacity. Clinical assessments and structured interviews collected morbidity and socio-environmental data. Logistic regression identified significant predictors of heat-related morbidity.

Results: A total of 62% reported at least one heat-related symptom, with higher prevalence in participants aged ≥80 years (74.5%) compared with younger elderly (57.8%). Multimorbidity, low adaptive capacity (limited cooling access), and high heat exposure were significant morbidity predictors. Females reported greater symptom burden. The HVAQ effectively characterized individual vulnerability profiles.

Conclusions: Utilizing the validated HVAQ enables comprehensive assessment of multidimensional heat vulnerability among rural elderly, guiding focused public health interventions across exposure, sensitivity, and adaptation factors.

Keywords: Climate change, Elderly, Geriatrics, Heatwaves, Multimorbidity, National Disaster Management Authority, Population aging, Rural India, Vulnerability assessment.

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Introduction

Climate change stands as one of the greatest global health threats of the 21st century, manifesting notably through increasingly frequent and intense heatwaves worldwide. India is identified as a heatwave hotspot with severe consequences for public health and socioeconomic development.[1,2] The Indian subcontinent has experienced rising average temperatures over the past century, with heatwave frequency increasing by approximately 30–40% in recent decades.[3,4] Projections forecast further escalation in intensity, duration, and geographical spread of extreme heat events over the next few decades, posing an existential risk to the most vulnerable populations.[5]

Heatwaves exert a disproportionate burden on health, causing excess mortality, morbidity, and reduced quality of life—effects especially pronounced in elderly populations. Older adults commonly experience physiological impairments such as reduced thermoregulatory capacity, diminished cardiovascular resilience, and blunted thirst response that increase susceptibility to heat stress.[6,7] Concurrently, multimorbidity—the coexistence of multiple chronic conditions such as hypertension, diabetes mellitus, and cardiovascular disease—is widespread in aging populations, worsening heat sensitivity due to medication side effects, impaired hydration, and autonomic dysfunction.[8,9] Additionally, frailty and cognitive impairment prevalent in older adults further complicate adaptation during extreme heat.[10,11]

In India, the elderly constitute one of the fastest-growing demographic groups, projected to reach nearly 20% of the population by 2050.[12] However, rural elderly experience pronounced social and environmental vulnerability, including poverty, low literacy, lack of social protection, suboptimal housing, and limited access to cooling resources such as fans or air conditioning.[13,14] The rural population often depends on agriculture and outdoor labor, increasing heat exposure. Healthcare accessibility is frequently constrained because of infrastructure deficits, geographic remoteness, and resource scarcity.[15] Such compounding factors heighten the risks of heat-related morbidity and mortality among this group, yet locally relevant evidence remains sparse.

Recent literature substantiates the conclusions that the elderly, particularly in socioeconomically disadvantaged and rural settings, bear a major share of heatwave impacts in India. A national mortality surveillance program demonstrated that over 70% of heat-related deaths occur in individuals aged 60 and above, and NCRB data reveal increasing annual heatwave fatalities with clustering in rural districts of northern and central India.[16,17] Other studies from states like Maharashtra and Uttar Pradesh show significant associations

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between heatwave seasons and increased hospitalizations for cardiovascular, respiratory, renal, and heat exhaustion syndromes in the elderly.[18,19]

Despite recognition of these health effects, accurately identifying vulnerable individuals and quantifying multidimensional heat risk remain a key challenge for Indian public health planning. Standard epidemiologic studies typically focus on exposure or clinical outcomes but often neglect integrating social determinants, coping capacity, and physiological sensitivity into comprehensive vulnerability assessments. This gap complicates targeting interventions such as heat action plans, early warning systems, and social support programming effectively and equitably.[20]

To address this, the Indian National Disaster Management Authority (NDMA) and allied agencies have promoted standardized frameworks for heat vulnerability assessment combining three domains: Exposure (environmental heat load, duration of heat exposure), sensitivity (age, health status, socioeconomic deprivation), and adaptive capacity (access to cooling, health services, social support).[21,22] These frameworks encourage application of validated Heat Vulnerability Assessment Questionnaires (HVAQs) tailored for Indian contexts, enabling granular community-level risk stratification and monitoring over time.

Several recent pilot and multi-site studies in India have begun employing such multidimensional HVAQ instruments, elucidating complex vulnerability profiles among urban slum dwellers and rural agrarian populations.[23,24] For instance, a mixed-methods pilot study in rural Maharashtra documented how housing conditions, outdoor work patterns, water availability, and social networks moderate heat stress experienced by residents, especially the elderly and women engaged in biomass fuel cooking.[25] Similarly, national heatwave risk mapping combining satellite data, socioeconomic indices, and health statistics has identified high-risk districts for targeted interventions.[26]

Nevertheless, few studies have specifically examined rural elderly populations in northern India using validated HVAQ tools alongside clinical symptom assessments. This study aims to address this gap by integrating validated and standardized measures into epidemiological research to enhance methodological rigor and comparability, thereby informing scalable resilience-building interventions and evidence-based policy formulation.

Objectives of this Study

- Estimate the prevalence and patterns of heat-related morbidity among the rural elderly in northern India during peak heatwave periods.
- To assess multidimensional heat vulnerability in this cohort encompassing exposure, sensitivity, and adaptive capacity domains by using a validated HVAQ, adapted from the NDMA national framework.
- Identify individual-level predictors of heat-related morbidity, integrating socio-demographic, clinical, and environmental parameters.
- Inform contextually appropriate public health interventions and policy initiatives to mitigate heat-related risks and enhance climate resilience among vulnerable rural elderly populations in India.

Materials and Methods

Objective 1: Estimate heat-related morbidity prevalence and patterns

Methodology

- A community based cross-sectional study was conducted between April and June 2025, coinciding with peak heatwave conditions (>45°C) in a rural district of northern India.
- Elderly participants aged 60 years and above ($n = 356$) were recruited via household census.
- Structured interviews collected self-reported heat-related symptoms using validated symptom checklists relevant to rural Indian populations, including fatigue, dizziness, dehydration, heat rash, disturbed sleep, muscle cramps, nausea, and fainting.
- Clinical assessments complemented symptom data to verify morbidity status.

Objective 2: Apply a validated HVAQ, adapted from the NDMA national framework, to assess multidimensional heat vulnerability in this cohort encompassing exposure, sensitivity, and adaptive capacity domains.

Methodology

- The HVAQ was adapted from the NDMA's Heat Wave Vulnerability Assessment Framework (2022), tailored for the local language and rural northern Indian context.
- The semi-structured questionnaire focused on the following three domains:
  - Exposure: Heatwave frequency, duration, time outdoors, occupational exposure
  - Sensitivity: Age-group categorization, multimorbidity status, nutritional and health indicators
  - Adaptive capacity: Availability of cooling methods (fans, air conditioning), access to drinking water, social support, and living arrangements.
- The tool was piloted for cultural acceptability and clarity before deployment.

Objective 3: Identify individual predictors of heat-related morbidity

Methodology

- Collected detailed socio-demographic, clinical, and environmental data utilizing structured interviews and household observations
- Conducted multivariable logistic regression analysis with heat-related morbidity (presence of ≥ 1 symptom) as the dependent variable
- Independent variables included age category, sex, multimorbidity, access to cooling, social isolation, and housing type
- Adjusted odds ratios (AORs) with 95% confidence intervals and *p*-values assessed the strength and significance of the association.

Objective 4: Inform contextually appropriate public health interventions and policy initiatives to mitigate heat-related risks and enhance climate resilience among vulnerable rural elderly populations in India.

Methodology

- Synthesized quantitative prevalence, vulnerability, and predictor data to identify key modifiable factors.
- Developed recommendations emphasizing infrastructural improvements, enhanced community support, targeted health education, and heat action plans.

Table 1: Heat-related morbidity status

Symptom	*Number reporting symptom*	*Percentage (%)*
Fatigue	146	41
Dizziness	100	28
Dehydration	89	25
Heat rash	60	17
Disturbed sleep	107	30
Muscle cramps	47	13
Nausea or vomiting	25	7
Severe dizziness or fainting	22	6
Multiple (≥ 3) symptoms	116	33
Multiple (≥ 6) symptoms	38	11

Table 2: Coping behaviors during heatwaves

Behavior	*Percentage of participants (%)*
Increased water intake	67
Staying indoors afternoons	55
Using hand fans	43
Bathing/showers	39
Use of electric fans	34
Wearing lighter clothing	29
Seeking shade outdoors	22
Visiting cooling shelters	11

- Included gender-sensitive strategies, addressing increased vulnerability identified among elderly women.

Results

Objective 1: Estimate heat-related morbidity prevalence and patterns

- Table 1: Heat-related morbidity status gives comprehensive symptom counts highlighting the burden of multiple concurrent heat-related illness.
- Table 2: Coping behaviors during heatwaves describes behavioral adaptations quantified among study participants, such as increased water intake, staying indoors and use of fans.

Objective 2: Apply the Validated HVAQ to assess multidimensional heat vulnerability in this cohort encompassing exposure, sensitivity, and adaptive capacity domains.

- Table 3: Heat-related symptom prevalence by age-group and gender presents the distribution of symptoms showing higher prevalence among older subsets (>80 years) and females.
- Table 4: Participant demographics and housing characteristics outlines proxies of sensitivity and adaptive capacity, including mutimorbidity status and cooling device access.

Objective 3: Identify individual predictors of heat-related morbidity

- Table 5: Multivariable logistic regression of predictors of heat morbidity illustrates age ≥ 80 years, multimorbidity, and cooling access as significant independent risk factors.

Objective 4: Inform public health interventions

- In-depth discussion and conclusion sections articulate policy relevance.

Table 3: Heat-related symptom prevalence by age-group and gender

Symptom	*Overall (%)*	*60–79 yrs (%)*	*≥80 yrs (%)*	*Male (%)*	*Female (%)*
Fatigue	41	37	52	33	47
Dizziness	28	23	41	19	35
Dehydration	25	23	31	22	28
Heat rash	17	15	22	11	22
Disturbed sleep	30	26	39	21	37

Table 4: Participant demographics and housing characteristics

Characteristic	*Number (N = 356)*	*Percentage (%)*
Age-group		
60–79 years	262	73.6
≥80 years	94	26.4
Sex		
Male	163	45.8
Female	193	54.2
Housing type		
Kutcha/semi-pucca	235	66.0
Pucca	121	34.0
Access to cooling tools		
Fans or AC	121	34.0
No cooling access	235	66.0
Multimorbidity (≥2)	139	39.0

Table 5: Multivariable logistic regression: Predictors of heat morbidity

Predictor	*Adjusted odds ratio (AOR)*	*95% confidence interval (CI)*	*p-value*
Age ≥ 80 years	1.74	1.22–2.89	0.004
Multimorbidity	2.63	1.57–4.39	<0.001
No access to cooling	2.11	1.26–3.55	0.006
Female sex	1.58	1.04–2.41	0.032
Living alone/Social isolation	1.38	0.82–2.31	0.210

- Identified adaptations and behavioral practices inform culturally appropriate interventions to enhance resilience among the rural elderly.

Age ≥ 80, multimorbidity, and poor adaptive capacity significantly increased the odds of reporting heat-related morbidity. Female gender was also a significant risk factor. Social isolation was associated but not statistically significant after adjustment.

Discussion

This study reveals a high burden of heat-related morbidity among rural elderly residents in northern India, confirming their disproportionate vulnerability to escalating heatwave events driven by climate change. Using a validated HVAQ adapted from the NDMA framework, the study comprehensively assessed exposure, sensitivity, and adaptive capacity domains, elucidating complex interplays underlying heat vulnerability in this population.

Advanced age emerged as a strong risk factor, consistent with physiological declines in thermoregulation and increased multimorbidity susceptibility described in the literature.[6,7] Participants aged 80 and above had significantly higher odds of heat-related symptoms, mirroring trends reported in multiple Indian and international studies.[8,9] The significant influence of multimorbidity underscores the role of chronic health conditions in exacerbating heat stress impacts, possibly related to medication side effects and diminished cardiovascular reserve.[27]

Adaptive capacity limitations, particularly poor access to cooling technologies such as electric fans and air conditioning, were significant contributors to heat vulnerability. These findings align with prior evidence that infrastructural deficits amplify heatwave health impacts in resource-constrained rural settings.[13,14,22] Social determinants, including gender and living alone, also affected vulnerability: Females experienced higher symptom burdens likely linked to greater daytime heat exposure through household and fieldwork and reduced autonomy over coping strategies, a pattern echoed in several community-based studies from India.[22,23]

The diversity of coping behaviors documented indicates a culturally embedded and resource-constrained approach to managing heat exposure. Increased water intake, reduced outdoor activity during peak sun, use of hand fans, and bathing were common adaptive strategies. However, access to these options varied by socioeconomic status, household composition, and local infrastructure, echoing research demonstrating the influence of housing structure, social support, and economic resources on heat-coping efficacy.[22,25] Notably, women were less likely to adopt some heat reduction behaviors like changing clothing or reducing activity, highlighting gendered vulnerabilities warranting targeted intervention.

These insights affirm calls for integrated heat-health action plans that transcend clinical risk factors to encompass social adaptability and infrastructural improvements. Structural interventions such as improving housing ventilation, promoting low-cost cooling technologies, and community cooling centers will be essential. Behavioral adaptation support via health education, early warning systems, and community mobilization can synergistically mitigate risks, especially for socially isolated or highly sensitive subgroups.

The validated HVAQ showed utility in identifying locally relevant vulnerability profiles, useful for public health surveillance and tailoring interventions. Embedding such tools in surveillance programs can enable dynamic tracking of hazard, exposure, and adaptive capacity metrics, improving heatwave response precision.

Limitations include the cross-sectional design precluding causal inference and reliance on self-reported symptoms subject to recall bias. The tool, while validated nationally, may require further local contextualization to capture diversity across Indian regions. Nevertheless, this study contributes substantially to evidence on climate-related health risks among rural Indian elderly and strengthens the case for multidimensional vulnerability assessment.

Conclusion

This study highlights the substantial burden of heat-related morbidity experienced by rural elderly populations in northern India, emphasizing their heightened vulnerability amidst intensifying heatwave events linked to climate change. Advanced age, multimorbidity, and limited adaptive capacity—particularly poor access to cooling resources—emerged as strong independent predictors of heat-related symptoms.

The use of a nationally validated HVAQ facilitated a multidimensional appraisal of exposure, sensitivity, and adaptive capacity domains, thereby capturing the complex interplay of physiological, environmental, and social factors influencing heat vulnerability. This comprehensive approach aligns with global and Indian public health frameworks, supporting more precise identification of high-risk subgroups and informing targeted prevention strategies.

Findings underscore the urgent need to strengthen rural health systems and community infrastructure, including enhancing access to affordable cooling options and ensuring reliable water supplies. Behavioral interventions such as health education emphasizing effective heat-coping mechanisms—especially among elderly women who face differential exposure and vulnerability—are critical.

Importantly, policy efforts must prioritize intersectoral coordination, integrating health, rural development, and social welfare departments to address upstream determinants of vulnerability, such as housing quality, social isolation, and economic insecurity. Tailored heat action plans incorporating age- and gender-sensitive components can mitigate morbidity and mortality risks, bolster resilience, and contribute to equitable climate adaptation.

Future research should expand longitudinal surveillance utilizing validated vulnerability tools to monitor temporal trends and evaluate intervention impact across diverse rural contexts in India. This study sets a foundation for such efforts, advocating for systematic heat vulnerability assessments as a cornerstone of climate-resilient health systems poised to safeguard rapidly aging rural populations against mounting heat threats.

Ethical Approval and Accordance

The study was approved by the Institutional Ethics Committee, Sarojini Naidu Medical College (Approval No: SNMC/IEC/DHR/2025/108). All the procedures performed in this study involving human participants were in accordance with the ethical standards of the Institutional Ethics Committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available due to ethical and confidentiality considerations but are available from the corresponding author on reasonable request, subject to appropriate ethical and institutional approvals.

Artificial Intelligence (AI) Disclosure

No AI-assisted technologies were used in the preparation, analysis, or writing of this manuscript.

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Authors' Contributions

Dr Pratibha Singh contributed to the conception and design of the study, data collection, data analysis, interpretation of findings, and drafting of the manuscript. Dr Renu Agrawal supervised the study, provided critical intellectual input, contributed to the interpretation of the findings, and critically reviewed and revised the manuscript. Both authors approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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ORIGINAL ARTICLE

Anemia in Pregnancy: A Cross-sectional Study of Awareness Dietary Habits and Supplementation Compliance with Comparative Insights

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Abstract

Aims and background: Anemia during pregnancy (ADP) remains a major public health concern in India despite longstanding iron–folic acid (IFA) supplementation programs. Poor adherence and inadequate dietary practices continue to limit program effectiveness. This study assessed pregnant women's knowledge, attitudes, and practices (KAPs) related to anemia, iron-rich diet, and IFA supplementation, and examined the association of these factors and sociodemographic variables with maternal hemoglobin (Hb) levels.

Materials and methods: A prospective cross-sectional study was conducted among 100 anemic pregnant women attending a secondary-care government hospital in Hyderabad, India, between November 2023 and August 2024. Data were collected using the validated Anemia in Pregnancy Knowledge, Attitude, and Practice Questionnaire (ADPKAPQ). Statistical analysis was performed using SPSS v28.0, applying descriptive statistics, Chi-square tests, independent *t*-tests, Pearson correlation, and multiple linear regression.

Results: Awareness of ADP was reported by 50% of participants, while 55% identified inadequate iron intake as a cause. Knowledge of symptoms and consequences was limited; 70% were unaware of fetal risks. Although 95% reported consuming some supplements, adherence specifically to IFA tablets was only 8%. Education level was significantly associated with Hb awareness ($\chi^2 = 20.87$, $p < 0.001$), and trimester was associated with awareness of critical Hb levels ($\chi^2 = 9.87$, $p < 0.01$). Frequent tea/coffee intake and pica practices were commonly reported.

Conclusion: A clear gap exists between awareness and the implementation of effective preventive practices for maternal anemia. Improved antenatal education and culturally appropriate nutritional counseling are needed to enhance IFA adherence and dietary behavior.

Clinical significance: Strengthening behavior-focused antenatal interventions can improve maternal Hb status and help reduce adverse maternal and fetal outcomes associated with Anemia in pregnancy.

Keywords: Anemia in pregnancy, Compliance, Dietary habits, Iron and folic acid supplementation, Knowledge-attitude-practice, Maternal health.

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Introduction

Anemia in pregnancy remains a major global public health concern, particularly in low- and middle-income countries (LMICs). Defined by the World Health Organization (WHO) as a hemoglobin (Hb) concentration below 11.0 gm/dL during pregnancy, anemia reduces the blood's oxygen-carrying capacity and compromises maternal and fetal health outcomes.[1] The condition contributes significantly to maternal morbidity and mortality and is associated with impaired fetal growth and adverse long-term developmental consequences in children.

The global burden of anemia in pregnancy remains substantial. WHO estimates indicate that approximately 37% of pregnant women worldwide were anemic in 2021, with prevalence exceeding 40% in South Asia.[1] India bears a disproportionate share of this burden. Data from the National Family Health Survey-5 (NFHS-5, 2019–2021) show that 52.2% of pregnant women in India are anemic, reflecting only modest improvement despite longstanding national nutritional interventions.[2] These figures highlight persistent gaps in program reach, adherence, and behavioral change.

Maternal anemia is strongly associated with preterm birth, low-birth-weight, fetal growth restriction, postpartum hemorrhage, and increased maternal mortality.[3,4] Physiological changes during pregnancy, including marked plasma volume expansion with relatively smaller increases in red cell mass, further heighten susceptibility, particularly among women with inadequate dietary intake and limited healthcare access.

India has implemented multiple national programs, including the National Iron Plus Initiative (NIPI), to promote iron–folic acid (IFA) supplementation. However, adherence remains suboptimal; NFHS-5 reports that only 26.0% of pregnant women consumed IFA tablets for at least 180 days during pregnancy.[2] Barriers to effective prevention include limited knowledge of anemia, misconceptions

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regarding iron supplements, side-effect concerns, poor dietary diversity, and sociocultural practices that inhibit iron absorption. Sociodemographic determinants such as maternal education, socioeconomic status, parity, and access to health services further influence anemia risk and preventive behaviors.[5,6]

Understanding pregnant women's knowledge, attitudes, and practices (KAPs) regarding anemia is essential for designing effective, culturally appropriate interventions. It is hypothesized that inadequate knowledge and suboptimal practices regarding iron intake and IFA supplementation are associated with lower maternal Hb levels, and that these relationships are influenced by sociodemographic factors.

Therefore, this study aimed to assess pregnant women's KAP regarding anemia, an iron-rich diet, and IFA supplementation and to examine the associations of these factors, along with key sociodemographic variables, with maternal Hb levels.

Materials and Methods

Study Design and Setting

A prospective cross-sectional study was conducted between November 2023 and August 2024 in the antenatal outpatient department (OPD) of the Department of Obstetrics and Gynecology at a secondary-care government hospital in Hyderabad, India. The hospital serves a large population of women from socioeconomically disadvantaged communities, providing an appropriate setting to investigate anemia during pregnancy (ADP).

Study Population and Sampling

The study population consisted of pregnant women diagnosed with anemia during routine antenatal evaluation. A total of 100 participants were recruited using purposive sampling.

Inclusion Criteria

- Pregnant women in any trimester.
- Hemoglobin levels below trimester-specific cut-offs (first and third trimester: Hb <11.0 gm/dL; second trimester: Hb <10.5 gm/dL).
- Age between 18 and 45 years.
- Willingness to provide written informed consent.

Exclusion Criteria

- Known Hb opathies (e.g., thalassemia, sickle cell disease).
- Chronic systemic illnesses such as renal failure or malignancy.
- Refusal to participate.

Anemia severity was classified according to WHO criteria as mild (10.0–10.9 gm/dL), moderate (7.0–9.9 gm/dL), or severe (<7.0 gm/dL).

Study Instrument

Data were collected using the Anemia in Pregnancy Knowledge, Attitude, and Practice Questionnaire (ADPKAPQ), a structured and revalidated tool developed from previously published KAP instruments and adapted to the local sociocultural context. Content validity was established through expert review, and reliability testing demonstrated acceptable internal consistency. The questionnaire comprised four sections:

1. Sociodemographic and obstetric details.
2. Knowledge regarding anemia, symptoms, causes, consequences, and iron-rich foods.
3. Attitudes toward antenatal care (ANC) and IFA supplementation.
4. Practices related to dietary habits, tea/coffee intake, pica, and IFA adherence.

Data Collection Procedure

Trained clinical pharmacists administered the questionnaire through face-to-face interviews in the local languages (Telugu or Urdu). Each interview lasted approximately 15–20 minutes. Hemoglobin values were obtained from participants' antenatal medical records documented during the same visit.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee (Approval No: AUCP/IEC/23-24/PharmD/10/02). Written informed consent was obtained from all participants prior to enrollment. Participant confidentiality and anonymity were maintained throughout the study.

Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics version 28.0.

- Descriptive statistics (mean, standard deviation, frequencies, percentages) summarized demographic variables and KAP responses.
- Chi-square tests assessed associations between categorical sociodemographic variables and KAP levels.
- Independent *t*-tests and one-way analysis of variance (ANOVA) compared mean Hb levels across KAP categories.
- Pearson correlation analysis examined relationships between KAP scores and Hb levels.
- Multiple linear regression was performed to identify independent predictors of Hb concentration.
- A p-value of < 0.05 was considered statistically significant.

Results

A total of 100 anemic pregnant women were included in the study. The majority were aged 19–30 years (93%); 96% were homemakers; 45% had completed secondary education; and 29% had university-level education. A total of 44% were multigravida, 13% reported a history of abortion, and 9% had anemia in a previous pregnancy. Nausea and vomiting during early pregnancy were reported by 65% of participants (Tables 1 and 2).

Awareness of ADP was present in 50% of participants. While 64% knew normal Hb levels and 47% reported awareness of Hb cut-offs for anemia, only 55% identified inadequate iron intake as a cause. Knowledge of symptoms was variable, with weakness (66%) and dizziness (61%) most frequently recognized; however, 23% reported no knowledge of symptoms. Seventy percent were unaware of potential fetal complications (Table 3).

Although 95% reported taking some form of supplement, adherence to IFA tablets as recommended was only 8%. Tea or coffee consumption was reported by 79%, meal skipping by 21%, and pica by 18%. Most participants (89%) believed that treating anemia benefits fetal health, but only 30% recognized that untreated anemia could lead to serious delivery complications (Tables 4 to 9).

Awareness of critical Hb levels improved with advancing gestation, with higher recognition in later trimesters (Table 5). Gynecologists were the primary source of information (73%), followed by pharmacists (46%) (Table 6).

Table 1: Demographic characteristics of participants

Characteristic	*Category*	*Number (N)*	*Percentage (%)*
Age (years)	19–30	93	93
	>30	7	7
Education level	Illiterate	5	5
	Primary	21	21
	Secondary	45	45
	Graduate	29	29
Religion	Hindu	68	68
	Muslim	31	31
	Christian	1	1
Occupation	Housewife	96	96
	Employed	4	4
Gravida status	1 (Primi)	39	39
	2	38	38
	≥3	23	23
Parity status	0	43	43
	1	44	44
	2	9	9
	≥3	4	4

Table 2: Medical and pregnancy history

Medical history	*Category/ response*	*Number (N)*	*Percentage (%)*
History of abortion	Yes	13	13
	No	87	87
Anemia in previous pregnancies	Yes	9	9
	No	91	91
Vomiting in early pregnancy	Yes	65	65
	No	35	35

Table 3: Participants' knowledge regarding anemia in pregnancy (ADP) ($N = 100$)

Knowledge area	*Category/response*	*Number (N)*	*Percentage (%)*
Awareness of ADP	Yes	50	50
	No	50	50
Knowledge of normal Hb levels (gm/dL)	11–14.3	64	64
	I don't know	36	36
Knowledge of Hb levels for anemia	Yes	47	47
	No	53	53
Causes of ADP	Iron-poor diet	55	55
	Vitamin B12 and folate deficiency	27	27
	Others (worm infection, history, etc.)	18	18
	I don't know	41	41
Knowledge of signs and symptoms	Tiredness	52	52
	General body weakness	66	66
	Dizziness	61	61
	Others (shortness of breath, paleness, etc.)	31	31
	I don't know	23	23
Knowledge on the effects of IDA during pregnancy	Decreased fetal growth	23	23
	Low-birth-weight babies	10	10
	Influences a child's immunity	18	18
	I don't know	70	70

ADP, anemia during pregnancy; IDA, iron deficiency anemia

Green leafy vegetables were the most commonly identified iron-rich food (75%), followed by dates and dried fruits (49%); only 5% demonstrated comprehensive knowledge of iron-rich foods. Tea and coffee were the most frequently identified items to avoid during pregnancy (79%) (Tables 7 and 8).

Education level was significantly associated with knowledge of Hb levels ($\chi^2 = 20.87$, $p < 0.001$), while age was not associated with anemia awareness. Education was not significantly associated with the belief that anemia complicates delivery ($p > 0.05$) (Table 10). Iron–folic acid adherence was associated with the belief that anemia affects fetal health ($\chi^2 = 4.23$, $p \approx 0.04$), whereas no association was found between tea/coffee consumption and knowledge of iron-rich foods (Table 11). Trimester was significantly associated with awareness of critical Hb levels ($\chi^2 = 9.87$, $p < 0.01$) (Table 12).

Discussion

This study highlights a persistent gap between awareness and the implementation of effective preventive practices for anemia in pregnancy. Although half of the participants had heard of ADP, detailed knowledge regarding its causes, consequences, and prevention remained inadequate. These findings are consistent with prior studies from similar low- and middle-income settings that report fragmented maternal knowledge despite ongoing public health programs.[7,8]

Gynecologists emerged as the primary source of information, reinforcing the pivotal role of clinicians in antenatal education, as also observed in earlier research.[7] However, reliance on facility-based counseling alone may limit knowledge dissemination, particularly when consultation time is constrained.

Dietary knowledge was largely limited to a few commonly recognized foods, such as green leafy vegetables and dried fruits, whereas a comprehensive understanding of iron-rich diets was rare. Comparable gaps in awareness of dietary diversity have been documented among South Asian populations.[9,10] The high prevalence of tea and coffee consumption in this cohort is noteworthy, given well-established evidence that polyphenols in these beverages inhibit non-heme iron absorption.[11,12] Such dietary

Table 4: Participants' practices and attitudes toward ADP management

Practice/attitude	*Category/ response*	*Number (N)*	*Percentage (%)*
Adherence to IFA in the past year	Yes	8	8
	No	88	88
Adherence to iron and multivitamin supplementation	Yes	95	95
	No	5	5
Time of taking iron tablets	After food	100	100
Side effects of iron tablets	Yes	17	17
	No	83	83
Practice of skipping meals during pregnancy	Yes	21	21
	No	79	79
Coffee and tea drinking habit	Yes	79	79
	No	21	21
Practice of pica during pregnancy	Yes	18	18
	No	82	82
Attitude toward treatment benefits for the baby	Yes	89	89
	No	0	0
	I don't know	11	11
Awareness that anemia is serious if untreated	Yes	30	30
	No	5	5
	I don't know	65	65
Awareness that anemia complicates delivery	Yes	30	30
	No	8	8
	I don't know	62	62

IFA, iron–folic acid

Table 5: Awareness of Hb levels in different trimesters

Trimester	*Less than 11 gm/dL*	*More than 11 gm/dL*	*I don't know*	*Other*
First trimester	11 (11%)	76 (76%)	1 (1%)	12 (12%)
Second trimester	40 (40%)	48 (48%)	1 (1%)	11 (11%)
Third trimester	87 (87%)	1 (1%)	0 (0%)	12 (12%)

Table 6: Sources of information about ADP

Source	*Number (N)*	*Percentage (%)*
Gynecologist	73	73
Pharmacist	46	46
Healthcare workers	1	1
Family	21	21
Television	0	0
I don't know	1	1
Others	0	0

Table 7: Knowledge of iron-rich foods

Food item	*Number (N)*	*Percentage (%)*
Green leafy vegetables	75	75
Beetroot	60	60
Liver/chicken/mutton	54	54
Dates/dry fruits	49	49
Eggs	22	22
Jaggery	10	10
I don't know	3	3
All the above	5	5

Table 8: Foods to avoid or limit during pregnancy

Food to avoid/limit	*Frequency (N)*	*Percentage (%)*
Coffee/tea	79	79.0
Green leafy vegetables	27	27.0
Spices	15	15.0
Milk	13	13.0
Sweets	10	10.0
I don't know	2	2.0

Table 9: Attitudes toward treatment and awareness of anemia consequences

Attitude/belief	*Frequency (N)*	*Percentage (%)*
Believe anemia treatment helps the baby	89	89.0
Unsure/don't believe	11	11.0
Believe anemia is serious	30	30.0
Do not believe	5	5.0
Don't know	65	65.0
Believe anemia complicates delivery	30	30.0
Do not believe	8	8.0
Don't know	62	62.0

Table 10: Demographics and knowledge/awareness association

Variable	*χ^2 (Chi-square)*	*df*	*p-value*
Education level × knowledge of normal Hb	20.87	3	<0.001
Age-group × awareness of ADP	0.12	1	>0.05
Education level × belief anemia complicates delivery	5.86	3	≈0.12

ADP, anemia during pregnancy

Table 11: Practice/adherence and knowledge/belief associations

Variable	*χ^2 (Chi-square)*	*df*	*p-value*
IFA adherence × belief anemia affects the baby	4.23	1	≈0.04
Coffee/tea habit × knowledge of iron-rich foods	1.02	1	>0.05

Table 12: Clinical factors and knowledge association

Variable	*χ^2 (Chi-square)*	*df*	*p-value*
Trimester × knowledge of critical Hb (<11 gm/dL)	9.87	2	<0.01

practices may undermine the benefits of supplementation and food-based interventions.

Iron–folic acid adherence in this study was markedly lower than that reported in several regional studies.[13] However, high self-reported intake of "general supplements" suggests possible confusion regarding IFA-specific recommendations. Similar discrepancies between reported supplement use and actual adherence have been described in maternal nutrition research, often linked to side effects, misconceptions, and inadequate counseling.[14,15]

Limited awareness of anemia-related maternal and fetal complications observed here parallels findings from other Indian studies.[16] Education level showed a significant association with Hb awareness, supporting evidence that maternal education strongly influences health literacy and antenatal practices.[5,17] Increased awareness in later trimesters suggests that repeated antenatal contact improves knowledge, emphasizing the value of continuous counseling throughout pregnancy.

Overall, the findings indicate that while attitudes toward anemia management are generally positive, knowledge gaps and suboptimal practices persist, underscoring the need for structured, culturally sensitive antenatal education and stronger reinforcement of IFA adherence.

Limitations

This study was conducted at single center and sample size was small. Future studies need to be conducted including participants from more than one hospital and large sample size with fine tuned methodology.

Conclusion

This study demonstrates that although general awareness of ADP exists, substantial deficiencies remain in detailed knowledge, dietary practices, and adherence to IFA supplementation. Misconceptions regarding causes, symptoms, and consequences of anemia, particularly fetal and delivery-related risks, were common. Sociodemographic factors, particularly maternal education, significantly influenced awareness of Hb levels, whereas advancing gestational age was associated with improved recognition of critical Hb thresholds. Despite positive attitudes toward anemia treatment, preventive practices such as consistent IFA use and avoidance of iron absorption inhibitors were inadequate. These findings indicate that current antenatal education and supplementation strategies are not being translated effectively into sustained behavioral change. Strengthening structured, culturally tailored counseling and reinforcing key nutritional messages throughout pregnancy are essential to bridge the gap between knowledge and practice.

Clinical Significance

Improving maternal understanding of anemia, promoting appropriate dietary practices, and enhancing adherence to IFA supplementation can directly contribute to improved maternal Hb status and a reduced risk of adverse pregnancy outcomes, including low-birth-weight, preterm birth, and maternal complications. Integrating focused anemia counseling into routine ANC and leveraging frontline healthcare providers for consistent follow-up may substantially improve the effectiveness of existing national anemia control programs.

Data Availability

Data is available with authors in Excel sheet.

Artificial Intelligence (AI) Disclosure

Grammerly was used for grammer corrections.

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Authors' Contributions

All authors contributed equally for this study.

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ORIGINAL ARTICLE

Effect of Maternal Mobility in the First Stage on Labor Progress and Maternal and Neonatal Outcomes among Primigravida Women

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Abstract

Introduction: Maternal mobility, including ambulation and upright postures, has been shown to influence labor progress and childbirth outcomes among primigravida mothers. However, its structured application in routine intrapartum care remains limited in many settings.

Objective: To determine the effect of maternal mobility in the first stage on labor progress and maternal and neonatal outcomes among primigravida women.

Methods: A quantitative, post-test-only control group study was conducted on 240 primigravida women without antenatal complications. During the active stage of labor (cervical dilation: 5–6 cm), six cycles of structured mobility, including walking, standing, squatting, cat position, and sitting for 20 minutes each, followed by 10 minutes of rest in the left lateral position, were administered to the experimental group; however, the control group received routine intrapartum care. Labor progress, maternal outcomes, and neonatal outcomes were assessed within 24 hours using standardized and validated tools, such as partograph, obstetrical parameters assessment sheet and APGAR score.

Results: The mean duration of cervical dilatation from 5 cm to full dilation in the experimental group was 3.27 hours, which is shorter than the approximately 4 hours reported for primigravida mothers in existing literature. The proportion of normal vaginal deliveries was higher in the experimental group (88.3%) compared with the control group (72.5%). Women who practiced mobility experienced significantly lower rates of prolonged labor (5.8%) and operative or assisted deliveries (11.7%) than 14.1 and 27.5% among controls, with *p*-values of 0.03 and 0.002, respectively. Maternal satisfaction scores were significantly higher in the experimental group (19.2 $\pm$ 0.6) than in the control group (15.2 $\pm$ 1.9). Neonatal outcomes were also more favorable in the experimental group, with fewer newborns requiring resuscitation (11.7%) as compared to the control (27.5%), and all infants exhibiting normal APGAR scores at birth.

Conclusion: Structured maternal mobility during the first stage of labor is a safe and effective intervention that improves labor progress, enhances maternal satisfaction, and contributes to better maternal and neonatal outcomes.

Keywords: First stage of labor, Labor progress, Maternal mobility, Maternal outcome and neonatal outcome.

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Introduction

Mobility during the first stage of labor, including walking, upright postures, and frequent position changes, is an important component of evidence-based intrapartum care. Restricting women to bed in the supine or lithotomy position has been linked to prolonged labor, increased discomfort, and higher rates of interventions.[1] Recent randomized controlled trials have demonstrated that maternal ambulation during the first stage significantly shortens the duration of labor, improves the efficiency of uterine contractions, and facilitates cervical dilation.[2,3] This facilitation of the labor process reduces the need for augmentation and operative delivery, thereby supporting the achievement of spontaneous vaginal birth.[2,4]

In terms of maternal outcomes, mobility has been shown to decrease pain intensity through improved pelvic dimensions and fetal descent, reducing the demand for pharmacological analgesia.[2,5] Importantly, women who were encouraged to remain mobile during the first stage reported greater satisfaction and a stronger sense of control over their birthing process compared with those confined to recumbent positions.[3,6] Such non-pharmacological measures also align with the philosophy of respectful maternity care, enhancing maternal psychological well-being.

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Neonatal outcomes are likewise positively influenced by maternal mobility. Evidence suggests that ambulation does not increase adverse neonatal events and may contribute to improved APGAR scores and fewer birth injuries, since optimal fetal positioning is promoted by upright maternal postures.[1,2,4] Moreover, by reducing intrapartum interventions such as cesarean

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sections and instrumental deliveries, mobility indirectly supports early initiation of breastfeeding, a key determinant of neonatal health.[7] Overall, current evidence highlights that mobility in the first stage of labor is a safe, low-cost strategy with significant benefits for both mothers and newborns, warranting wider integration into routine intrapartum care.

Aim of the Study

To determine the effect of maternal mobility in the first stage on labor progress and maternal and fetal outcomes.

Objectives

- To compare labor progress between experimental and control groups, as measured by duration of cervical dilation and progress of labor using a partograph.
- To assess maternal outcomes, including mode of delivery, duration of the first stage of labor, intensity of labor pain, and maternal satisfaction.
- To evaluate neonatal outcomes, including APGAR score at 1 and 5 minutes, need for resuscitation, birth injuries, and initiation of breastfeeding.

Methods

Design and Participants

A quantitative research approach with a control group post-test design was adopted for this research. In this study, the tertiary care obstetrics hospital and the primigravida meeting eligibility criteria were conveniently selected and were randomly assigned to either the experimental or control group using an alternate-day allocation method to prevent sample contamination. As the research variables—maternal and fetal outcomes—could only be assessed after delivery, a post-test-only control group design was employed.

Research Setting

The study was conducted in the labor room of a tertiary care government teaching hospital in an urban area of India, which manages a high volume of deliveries each month and predominantly serves economically disadvantaged women who receive cost-free maternity care. The hospital operates 24/7 throughout the year, with obstetricians and midwives available in the labor room.

Inclusion/Exclusion Criteria

Primigravida women at 36–41 weeks of gestation, presenting in the first stage of labor with a live singleton fetus in cephalic presentation, were included. Women with maternal or fetal risk factors or premature rupture of membranes were excluded.

Sample Size and Sampling

Previous studies on maternal ambulation during the first stage of labor reports a wide range of effect sizes (0.5–0.94); however, due to methodological heterogeneity and limited rigor in these studies.[1] However, due to weak rigor in these studies, a conservative effect size of 0.2 was assumed for the present study to avoid overestimation. Using the formula $n = \delta^2(Z\alpha/2 + Z\beta)^2/\sigma^2$ with 80% power, 5% significance, $\delta = 0.2$, and $\sigma^2 = 0.25$, the required sample was 196. Accounting for 20% attrition, the final sample was determined to be 240 (120 each in the experimental and control groups). The study employed consecutive sampling, and 220 primigravida women were included in the final analysis, ensuring adequate statistical power.

Data Collection

Instruments

Partograph recorded cervical dilatation, fetal heart rate, contractions and use of any drugs. In the present study, cervical dilatation was analyzed as a labor outcome. Obstetrical parameter assessment chart included perineal outcome of the participant was assessed after delivery and included examination of the perineum for tears, vulval edema, vulvar hematoma, presence of episiotomy sutures, and any other abnormalities in the perineum. Participants having any of these conditions were given a score of zero, and participants without any of these conditions were given a score of one. A composite perineal outcome score was calculated based on predefined obstetrical parameters recorded in the obstetrical parameter assessment chart.

The maternal outcome was assessed during the delivery and also after delivery. Aspects of maternal outcome, like the experience of discomfort during the second stage, were self-reported by the participants immediately after delivery. Other aspects of the maternal outcome included pain, requirement of medical and surgical interventions, and presence of prolonged labor. The score in maternal outcome ranged from zero to eight, with a higher score indicating a better maternal outcome.

The maternal satisfaction was assessed through the total score in all three aspects, namely maternal outcome, perineal outcome, and fetal outcome. The maximum score in maternal satisfaction could be 20, with six scores each in perineal outcome and fetal outcome and eight scores in maternal outcome. A higher score in the maternal satisfaction indicated a higher level of satisfaction.

The content validity of all the tools was established with the help of seven experts from the field of gynecology and obstetrics. All the tools achieved a scale content validity index of 0.9–1.

Two independent observers simultaneously and independently recorded observations for 24 women (pilot study) in the first stage of labor for determining interrater reliability. Inter-rater reliability of the partograph parameters, including fetal heart rate, frequency of uterine contractions, cervical dilation, maternal vital parameters, and use of drugs and intravenous fluids, was high, with intraclass correlation coefficient (ICC) values ranging from 0.91 to 1.00. The obstetrical parameter assessment chart also demonstrated excellent inter-rater reliability, with perfect agreement between observers (ICC/Cohen's kappa = 1.0).

Intervention

The intervention included the following steps in the experimental group – identification of the active phase of labor when the cervical dilation is ≥5 cm as per vaginal examination, followed by strong progressive uterine contractions. Then the participants were encouraged to engage in mobility activities including sitting, standing, squatting, and hand-knee positions as per their tolerability for 20 minutes. Following the mobility, they were allowed rest periods of 10 minutes on the bed in the left lateral position with simultaneous monitoring for the maternal and neonatal well-being. This cycle of 20 minutes of mobility with 10 minutes of rest was repeated six times or until full cervical dilation, whichever occurred first. The data collection was done by the primary researcher using observation, self-report, and record analysis.

Data Analysis

Statistical Package for the Social Sciences (SPSS)-20 was used in this study. Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to describe the demographic and background characteristics of the research groups. Inferential statistics as one-sample *t*-test, Chi-square, and independent *t*-tests, were used.

Reporting Guideline Used

The manuscript was prepared in accordance with the strengthening the reporting of observational studies in epidemiology (STROBE) reporting guidelines for non-randomized observational studies, and relevant components of consolidated standards of reporting trials (CONSORT) were considered for transparent reporting of intervention procedures and outcomes.

Ethical Considerations

Informed written consent was obtained from all the human adult participants. The ethical permission was obtained from the hospital's institutional ethics committee (Ref: SDNH/IHIEC/2021/27/34166) dated 01/01/2021.

Results

The majority (64%) of the study participants were in the age-group between 21 and 25 years. Regarding education, most of the women in both groups were educated up to high school (experimental, 40.8%; control, 40%). Both groups were found comparable in terms of age, education, income, BMI, and gestational age (Table 1).

The perineal outcome score represented a composite index derived from predefined obstetrical parameters, rather than a single clinical measure. Individual outcome components are presented separately in Tables 2 to 4 to improve clarity and interpretability. The mean perineal outcome scores were similar between the experimental (5.32 ± 0.47) and control groups (5.34 ± 0.48), showing no significant difference [t (238) = 0.41, $p = 0.68$]. However, specific complications were significantly lower in the experimental group, with fewer cases of prolonged labor requiring intervention (5.83 vs 14.17%; $\chi^2 = 4.63$, $p = 0.03$) and asphyxiated newborns requiring resuscitation (11.67 vs 27.50%; $\chi^2 = 9.55$, $p = 0.002$). These findings suggest that mobility during labor may reduce certain perineal complications despite similar overall perineal scores (Table 2).

As shown in Table 3, the experimental group showed significantly better maternal and neonatal outcomes compared to the control group. A higher proportion of women in the experimental group had normal vaginal deliveries with fewer perineal complications, such as prolonged labor and neonatal asphyxia. Additionally, maternal satisfaction scores were significantly higher among the experimental group, indicating that the intervention positively influenced the childbirth experience and outcomes. As shown in Table 4, the experimental group demonstrated significantly better fetal and neonatal outcomes than the control group. Newborns in the experimental group had higher overall fetal outcomes and

Table 1: Baseline demographic and obstetrical comparability of participants ($n_1 + n_2 = 120 + 120$)

Characteristic	*Experimental (n = 120)*	*Control (n = 120)*	χ^2	*df*	*p-value*
Age (years)			3.538	2	0.171
Below 20	25 (20.8%)	28 (23.3%)			
21–25	77 (64.2%)	64 (53.3%)			
≥26	18 (15.0%)	28 (23.3%)			
Education			0.192	4	0.996
Primary or less	14 (11.7%)	15 (12.5%)			
High school	49 (40.8%)	48 (40.0%)			
Intermediate	24 (20.0%)	26 (21.7%)			
Graduation	30 (25.0%)	28 (23.3%)			
Post-graduation	3 (2.5%)	3 (2.5%)			
Income (Rs/month)			0.9	4	0.925
<5000	4 (3.3%)	6 (5.0%)			
5,001–10,000	21 (17.5%)	22 (18.3%)			
10,001–15,000	39 (32.5%)	42 (35.0%)			
15,001–20,000	30 (25.0%)	26 (21.7%)			
>20001	26 (21.7%)	24 (20.0%)			
BMI			0.708	2	0.702
Underweight	9 (7.5%)	6 (5.0%)			
Normal	106 (88.3%)	108 (90.0%)			
Overweight	5 (4.2%)	6 (5.0%)			
Gestational age			1.646	2	0.439
<37 weeks	9 (7.5%)	14 (11.7%)			
37–40 weeks	86 (71.7%)	78 (65.0%)			
>40 weeks	25 (20.8%)	28 (23.3%)			

*$p \leq 0.05$, significant. BMI, body mass index

Table 2: Perineal outcomes and complications among experimental and control groups ($n_1 + n_2 = 120 + 120$)

Outcome/complication	*Experimental (n = 120)*	*Control (n = 120)*	*Test statistic*	*df*	*p-value*
Perineal outcome score (Mean ± SD)	5.32 ± 0.47	5.34 ± 0.48	$t = 0.41$	238	0.68
Prolonged labor requiring intervention	7 (5.83%)	17 (14.17%)	$\chi^2 = 4.63$	1	0.03*
Asphyxiated newborn requiring resuscitation	14 (11.67%)	33 (27.50%)	$\chi^2 = 9.55$	1	0.002*

An independent samples *t*-test was used for mean perineal outcome scores. Chi-square test was applied for perineal complications. *$p < 0.05$ considered statistically significant

Table 3: Comparison of delivery outcomes, perineal complications, and maternal satisfaction among experimental and control groups ($n_1 + n_2 = 120 + 120$)

Variable	*Experimental group*	*Control group*	*Test value*	*df*	*p-value*
Mode of delivery ($n = 120$ each)			$\chi^2 = 9.55$	1	0.002*
Normal vaginal delivery	106/120 (88.3%)	87/120 (72.5%)			
Assisted vaginal delivery/LSCS	14/120 (11.7%)	33/120 (27.5%)			
Prolonged labor requiring intervention (assessed $n = 120$ each)	7/120 (5.8%)	17/120 (14.2%)	$\chi^2 = 4.63$	1	0.030*
Asphyxiated newborn requiring resuscitation (live births assessed: $n = 120$ each)	14/120 (11.7%)	33/120 (27.5%)	$\chi^2 = 9.55$	1	0.002*
Maternal satisfaction score (completed questionnaires)			$t = 22.0$	238	<0.001*
Mean ± SD	19.2 ± 0.6 ($n = 120$)	15.2 ± 1.9 ($n = 120$)			

*$p < 0.05$, significant; values are expressed as frequency/denominator (percentage) unless stated otherwise; χ^2 test applied for categorical variables; independent *t*-test applied for maternal satisfaction score; df for *t*-test calculated as $n_1 + n_2 - 2$. LSCS, lower segment cesarean section

Table 4: Comparison of fetal outcome, APGAR score, and breastfeeding initiation among experimental and control groups ($n_1 + n_2 = 240$)

Variable	*Experimental group*	*Control group*	*Test value*	*df*	*p-value*
Overall fetal outcome score (Mean ± SD)	5.84 ± 0.37	4.32 ± 1.50	$t = 10.74$	238	<0.001*
APGAR score at birth ($n = 120$ each)			Fisher's exact	–	<0.001*
Normal score	120/120 (100%)	87/120 (72.5%)			
Below normal	0/120 (0%)	33/120 (27.5%)			
Initiation and maintenance of breastfeeding			Fisher's exact	–	<0.001*
No difficulty	106/120 (88.3%)	18/87 (20.7%)			
Experienced difficulty	14/120 (11.7%)	69/87 (79.3%)			

*$p < 0.05$, significant; values are expressed as frequency/denominator (percentage) unless otherwise stated; independent *t*-test applied for comparison of mean foetal outcome scores; Fisher's exact test applied where expected cell counts were <5 or where a zero cell was present

APGAR scores, indicating improved vitality at birth. Moreover, mothers in the experimental group initiated and maintained breastfeeding more successfully, with fewer difficulties, suggesting enhanced maternal–infant interaction and smoother postnatal adaptation.

Figure 1 illustrates the progression of labor pain scores across time points in the experimental group and reflects the physiological progression of labor rather than a comparative effectiveness outcome. At the beginning of active labor, the mean pain score was 10.9 ± 1.2, ranging from 8 to 12, indicating mild pain. After 2 hours, the mean pain score increased to 22.8 ± 2.12 (range 20–26), suggesting a transition to moderate pain as labor progressed. At 4 hours or near full cervical dilatation, the mean pain score further increased to 38.78 ± 1.72 (range 30–40), representing severe pain in most participants. Overall, a progressive increase in pain intensity over time in the experimental group, which is consistent with the normal physiological progression of labor. The relatively low SD values indicate consistent pain responses among participants at each time point.

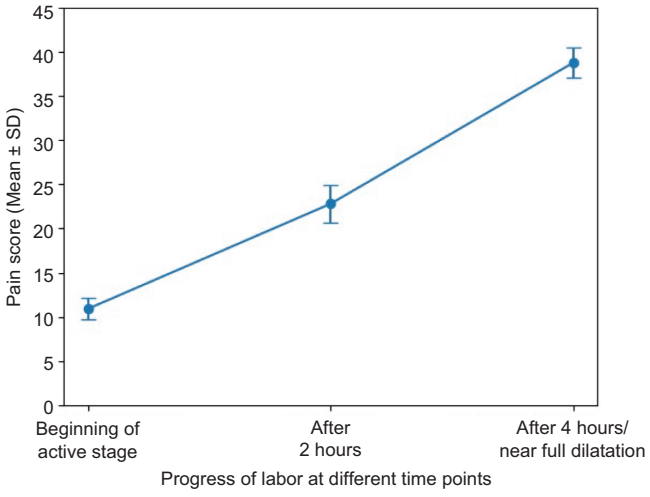

Fig. 1: Line graph showing the progress of labor pain for the experimental group

Discussion

The present study evaluated the effectiveness of structured maternal mobility during the first stage of labor in its progress, maternal and neonatal outcomes among primigravida women in a tertiary care setting. The findings demonstrate that maternal mobility positively influenced labor dynamics, maternal satisfaction, and selected neonatal outcomes.

Effect on Labor Progress

Women who engaged in structured mobility experienced significantly shorter durations of cervical dilatation and fewer instances of prolonged labor requiring intervention. This finding is physiologically plausible, as upright and ambulatory positions are known to enhance gravitational forces, increase pelvic outlet dimensions, and promote optimal fetal alignment, thereby facilitating efficient uterine contractions and cervical effacement. Similar reductions in labor duration with ambulation during the first stage have been reported in randomized and quasi-experimental studies, supporting the consistency of this effect across settings.[3,8]

Although overall perineal outcome scores did not differ significantly between groups, the experimental group exhibited fewer labor-related complications. This suggests that while maternal mobility may not directly alter perineal integrity, it contributes to smoother labor progression and reduces secondary complications associated with prolonged labor.[9]

Maternal Outcomes and Mode of Delivery

The significantly higher rate of normal vaginal delivery and maternal satisfaction observed in the experimental group underscores the role of mobility as a supportive intrapartum intervention. Mobility likely enhances maternal autonomy, reduces perceived loss of control, and facilitates coping with labor pain. These findings are consistent with previous studies reporting improved maternal satisfaction and reduced operative delivery rates among women encouraged to remain mobile during labor.[10] Pain scores in the experimental group increased progressively over time, reflecting the normal physiological course of labor rather than an adverse effect of mobility. Importantly, mobility did not exacerbate pain but may have supported women's ability to tolerate labor through active coping and positional comfort.[3]

Neonatal Outcomes

Neonatal outcomes were more favorable in the experimental group, with higher APGAR scores and fewer newborns requiring resuscitation. Improved fetal oxygenation associated with upright maternal positioning and reduced intrapartum interventions may explain these findings. While some randomized trials have reported no significant neonatal differences, variations in study design, sample size, and timing of intervention may account for these discrepancies.[2]

Early initiation of breastfeeding was also more successful among women in the mobility group. This may be indirectly attributed to reduced operative deliveries and improved maternal-infant interaction immediately after birth, both of which are known to support early breastfeeding practices.[11]

Strengths and Limitations of the Study

A major strength of this study is its comprehensive coverage of maternal, fetal, and neonatal outcomes aligned with the stated objectives and a robust sample (n = 240). However, limitations include the inability to blind participants and providers, a single-center context, and a lack of longer-term breastfeeding follow-up. Pain progression during the active stage of labor was assessed only in the experimental group. This limits direct comparison of pain between groups, which was due to the large sample size and feasibility considerations for frequent assessments. Implementation of maternal ambulation as per the available recent literature highlights that staff attitudes, institutional protocols, and provider familiarity with alternative positions significantly influence uptake.[12] To maximize benefit, mobility protocols must be paired with staff training, supportive infrastructure, and policy change.

Conclusions and Recommendations

Maternal mobility during the first stage of labor was found to significantly enhance labor progress, increase normal vaginal births, and improve maternal and neonatal outcomes. The intervention also facilitated better APGAR scores and early initiation of breastfeeding. Incorporating maternal mobility into intrapartum practice offers a simple, safe, and effective approach to promoting positive childbirth experiences.

Recommendations for Nursing Practice, Education, Research, and Policymaking

Encourage maternal mobility and upright positions during labor to optimize maternal and neonatal outcomes. Train nurses and midwives in facilitating safe, evidence-based intrapartum mobility. Conduct larger, multi-center studies to validate benefits and assess long-term outcomes. Develop guidelines and resources to support mobility-friendly labor practices in maternity units.

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

N Rathina – Conceptualization, data collection and analysis. Sunita Srivastava – Conceptualization, preparing first draft of the manuscript and revising it and finalizing it. Sarita Dheeraj– Conceptualization and critique of the manuscript. N Rathina 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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ORIGINAL ARTICLE

Trends and Determinants of Cesarean Section Deliveries in South Asia: A Comparative Study of Medicalization and Socioeconomic Disparities

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Abstract

Cesarean section (C-section) is a lifesaving obstetric procedure when medically required. In recent decades, cesarean births have increased sharply across South Asia, raising concerns about over medicalization and growing socioeconomic gaps in maternal care. This study assessed trends and determinants of cesarean deliveries across six South Asian countries using nationally representative Demographic and Health Survey (DHS) data. Cesarean delivery for the most recent birth was the outcome variable. Key predictors included maternal age, education, residence, and type of health facility. Comparative analyses were conducted across countries and population subgroups. Results show a marked rise in cesarean rates across the region. Bangladesh (44.5%) and the Maldives (42.6%) reported the highest prevalence, while Afghanistan had very low utilization (3.6%). Higher rates were observed among older, educated, urban, and wealthier women. Private facilities consistently reported substantially higher cesarean use than public institutions. Clear urban rural and wealth based inequalities indicate uneven access to obstetric services. In several countries, cesarean rates exceed recommended levels, suggesting overuse among advantaged groups alongside underuse among disadvantaged populations. Overall, South Asia faces a dual burden of excessive cesarean use among wealthier groups and limited access among poorer women. Stronger regulation of private providers, promotion of evidence-based practices, and improved equitable access to maternal health services are essential to ensure safe and appropriate cesarean use and better maternal and neonatal outcomes.

Keywords: Cesarean section, Maternal health, Maternal healthcare utilization, Medicalization of childbirth, Private healthcare sector, Socioeconomic inequality, South Asia, Urban rural disparity.

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Introduction

The landscape of maternal healthcare in South Asia has undergone a profound structural, clinical, and philosophical transformation over the past three decades. Historically characterized by home births attended by traditional birth attendants within community-centric networks, the region has witnessed a massive, policy-driven shift toward institutional deliveries. Propelled by global health imperatives such as the millennium development goals (MDGs) and the subsequent sustainable development goals (SDGs), South Asian nations implemented diverse demand-side financing schemes, conditional cash transfers, and sweeping infrastructural expansions to incentivize facility-based childbirth.[1] While these interventions have been unequivocally successful in expanding access to skilled birth attendance and drastically reducing the region's maternal mortality ratio (MMR) which fell significantly from 384 per 1,00,000 live births in 2000 to 157 in 2017 this epidemiological triumph has been accompanied by an unintended, escalating, and highly complex phenomenon: The rapid and unchecked over-medicalization of childbirth.[2]

Central to this paradigm of over-medicalization is the unprecedented surge in cesarean section (C-section) deliveries. The World Health Organization (WHO) has historically maintained, based on extensive ecological analyses and systematic reviews of population-level data, that a national C-section rate between 10 and 15% is optimal for minimizing maternal and neonatal mortality.[3] The WHO explicitly and repeatedly states that rates exceeding this 10–15% threshold yield no further reductions in mortality metrics at the population level; conversely, excessive surgical intervention exposes both the mother and the infant to significant short- and long-term iatrogenic risks.[4] Despite these definitive global guidelines and clinical warnings, the prevalence of surgical deliveries in South Asia has skyrocketed far beyond medical necessity, transforming an essential, life-saving emergency intervention into a routine, commodified mode of delivery.[5]

This demographic transition in birthing practices has engendered a severe public health crisis defined by a "dual burden" of inequitable obstetric care. Researchers and public health epidemiologists describe this overarching paradigm as the simultaneous, paradoxical coexistence of "too much, too soon" and "too little, too late."[3] In affluent urban centers and within the rapidly expanding, loosely regulated private healthcare sector, women are routinely subjected to unnecessary surgical deliveries.

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Table 1: Demographic Health Survey conducted in South Asia region (1991–2022)

Country	*1991*	*1993*	*1996*	*1999*	*2000*	*2001*	*2004*	*2006*	*2007*	*2009*	*2011*	*2012*	*2014*	*2015*	*2016*	*2017*	*2020*	*2022*
Afghanistan														1				
Bangladesh					1		2		3		4		5			6		7
India		1		2				3						4			5	
Maldives										1					2			
Nepal			1			2		3			4				5			6
Pakistan	1							2				3				4		

These interventions are driven by a complex confluence of provider-induced demand, perverse financial incentives, institutional convenience, and shifting socio-cultural preferences regarding birth.[2] Conversely, in remote, socioeconomically marginalized rural areas and among the lowest wealth quintiles, highly vulnerable populations continue to face a tragic deficit in access to comprehensive emergency obstetric care, leading to preventable maternal and perinatal deaths due to an absolute unmet need for life-saving surgery.[3]

The drivers of this phenomenon are deeply entrenched and cannot be comprehensively understood through a purely clinical or biomedical lens. The acceleration of C-section rates is deeply rooted in the broader medicalization of human reproduction and the systemic architecture of regional health systems. Anthropological frameworks, most notably the "technocratic model of birth," reveal how modern obstetrics frequently conceptualizes the female body as a defective machine requiring technological management, fundamentally altering the relationship between women, their bodies, and the physiological birthing process.[6] In South Asia, this technocratic paradigm has been heavily commercialized. The proliferation of private healthcare facilities has commoditized surgical birth, turning it into a highly lucrative enterprise that exploits informational asymmetries between patients and providers.[1]

Consequently, the soaring C-section rates across countries like India, Bangladesh, Pakistan, Nepal, and Sri Lanka serve as a critical diagnostic barometer for underlying systemic dysfunctions. They expose deep-seated socioeconomic disparities, structural flaws in healthcare financing and insurance models, and a systemic failure of state apparatuses to regulate private medical providers effectively. This introductory review provides an exhaustive, comparative analysis of the trends and determinants of C-section deliveries across South Asia, laying the groundwork for further empirical research. By synthesizing multi-country Demographic and Health Survey (DHS) data, National Family Health Survey (NFHS) statistics, Multiple Indicator Cluster Surveys (MICS), and contemporary epidemiological literature, this analysis deconstructs the socioeconomic, maternal, and institutional drivers of surgical births. Furthermore, it explores the theoretical underpinnings of birth medicalization, the cascading economic and nutritional consequences of unnecessary surgeries, and the urgent policy interventions required to restore equity, safety, and humanism to maternal healthcare across the subcontinent.

Methodology

Data Source

The present study used data from the DHS STATcompiler https://www.statcompiler.com/en/, a nationally representative survey that provides comparable information on population and health indicators across countries. Data from South Asian countries, covering a total of six countries (India, Bangladesh, Nepal, Pakistan, Afghanistan, and Maldives), were utilized for the analysis. Country wise Demographic Health Survey conducted from 1991 to 2022 is mentioned in the Table 1.

Outcome Variable

The C-section delivery variable was considered as the primary outcome variable, indicating whether the most recent birth was delivered through C-section, enabling examination of delivery practices across socio demographic and healthcare characteristics in the region.

Explanatory Variable

In this study, selected explanatory variables were examined as determinants of C-section deliveries, including region (South Asia), age (years), education, place of residence, and type of health facility.

Statistical Analysis

The study uses secondary data from DHS conducted across selected South Asian countries between 1991 and 2022 to examine trends and differentials in C-section deliveries. A descriptive and comparative statistical approach was applied, including trend analysis to assess changes over time and cross-sectional comparisons using recent survey rounds. The analysis further explores variations by age, residence, education, wealth quintile, and type of health facility.

Result

The Figure 1 presents the trend in C-section deliveries across selected South Asian countries over time, showing a consistent rise in institutional surgical births across the region. Bangladesh demonstrates the most rapid increase, rising from very low levels in the late 1990s to about 44.5% by 2022, indicating a sharp transition toward medicalized childbirth. India also shows a steady upward trend, increasing from nearly 3% in the early years to around 23.5% in recent estimates, reflecting expanding access to institutional delivery along with changing clinical practices. Pakistan follows a similar pattern, with cesarean deliveries increasing from about 2.8% to nearly 25.8% by the mid-2010s. Nepal records gradual growth, reaching approximately 18.2% by 2022, suggesting improving maternal health service utilization. The Maldives exhibits comparatively high levels throughout the observed period, exceeding 36% and crossing 40% in later years, which may indicate greater availability of advanced obstetric care.

The Figure 2 compares the prevalence of C-section deliveries across selected South Asian countries based on recent DHS

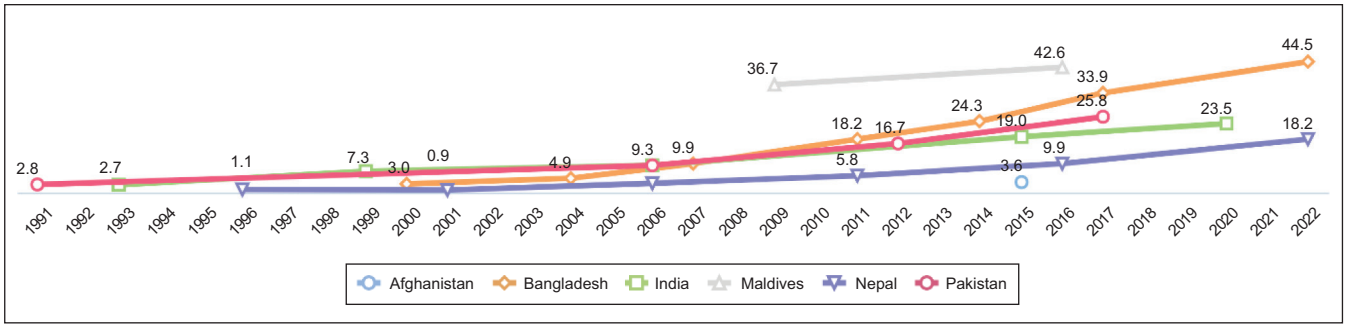

Fig. 1: Trend in C-section deliveries across selected South Asian countries 1991–2022

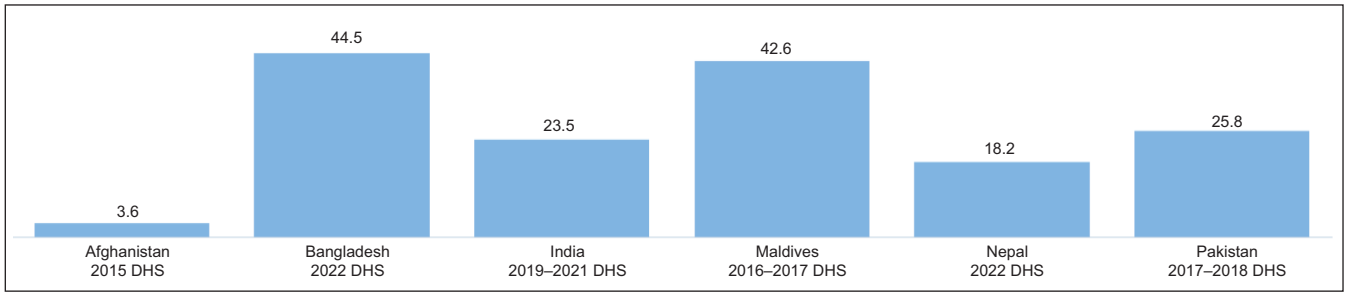

Fig. 2: Prevalence of C-section deliveries across selected South Asian countries based on recent DHS estimates

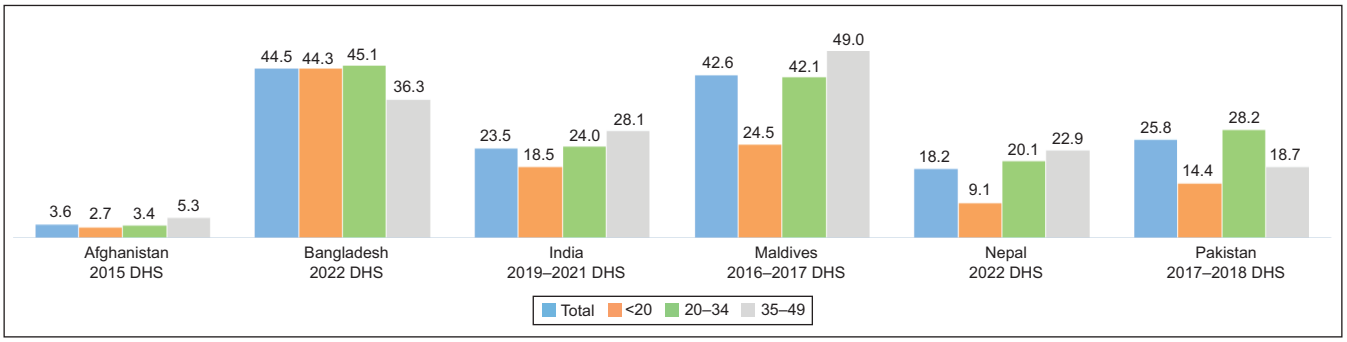

Fig. 3: Age wise differentials in C-section deliveries across selected South Asian countries using recent DHS estimates

estimates. The findings reveal substantial cross-country variation in C-section use within the region. Bangladesh reports the highest proportion of cesarean deliveries at 44.5%, followed closely by the Maldives at 42.6%, indicating a very high reliance on surgical childbirth in these settings. Pakistan and India show moderate levels, with C-section rates of 25.8 and 23.5%, respectively, suggesting increasing institutional delivery and medical intervention during childbirth. Nepal records a comparatively lower prevalence at 18.2%, while Afghanistan shows the lowest level at only 3.6%, reflecting limited access to advanced obstetric care services.

It shows a regional disparity in C-section utilization, which may be associated with differences in healthcare infrastructure, accessibility of maternal health services, socioeconomic development, and variations in obstetric practices across countries. The pattern also indicates that several countries have already exceeded the recommended optimal level of C-section deliveries, raising concerns regarding potential over medicalization of childbirth in parts of South Asia.

The Figure 3 presents age wise differentials in C-section deliveries across selected South Asian countries using recent DHS estimates. Afghanistan reports the lowest C-section prevalence across all age-groups, rising slightly from 2.7% among women aged below 20 years to 5.3% among women aged 35–49 years. In contrast, Bangladesh shows consistently high C-section rates across reproductive age-groups, with the highest prevalence among women aged 20–34 years (45.1%), while women aged 35–49 years also record a high level at 36.3%.

In India, cesarean deliveries increase steadily with age, from 18.5% among mothers below 20 years to 28.1% among women aged 35–49 years, indicating greater medical intervention among older mothers. A similar pattern is evident in the Maldives, where C-section prevalence rises sharply with maternal age, reaching 49.0% among women aged 35–49 years, the highest observed across all countries and age-groups.

Nepal and Pakistan also demonstrate increasing C-section use with age. In Nepal, the rate increases from 9.1% among younger

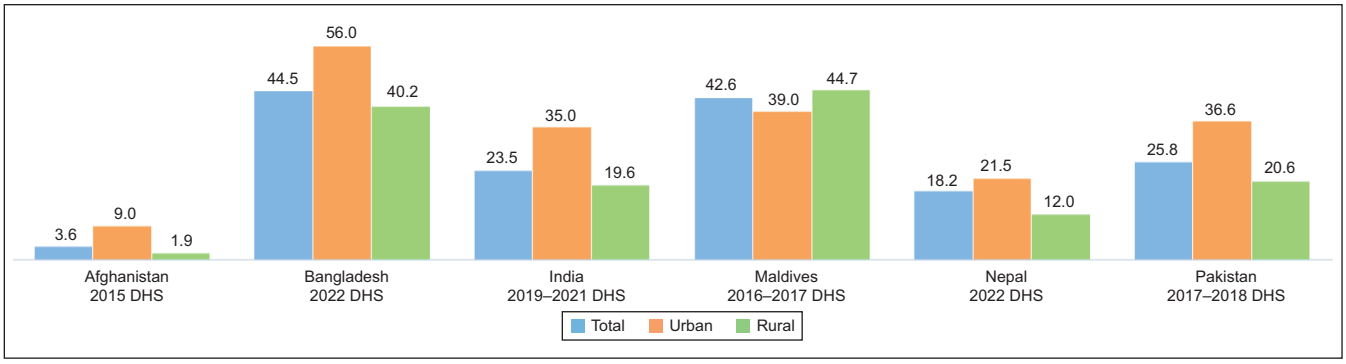

Fig. 4: Urban and rural differentials in C-section deliveries across selected South Asian countries based on recent DHS

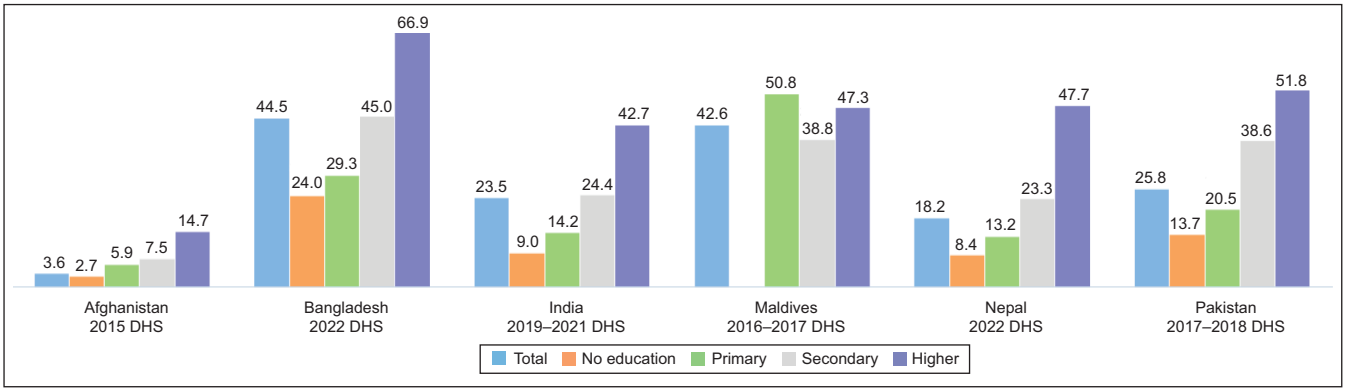

Fig. 5: Variation in C-section deliveries by women's educational attainment across selected South Asian countries using recent DHS data

mothers to 22.9% among older women, while in Pakistan it rises from 14.4 to 18.7% across the same age categories.

It is evident that maternal age as an important determinant of C-section delivery in South Asia, with older women consistently experiencing higher surgical delivery rates, possibly due to increased obstetric risks, delayed childbearing, and clinical decision-making associated with advanced maternal age.

The Figure 4 illustrates urban and rural differentials in C-section deliveries across selected South Asian countries based on recent DHS. Afghanistan shows very low overall utilization, with cesarean deliveries accounting for 3.6% of births, though urban areas report a higher prevalence (9.0%) compared to rural areas (1.9%). Bangladesh records the highest level of C-section delivery in the region, where urban prevalence reaches 56.0%, substantially exceeding the rural level of 40.2%, highlighting strong urban concentration of surgical childbirth.

In India, C-section prevalence stands at 23.5% overall, with a clear urban rural disparity, 35.0% in urban areas compared to 19.6% in rural settings. The Maldives presents a slightly different pattern, where both urban and rural rates are high, though rural areas (44.7%) marginally exceed urban areas (39.0%), suggesting widespread access to obstetric services across locations. Nepal and Pakistan also demonstrate notable residential inequality. In Nepal, cesarean delivery increases from 12.0% in rural areas to 21.5% in urban areas, while in Pakistan the rate rises sharply from 20.6% in rural regions to 36.6% in urban areas. Current study highlights persistent urban advantages in access to cesarean delivery services across South Asia, reflecting differences in healthcare infrastructure, availability of private health facilities, economic capacity, and service utilization patterns between urban and rural populations.

The Figure 5 presents the variation in C-section deliveries by women's educational attainment across selected South Asian countries using recent DHS data. A strong positive association between maternal education and C-section delivery is observed across all countries, indicating that women with higher education are more likely to undergo cesarean births. Afghanistan records very low C-section prevalence overall, though the rate increases gradually with education, rising from 2.7% among women with no education to 14.7% among those with higher education. Bangladesh shows extremely high levels across educational groups, with cesarean delivery increasing sharply from 24.0% among women with no education to 66.9% among highly educated women, suggesting substantial socioeconomic influence on delivery choices.

In India, C-section prevalence rises consistently with educational attainment, increasing from 9.0% among women without education to 42.7% among women with higher education. A similar educational gradient is evident in Nepal and Pakistan, where cesarean deliveries among highly educated women reach 47.7 and 51.8%, respectively, compared to much lower levels among women with no schooling. The Maldives presents comparatively high C-section use across all education categories, though women with primary education report the highest prevalence (50.8%), followed closely by those with higher education (47.3%), indicating widespread access to obstetric services regardless of educational background.

Education as a key socioeconomic determinant of C-section delivery in South Asia. Higher educational attainment is associated with greater utilization of institutional and often private healthcare services, increased awareness, delayed childbearing, and higher likelihood of medically assisted childbirth.

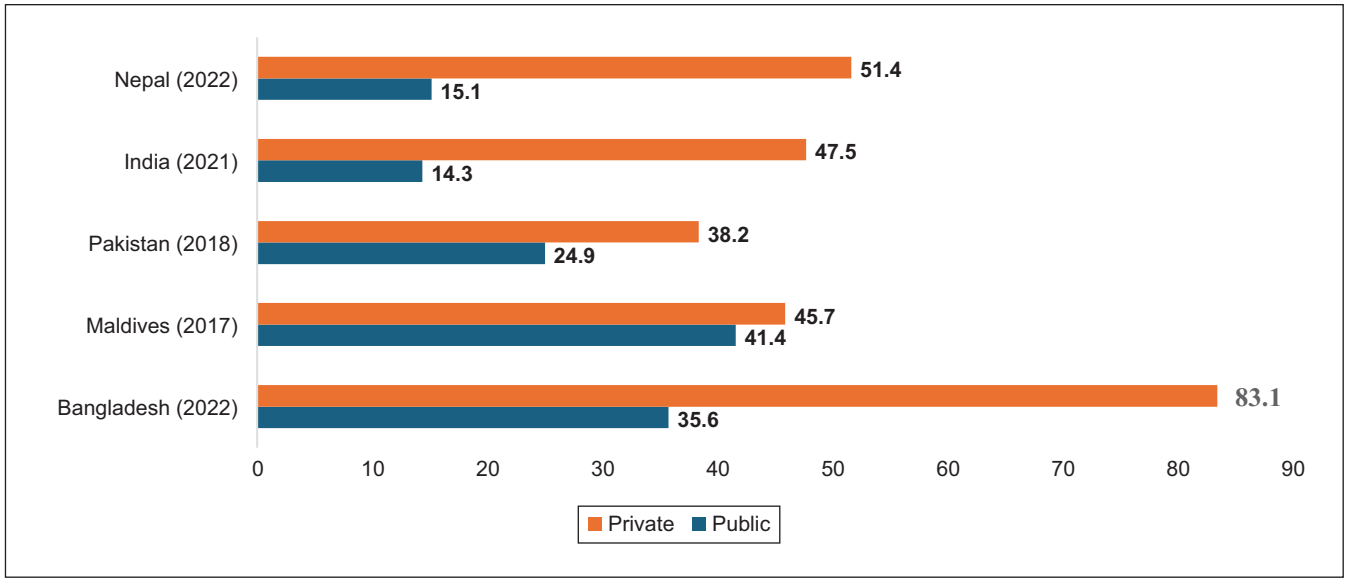

Fig. 6: Prevalence of C-section deliveries by type of health facility across selected South Asian countries using recent DHS data

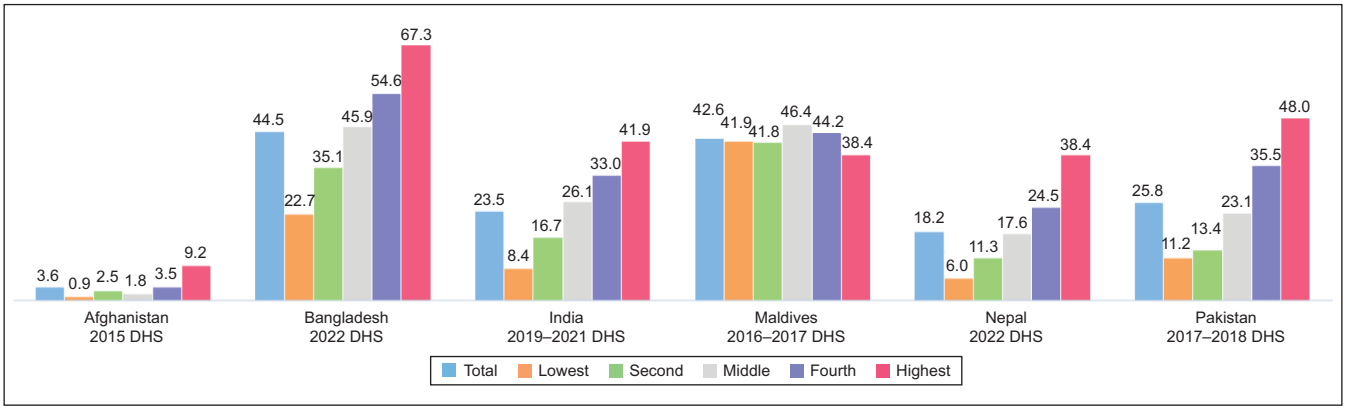

Fig. 7: Percentage of births delivered by C-section across selected South Asian countries using recent DHS data, disaggregated by wealth quintile

The Figure 6 illustrates the prevalence of C-section deliveries by type of health facility across selected South Asian countries, highlighting substantial differences between private and public healthcare sectors. Across all countries, C-section deliveries are consistently higher in private health facilities compared to public institutions.

Bangladesh records the widest gap, where cesarean deliveries account for 83.1% of births in private facilities compared to 35.6% in public facilities, indicating a strong concentration of surgical deliveries within the private sector. Nepal and India show similar patterns, with private sector cesarean rates reaching 51.4 and 47.5%, respectively, while public facility rates remain considerably lower at 15.1 and 14.3%.

In Pakistan, C-section prevalence is also higher in private facilities (38.2%) than in public facilities (24.9%), though the difference is relatively moderate. The Maldives presents a comparatively smaller disparity, with high C-section rates observed in both private (45.7%) and public (41.4%) facilities, suggesting widespread availability and utilization of obstetric surgical care across the health system.

The figure underscores the dominant role of the private healthcare sector in driving higher C-section rates in South Asia. The observed differences may reflect variations in service delivery practices, financial incentives, patient preferences, and access to institutional maternal healthcare, raising important public health concerns regarding potential overuse of cesarean procedures in private facilities.

The Figure 7 presents the percentage of births delivered by C-section across selected South Asian countries using recent DHS data, disaggregated by wealth quintile. Bangladesh shows the highest overall prevalence at 44.5%, rising sharply to 67.3% among the richest quintile, compared to 22.7% among the poorest. Pakistan and Nepal display similar patterns, with rates reaching 48.0 and 38.4%, respectively, among the wealthiest groups. India also demonstrates a marked disparity, increasing from 8.4% in the lowest quintile to 41.9% in the highest. In contrast, the Maldives exhibits relatively uniform rates across wealth groups, ranging from 38.4 to 46.4%, suggesting less pronounced inequality. Afghanistan reports the lowest overall cesarean prevalence at 3.6%, though even here the rate among the richest quintile, 9.2%, is substantially higher than among the poorest. Overall, the data indicate substantial wealth-based inequities in C-section utilization across South Asia, with higher use concentrated among economically advantaged population.

Discussion

The present study highlights a substantial rise in C-section deliveries across South Asian countries, indicating an ongoing transition toward medicalized childbirth in the region. The findings derived from recent DHS data demonstrate considerable cross-country variation along with strong socioeconomic, demographic, and health system differentials influencing C-section utilization. The increasing trend observed in Bangladesh, India, Pakistan, Nepal, and the Maldives reflects improvements in institutional delivery coverage and maternal healthcare access, though the magnitude of increase raises concerns regarding potential overuse of surgical intervention.

The rapid growth of C-section deliveries identified in this study is consistent with global evidence showing a steady increase in cesarean births, particularly in low- and middle-income countries. According to the WHO, C-section rates above 10–15% at the population level are not associated with additional reductions in maternal or neonatal mortality.[7] Several South Asian countries examined in this study, especially Bangladesh and the Maldives, have already surpassed this recommended threshold, suggesting a shift from medically necessary procedures toward elective or non-medically indicated cesarean deliveries. Similar trends have been documented by Boerma et al., who reported accelerating cesarean use worldwide, driven largely by socioeconomic development and expansion of private healthcare services.[8]

Maternal age emerges as an important determinant of C-section delivery across all countries included in the analysis. The study findings show higher cesarean prevalence among women aged 35–49 years compared to younger mothers. Existing literature supports this association, as advanced maternal age is linked with increased obstetric complications such as hypertension, gestational diabetes, and prolonged labor, which often result in surgical delivery.[9] Delayed childbearing among educated and urban women in South Asia may also contribute to rising cesarean rates.

Pronounced urban rural disparities observed in the study further reinforce the role of healthcare accessibility and socioeconomic advantage in shaping delivery outcomes. Urban women consistently report higher C-section utilization than rural women across most countries. Earlier studies from South Asia have shown that urban residence improves access to skilled birth attendants, specialized obstetric care, and private health facilities, which increases the likelihood of cesarean delivery.[1] Rural populations, on the other hand, often face infrastructural barriers, financial constraints, and limited availability of emergency obstetric services. Education related differentials identified in this analysis reveal a strong positive gradient between maternal education and C-section delivery. Women with higher education demonstrate substantially greater cesarean utilization across all countries. This finding aligns with previous research suggesting that educated women are more likely to seek institutional care, possess greater decision-making autonomy, and utilize private healthcare services.[10] Higher education is also associated with delayed fertility, smaller family size, and increased preference for planned childbirth, factors that may indirectly contribute to higher cesarean rates.

One of the most significant findings of the study relates to disparities by type of health facility. Cesarean section deliveries are markedly higher in private facilities compared to public institutions across South Asia. Bangladesh, India, and Nepal exhibit particularly wide public private gaps, supporting earlier evidence that financial incentives, provider convenience, and institutional practices may encourage higher surgical intervention in private settings.[7] Studies conducted in India and Bangladesh have similarly reported that private sector expansion plays a major role in the increasing medicalization of childbirth.[11] In contrast, the relatively smaller gap observed in the Maldives suggests more uniform access and regulation within the healthcare system.

From a public health perspective, the coexistence of low cesarean rates in countries such as Afghanistan and excessive levels in others reflects a dual burden of underuse and overuse within the region. While inadequate access to lifesaving obstetric care remains a challenge in resource constrained settings, unnecessary cesarean procedures expose mothers and newborns to avoidable health risks and increase healthcare costs. Addressing this imbalance requires strengthening clinical guidelines, improving regulation of private healthcare providers, and promoting evidence based obstetric decision-making.

Cesarean deliveries disproportionately concentrated among the richest women in Bangladesh, while similar socioeconomic gradients are observed in Pakistan, Nepal, and India. In India, the large gap between poorest and richest quintiles reflects unequal access to institutional and private maternity care, where cesarean deliveries are more common. Previous studies suggest that higher socioeconomic status, private health facility use, and maternal preference contribute to increased surgical deliveries in the region.[12] The results highlight a dual burden in South Asia, overuse among economically advantaged populations and underuse among poorer women, emphasizing the need for equitable and medically appropriate cesarean care.[13]

The study contributes to the growing body of literature emphasizing that C-section delivery in South Asia is shaped not only by medical need but also by socioeconomic inequality, demographic transition, and health system characteristics. Policy interventions aimed at ensuring equitable and appropriate use of C-section services are essential to achieving improved maternal and neonatal health outcomes in the region.

Key Limitations and Future Research

Cross-sectional DHS data limit causal interpretation. Future studies should use longitudinal or prospective designs. Limited explanatory variables prevented assessment of factors such as parity, previous C-section, pregnancy complications, and maternal preferences. Different survey years across countries may affect direct comparisons. Future research should use harmonized time periods. No maternal or neonatal outcomes were examined. Future studies should assess health outcomes, quality of care, and healthcare costs alongside C-section rates.

Conclusion

The study shows a substantial rise in C-section deliveries across South Asia, with wide variations between countries and population groups. Higher rates among older, educated, urban women and those delivering in private facilities suggest that socioeconomic status and access to healthcare strongly shape delivery choices. The findings point to a double burden in the region, overuse among wealthier groups alongside limited access for poorer women. In some countries, low rates signal gaps in access to essential obstetric services, while very high levels elsewhere raise concerns about unnecessary medical procedures. Promoting equitable and clinically

appropriate cesarean use through stronger regulation, better maternal health services, and evidence-based practice is critical to improving maternal and newborn health outcomes in South Asia.

Ethical Approval

The study is based on a secondary analysis of the demographic health survey, and no ethical approval was required. We registered and requested access to data from DHS online archive.

Artificial Intelligence (AI) Disclosure

No AI–assisted technologies were used.

Acknowledgment

The authors sincerely acknowledge the Demographic and Health Surveys (DHS) Program for providing access to the datasets used in this study. The authors also thank all survey participants and field teams involved in the respective DHS surveys.

Authors' Contributions

Sameer K Jena conceptualized the study, conducted data analysis, interpreted the findings, and drafted the manuscript. Moatula Ao contributed to study design, supervision, and critical revision of the manuscript. Liza K Gouda assisted in data interpretation and manuscript review. Jitendra Gouda contributed to methodological guidance and critical revision. All authors read and approved the final manuscript.

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ORIGINAL ARTICLE

Prevalence of Polypharmacy among the Geriatric Population in the Nearby Field Area of Indira Gandhi Hospital

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Abstract

Background: Population aging is a global phenomenon and represents a major public health challenge. Increased life expectancy and the growing burden of chronic diseases have resulted in increased medication use among older adults. Polypharmacy, commonly defined as the concurrent use of five or more medications, is associated with adverse drug reactions, drug–drug interactions, poor compliance, hospitalization, and increased healthcare expenditure. Although polypharmacy has become an important issue among elderly individuals, community-based studies from India remain limited.

Aim: To determine the prevalence and pattern of polypharmacy among the geriatric population residing in the nearby field area of Indira Gandhi Hospital, Dwarka Sector 9, New Delhi.

Materials and methods: A community-based observational cross-sectional study was conducted over a period of 3 months from 8 September to 7 November 2025. A total of 179 elderly individuals aged 65 years and above were selected by multistage simple random sampling. Information regarding demographic characteristics, disease profile, medication use, prescribing practices, self-medication, and adverse drug reactions was collected using a predesigned and pretested questionnaire. Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 23. Descriptive statistics were expressed as frequencies and percentages, and the Chi-square test was applied to assess associations between variables. A p-value < 0.05 was considered statistically significant.

Results: Among the 179 study participants, 109 (60.89%) were males, and 70 (39.11%) were females. Most participants belonged to the age-group of 70–74 years (41.90%). Overall, 164 (91.62%) participants were taking at least one medication. Hypertension (26.15%) and diabetes mellitus (24.87%) were the most common morbidities. Polypharmacy was observed in 38 participants (21.23%). Antihypertensive drugs (18.99%) and hypoglycemic agents (18.22%) were the most commonly consumed medications. Self-medication without a prescription was reported by 9.50% of participants, whereas adverse drug reactions were observed in 6.70%.

Conclusion: The prevalence of polypharmacy among elderly individuals residing in the nearby field area of Indira Gandhi Hospital was 21.23%. Rational prescribing, periodic medication review, and patient education are essential to reduce medication-related complications and improve the quality of care among older adults.

Keywords: Adverse drug reactions, Chronic diseases, Elderly, Geriatric population, Medication utilization, Polypharmacy.

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Introduction

Population aging is one of the most significant demographic transitions occurring worldwide. According to the World Health Organization, the proportion of elderly individuals is increasing rapidly, especially in developing countries such as India.[1] Advances in health care and improved life expectancy have resulted in a greater burden of chronic diseases and increased utilization of healthcare services.[2]

Older adults commonly suffer from multiple chronic illnesses, including hypertension, diabetes mellitus, arthritis, cardiovascular diseases, chronic respiratory disorders, and chronic kidney disease. Consequently, they are frequently exposed to multiple medications for prolonged periods.[3] Polypharmacy, generally defined as the use of five or more medications simultaneously, has become a growing concern in geriatric medicine because of its association with adverse drug reactions, drug interactions, medication non-adherence, functional decline, and increased hospitalization.[4,5]

Age-related physiological changes affect drug absorption, metabolism, distribution, and elimination, making elderly individuals particularly vulnerable to medication-related complications.[6] Inappropriate prescribing and self-medication practices further increase the risk of adverse events and poor therapeutic outcomes.[7]

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Source of support: The study was performed using departmental and institutional resources.

Conflict of interest: None

Several studies conducted across different countries have demonstrated a high prevalence of polypharmacy among older adults.[8,9] In India, community-based studies evaluating medication utilization patterns among elderly individuals are relatively scarce. Understanding the prevalence and determinants of polypharmacy is essential for promoting rational prescribing and improving medication safety among geriatric patients.[10]

Therefore, this study was undertaken to determine the prevalence of polypharmacy and medication utilization patterns

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among elderly individuals residing in the nearby field area of Indira Gandhi Hospital, Dwarka Sector 9, New Delhi.

Aim

To study the prevalence of polypharmacy and potentially inappropriate medication use among the geriatric population residing in the nearby field area of Indira Gandhi Hospital, Dwarka Sector 9, New Delhi.

Objectives

- To estimate the prevalence of polypharmacy among elderly individuals.
- To study the pattern of medication use among the study population.
- To assess adverse drug reactions associated with medication use.

Materials and Methods

Study Design

Community-based observational descriptive cross-sectional study.

Study Area

Nearby field area of Indira Gandhi Hospital, Dwarka Sector 9, New Delhi.

Study Duration

Three months (8 September–7 November 2025).

Study Population

Individuals aged 65 years and above residing in the study area.

Inclusion Criteria

- Individuals aged 65 years and above.
- Participants are willing to participate in the study.
- Individuals whose information was provided by caregivers or informants when required.

Exclusion Criteria

- Individuals aged below 65 years of age.
- Non-responders without an informant.
- Seriously ill or non-cooperative individuals.

Sample Size

The sample size was calculated using standard prevalence estimation formulas. The minimum calculated sample size was 178. A total of 179 elderly individuals were included in the study.

Sampling Technique

A multistage simple random sampling technique was employed.

Stage I

Among the four nearby areas of Indira Gandhi Hospital (Dwarka Sectors 7, 9, 10, and 11), Dwarka Sector 9 was selected by simple random sampling.

Stage II

Eligible elderly individuals were enumerated, and 179 participants were selected by simple random sampling.

Table 1: Age distribution of study subjects ($n = 179$)

Age-group (in years)	*Count*	*Percentage (%)*
≥80	11	6.15
65–69	66	36.87
70–74	75	41.90
75–79	27	15.08
Total	**179**	**100.00**

Bold values indicate statistically significant findings ($p < 0.05$)

Table 2: Distribution of study subjects according to medicines consumed for any disease ($n = 179$)

Medication	*Count*	*Percentage (%)*
Yes	164	91.62
No	15	8.38
Total	**179**	**100.00**

Bold values indicate statistically significant findings ($p < 0.05$)

Table 3: Distribution of study subjects based on the number of medicines consumed daily ($n = 179$)

Medicines consumed daily	*Count*	*Percentage (%)*
1	36	20.11
2	25	13.97
3	50	27.93
4	30	16.76
5	27	15.08
6	10	5.59
7	1	0.56
Total	**179**	**100.00**

Bold values indicate statistically significant findings ($p < 0.05$)

Table 4: Distribution of study subjects based on polypharmacy ($n = 179$)

Polypharmacy	*Count*	*Percentage (%)*
Present	38	21.23
Absent	141	78.77
Total	**179**	**100.00**

Bold values indicate statistically significant findings ($p < 0.05$)

Data Collection

Data were collected through house-to-house visits using a predesigned and pretested questionnaire translated into the local language. Information regarding demographic characteristics, disease profile, medication use, prescribing practices, self-medication, and adverse drug reactions was recorded.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 23. Descriptive statistics were expressed as frequencies and percentages. The Chi-square test was used to determine associations between variables. A p-value < 0.05 was considered statistically significant.

Results

A total of 179 elderly individuals aged 65 years and above participated in the study, as presented in Tables 1 to 10 and Figures 1 to 3.

Table 5: Distribution of study subjects based on categories of drugs consumed ($n = 179$)

Drugs consumed	*Count*	*Percentage (%)*
Antacids	34	6.59
Antianginal	15	2.91
Antiarrhythmics	0	0.00
Antibiotics	23	4.46
Anticancer	10	1.94
Anticoagulants	8	1.55
Antidepressants	1	0.19
Antiemetics	11	2.13
Antiepileptics	10	1.94
Anthelmintics	0	0.00
Antihypertensives	98	18.99
Antihistamines	3	0.58
Antirheumatics	15	2.91
Antispasmodics	0	0.00
Antitussives	4	0.78
Bronchodilators	30	5.81
Diuretics	18	3.49
Hypoglycemic	94	18.22
Hypolipidemics	8	1.55
NSAIDs	47	9.11
Others	69	13.37
PPIs	15	2.91
Sedatives	3	0.58
Total	**516**	**100.00**

NSAID, nonsteroidal anti-inflammatory drug, PPI, proton pump inhibitors. Bold values indicate statistically significant findings ($p < 0.05$)

Table 6: Distribution of study subjects based on the person prescribing the drugs ($n = 179$)

Person prescribing the drugs	*Count*	*Percentage (%)*
Government doctor	108	60.34
Private doctor	64	35.75
RMP	7	3.91
Total	**179**	**100.00**

RMP, registered medical practitioner. Bold values indicate statistically significant findings ($p < 0.05$)

Table 7: Distribution of study subjects based on taking drugs from the pharmacy without a prescription ($n = 179$)

Drugs are consumed directly from the pharmacy without a prescription	*Count*	*Percentage (%)*
Yes	17	9.50
No	162	90.50
Total	**179**	**100.00**

Bold values indicate statistically significant findings ($p < 0.05$)

Table 8: Distribution of study subjects based on medication other than allopathy ($n = 179$)

Medication consumed other than allopathy	*Count*	*Percentage (%)*
Yes	23	12.85
No	156	87.15
Total	**179**	**100.00**

Bold values indicate statistically significant findings ($p < 0.05$)

Table 9: Distribution of study subjects consuming medicines based on systems of medicine other than allopathy ($n = 179$)

Systems other than allopathy	*Count*	*Percentage (%)*
Ayurveda	14	53.85
Homeopathy	12	46.15
Siddha	0	0.00
Yunani	0	0.00

Table 10: Distribution of study subjects based on adverse drug reactions after consuming medication ($n = 179$)

Adverse drug reactions after taking medications	*Count*	*Percentage (%)*
Yes	12	6.70
No	167	93.30
Total	**179**	**100.00**

Bold values indicate statistically significant findings ($p < 0.05$)

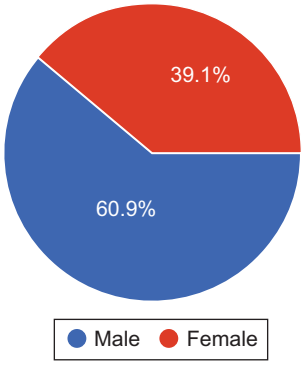

Fig. 1: Gender distribution of study subjects ($n = 179$)

Discussion

This community-based cross-sectional study assessed the prevalence and pattern of polypharmacy among elderly individuals residing in the nearby field area of Indira Gandhi Hospital, Dwarka Sector 9, New Delhi.

The majority of study participants belonged to the age-group of 70–74 years, and males constituted a greater proportion of the study population. Similar demographic characteristics have been reported by Fried et al. and Guthrie et al.[11,12]

In this study, 91.62% of participants were taking at least one medication. The high burden of medication use reflects the increasing prevalence of chronic diseases among elderly individuals. Comparable findings have been reported in previous studies evaluating medication use among older adults.[12]

Hypertension and diabetes mellitus were the most common morbidities observed in this study. These findings are in accordance with reports by Hajjar et al. and Morin et al., who demonstrated that cardiovascular diseases and diabetes are major contributors to medication burden among older adults.[13,14]

Polypharmacy was observed in 21.23% of study participants. This prevalence is comparable to findings reported in previous community-based studies. The increased prevalence of polypharmacy among elderly individuals can be attributed to multimorbidity and prolonged treatment requirements.[11]

Antihypertensive agents and hypoglycemic drugs were the most frequently consumed medications, reflecting the

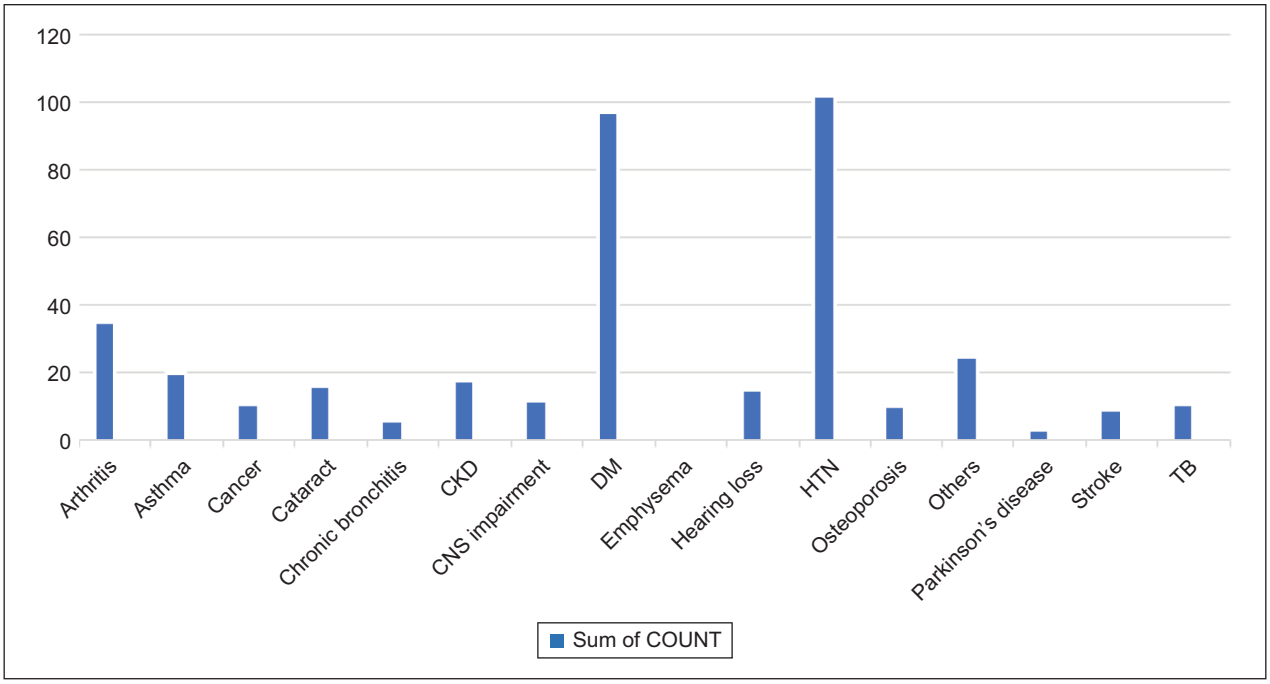

Fig. 2: Distribution of study subjects according to diseases suffered (*n* = 179)

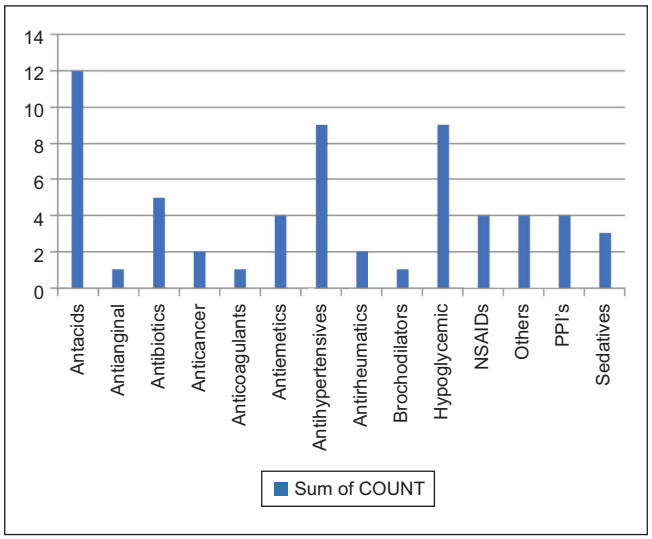

Fig. 3: Distribution of study subjects based on drugs consumed without prescription (*n* = 179)

predominance of hypertension and diabetes mellitus in the study population. Similar observations have been reported by earlier investigators.[13]

Self-medication practices were observed among 9.50% of participants. Unsupervised use of medications, particularly antacids and hypoglycemic agents, may predispose elderly individuals to adverse drug reactions and drug interactions. Such practices emphasize the need for patient education and rational medication use.[15]

Adverse drug reactions were reported in 6.70% of participants. Although the proportion was relatively low, elderly individuals remain particularly susceptible to medication-related complications because of age-related physiological changes and exposure to multiple drugs.[1,3]

The findings of this study highlight the importance of periodic medication review, rational prescribing, patient counseling, and close monitoring of drug therapy to reduce inappropriate polypharmacy and improve health outcomes among older adults.

Limitations of the Study

- The study was conducted over a short duration and involved a relatively small sample size.
- Being a cross-sectional study, causal relationships between polypharmacy and adverse outcomes could not be established.
- Medication information was based largely on self-reporting and may be subject to recall bias.
- Detailed prescription review and assessment of potentially inappropriate medications according to the Beers criteria were not performed.
- Since the study was conducted in a single geographical area, the findings may not be generalized to all elderly populations.

Conclusion

This study demonstrated that the prevalence of polypharmacy among elderly individuals residing in the nearby field area of Indira Gandhi Hospital, Dwarka Sector 9, New Delhi, was 21.23%. Hypertension and diabetes mellitus were the most common chronic diseases contributing to increased medication use. Antihypertensive and hypoglycemic agents constituted the most frequently consumed medications. Self-medication practices and adverse drug reactions were also observed among a proportion of participants. Rational prescribing, regular medication review, patient counseling, and close monitoring are essential to minimize medication-related complications and improve the quality of health care among elderly individuals.

Strengths of the Study

- The study was community-based and provided real-world information regarding medication utilization patterns among elderly individuals.
- Random sampling improved the representativeness of the study population.
- Information regarding polypharmacy, prescribing patterns, self-medication practices, and adverse drug reactions was evaluated simultaneously.
- The findings contribute to the limited community-based data available regarding polypharmacy among elderly individuals in India.

Recommendations

- Periodic medication review should be incorporated into routine geriatric care.
- Rational prescribing practices should be encouraged to reduce inappropriate polypharmacy.
- Elderly patients should be educated regarding safe medication practices and the hazards of self-medication.
- Regular screening for drug–drug interactions and adverse drug reactions should be undertaken.
- Further multicentric studies involving larger sample sizes are recommended.

Declarations

Ethical Approval

The study was conducted after obtaining approval from the Institutional Ethics Committee of Indira Gandhi Hospital, Dwarka Sector 9, New Delhi.

Institutional Ethics Committee Name: IGH

Approval Number: 4754

Date of Approval: 20/12/2025

Informed Consent Statement

Informed consent was obtained from all the participants for the publication of this research paper.

Clinical Trial Registration

Clinical trial registration was not applicable because this study was a community-based observational cross-sectional study.

Authentication Statement

The authors certify that this manuscript is original and has not been published previously. The manuscript is not under consideration for publication elsewhere. All authors have read and approved the final version of the manuscript and agree to its submission.

Data Availability

The data generated and/or analyzed during the present study are available from the corresponding author on reasonable request, subject to appropriate ethical and privacy considerations.

Artificial Intelligence (AI) Disclosure

ChatGPT (OpenAI) was used to assist with language editing, grammar correction, and improvement of the clarity and presentation of the manuscript. The authors reviewed and edited the output and take full responsibility for the accuracy, integrity, originality, and final content of the manuscript.

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Authors' Contributions

- Conceptualization and study design: Chandan Kumar, Amrita Mishra.
- Data collection and fieldwork: Chandan Kumar, Amrita Mishra.
- Data entry and statistical analysis: Chandan Kumar, Amrita Mishra.
- Interpretation of results and literature review: Chandan Kumar, Amrita Mishra.
- Manuscript drafting and critical revision: Chandan Kumar, Amrita Mishra.
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ORIGINAL ARTICLE

Effectiveness of Health Promotion Program on Knowledge and Lifestyle Practice Regarding Hypertension Prevention among Adults Residing in Urban Communities

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Received on: 10 August 2025; *Accepted on:* 07 December 2025; *Published on:* 28 September 2026

Abstract

Objectives: This study has been undertaken to assess the effectiveness of the Health Promotion Program on Knowledge and lifestyle practices regarding hypertension (HTN) prevention. The target population for the study was adults residing in selected urban communities and aged between 19 and 30 years (early adulthood).

Intervention: The Health Promotion Program was prepared and conducted by referring to Pender's Health Promotion Model, focusing on physical activity, stress management, and dietary management.

Methodology: A quantitative research approach with a pre-experimental research design was adopted for the study. A total of 60 samples were selected by a nonprobability convenience sampling technique. Data were collected using a structured questionnaire and checklist regarding HTN prevention. The data were collected and analyzed using both descriptive and inferential statistics to find out the significant difference between the pre-test and post-test knowledge and practice scores.

Results: Mean pre-test knowledge score was 14.21 ± 3.80 and mean post-test knowledge score was 22.35 ± 2.66 with mean difference of 8.13 and (t = 25.40, df = 59); Mean pre-test practice score was 8.22 ± 3.11 and mean post-test practice score was 15.65 ± 2.22 with mean difference of 7.43 and (t = 19.49, df = 59) was found statistically highly significant at 0.05 level of significance.

Discussion and conclusion: The Health Promotion Program had a significant influence on adults, resulting in a significant increase in knowledge and lifestyle practice after implementation of the program. Participants had expressed commitment to the plan of action regarding HTN prevention.

Keywords: Early adulthood, Health promotion, Hypertension, Knowledge, Lifestyle practice, Prevention.

Health and Population: Perspectives and Issues (2026): 10.5005/hppi-11041-0077

Introduction

Background of the Study

Non-communicable diseases (NCDs) are often referred to as "lifestyle diseases" because many of these conditions are preventable through changes in behavior and lifestyle. The primary risk factors for NCDs include tobacco use, alcohol consumption, unhealthy diets, and physical inactivity.[1] Chronic diseases have now become the leading cause of death among adults globally, with projections showing that by 2020, deaths from NCDs in developing countries will match those caused by communicable diseases. Annually, tobacco use is responsible for approximately 5 million deaths, while being overweight contributes to 2.8 million deaths. High cholesterol leads to around 2.6 million deaths, and hypertension (HTN) is responsible for 7.5 million deaths each year. It is expected that by 2030, the number of deaths from chronic NCDs will rise to 52 million annually. Cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes account for 80% of these deaths.[2]

Hypertension, a chronic and often asymptomatic condition, is a significant contributor to the burden of NCDs. It is defined by persistently high blood pressure and serves as a major risk factor for coronary artery disease, heart failure, cerebrovascular diseases, and chronic kidney disease. A large number of people with HTN in India are unaware of their condition, which exacerbates the health impact. In India, HTN contributes to 10.8% of all deaths and 4.6% of disability-adjusted life years (DALYs).[3]

The healthcare system faces several challenges, including the need to reduce healthcare costs and effectively prevent and manage NCDs. Improving the quality of care, ensuring access to care, and promoting health-focused care are essential for reforming the healthcare system in a way that benefits patients. A focus on health promotion and prevention should be at the core of any health system transformation. As the saying goes, "Prevention is better than cure." Through effective preventive measures, the burden of NCDs can be reduced. Therefore, the healthcare response should not only focus on diagnosing and treating diseases but also prioritize prevention and health promotion strategies.[4]

Health promotion programs aim to keep people healthy by addressing factors that influence health behavior. Nurses and

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healthcare professionals must understand the variables most predictive of health behaviors and incorporate this knowledge into practice. Healthcare is increasingly moving towards a science-based approach that integrates the latest insights from the behavioral and biological sciences to help people from diverse cultural backgrounds adopt healthier lifestyles.[5] Healthcare reform should focus on promoting health and preventing disease, particularly within community health settings. In these settings, health promotion and disease prevention programs can be implemented more effectively than in clinical settings that are focused on treatment.[4]

Higher levels of health knowledge typically lead to more positive behaviors related to health. Health promotion strategies that target modifiable risk factors for HTN can significantly help in preventing the condition and its complications. Key measures for preventing HTN include weight reduction, lifestyle changes, and the effective management of underlying conditions. Primary prevention, which includes educating the public and encouraging healthier lifestyle choices, is crucial for addressing HTN and its associated risks.[6] The impact of health promotion on the overall health of populations remains uncertain until it is applied broadly in community programs and services.[4] This study aimed to evaluate the effectiveness of health promotion programs in preventing HTN. It contributes valuable insights into various health promotion approaches that can be beneficial in the development and implementation of similar programs, ultimately helping to reduce the burden of HTN within communities.

Objectives and Scope of Paper

- Develop and implement a Health Promotion Program on HTN prevention.
- Assess effectiveness of Health Promotion Program.
- Contribute to the body of knowledge regarding various health-promoting approaches which can be helpful in the development and implementation of similar programs and services.

Review of Literature (ROL)

A comprehensive ROL was conducted to explore two key areas: (i) the existing knowledge and lifestyle practices related to HTN and its prevention and (ii) the effectiveness of health-promoting interventions aimed at preventing HTN. This review provided valuable insights into the current understanding of the topic.

The Health Promotion Program was developed by integrating various health promotion strategies identified through the ROL. Sources included the National Family Health Survey Reports, Rural Health Information Hub, training modules on NCD prevention for community workers, population-based policies for HTN prevention and control, WHO reports, the National Institute of Health, as well as previous research articles and relevant textbooks.[5,7–9]

Methodology

Research Approach, Design, Number of Samples, Sampling Technique, and Pilot Study

A quantitative research approach was employed, utilizing a pre-experimental one-group pre-test and post-test design. A total of 60 participants were selected using a non-probability convenience sampling method from urban communities in Vadodara. The reliability of the research tool was assessed using the test–retest method, with the tool showing a reliability coefficient of 0.91 for knowledge and 0.87 for practice. Data were collected from selected urban areas of Vadodara, including New Sama, Chhani, Bapod, Khodiyarnagar, and Kishanwadi, between June 6, 2024, and July 16, 2024.

Table 1: Description of health promotion program on HTN prevention

Description of health promotion program	
Meaning of HTN	Definition and nature of HTN
Pathophysiology	Common causes, risk factors, symptoms, and pathophysiology of HTN
Physical activity	Importance of physical activity in reduction of BP
	Facts and myths about the effect of physical activity on BP
Stress management	Stress management techniques
	Time management techniques
	Sleep and rest
Dietary management	Salt reduction, tips to reduce salt
	Sources of saturated and unsaturated fat and their effect on BP
	Hidden sources of sodium and cholesterol
	Instructions during purchasing, cooking, and eating foods

BP, blood pressure; HTN, hypertension

Description of Tool

Data were collected using a structured knowledge questionnaire and a checklist focused on HTN prevention. The tool was divided into two sections:

Section I

This section included structured questions designed to gather socio-demographic information from the participants, such as age, gender, religion, marital status, residential status, level of education, family income, family history of HTN, lifestyle habits (e.g., smoking, alcohol use), dietary patterns, type of work, and junk food consumption. Additionally, it included a set of questions to assess participants' knowledge of HTN and its prevention, covering areas like its definition, pathophysiology, physical activity, stress management, and dietary management.

Section II

This section contained a checklist to evaluate the participants' practices related to HTN prevention, specifically focusing on behaviors that support the reduction of HTN risk.

Description of Intervention (Health Promotion Program)

Table 1 reveals that the health promotion program based on Pender's Health Promotion Model was focused on stress management, dietary management, and the role of physical activity through various learning activities, such as group discussions and the use of audiovisual aids.[10–12] The program aimed to engage and empower individuals and communities to adopt healthier behaviors and make lifestyle changes that reduce the risk of developing HTN. Key elements considered in the development and delivery of the program included:

- Perceived benefits of HTN prevention.

Table 2: Frequency and percent distribution of pre-test and post-test scores of knowledge and lifestyle practice

			Pre-test		*Post-test*	
Variable	*Score*	*Grade*	*Frequency*	*%*	*Frequency*	*%*
Knowledge	≤8	Poor	5	8.33%	0	0%
	09–17	Average	36	60%	6	10%
	18–26	Good	19	31.66%	54	90%
Lifestyle practice	≤10	Poor	47	78.33%	0	0%
	≥11	Good	13	21.66%	60	100%

- Identification and reduction of barriers to HTN prevention.
- Enhancement of self-efficacy regarding HTN prevention.
- Exploration of positive and negative feelings toward adopting a healthy lifestyle.
- Assessment of interpersonal influences and situational factors affecting the target population.

These factors were integral in tailoring the program to effectively promote HTN prevention.

Analysis and Interpretation

Both descriptive and inferential statistical methods were employed to analyze the data.

Analysis and Interpretation of Demographic Data of Samples

The statistical analysis of frequency and percentage distribution of demographic variables provided valuable insights into the individual characteristics and lifestyle experiences of the participants. These factors were categorized into biological (age, gender), socio-cultural (religion, marital status, educational status, family history, family income, residential status), and lifestyle-related (dietary habits, bad habits, type of work, junk food consumption) factors.

The findings indicated that the majority of participants were in the 19–24 age-group (51.66%), male (63.33%), Hindu (95%), unmarried (51.66%), lived in homes (70%), and had at least a graduation-level education (58.33%). Regarding income, most had a monthly family income between 10,001 and 25,000 INR (36.66%) and reported a family history of HTN (55%). In terms of lifestyle, the majority had no bad habits (66.66%), followed a vegetarian diet (66.66%), engaged in moderate work (50%), and were prone to consuming junk food (78.33%).

Analysis and Interpretation of Pre-test and Post-test Knowledge and Practice Scores of Samples

Table 2 and Figure 1 reveal the frequency and percentage distribution of pre-test and post-test knowledge scores. Out of the 60 respondents, 5 (8.33%) had poor knowledge, 36 (60%) had average knowledge, and 19 (31.66%) had good knowledge in the pre-test. In contrast, the post-test results showed that none of the respondents had poor knowledge, 6 (10%) had average knowledge, and 54 (90%) demonstrated good knowledge.

Table 2 and Figure 2 reveal the frequency and percentage distribution of pre-test and post-test practice scores. The pre-test indicated that the majority of respondents, 47 (78.33%), exhibited poor practices, while 13 (21.66%) demonstrated good practices. However, in the post-test, all 60 (100%) respondents showed good practices related to HTN prevention.

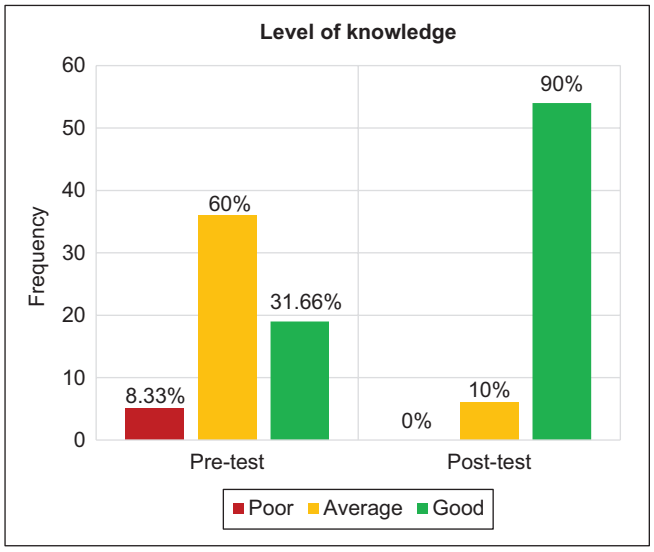

Fig. 1: Frequency and percent distribution of pre-test and post-test scores of knowledge

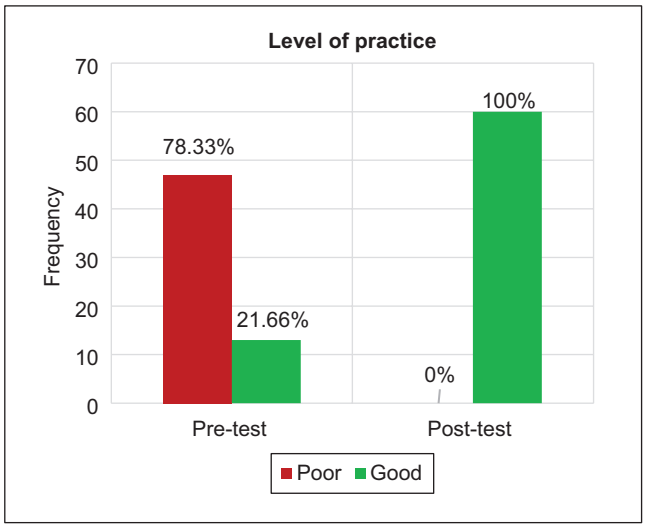

Fig. 2: Frequency and percent distribution of pre-test and post-test scores of lifestyle practice

Analysis and Interpretation of the Effectiveness of Health Promotion Program on Knowledge and Lifestyle Practice for HTN Prevention

The effectiveness of the intervention was evaluated using parametric tests (*t*-test) (Table 3). The mean pre-test knowledge

Table 3: Mean score, mean difference, SD, and "*t*" value of pre-test and post-test knowledge and practice scores (*N* = 60)

Variable	*Test*	*Mean*	*Mean difference*	*SD*	*"t" value*	*df*	*p-value*
Knowledge	Pre-test	14.21	8.13	3.80	25.40	59	0.000*
	Post-test	22.35		2.66			
Practice	Pre-test	8.22	7.43	3.11	19.49	59	0.000*
	Post-test	15.65		2.22			

*Level of significance 0.05. SD, standard deviation

score was 14.21 ± 3.80, while the mean post-test knowledge score was 22.35 ± 2.66, with a mean difference of 8.13 (t = 25.40, df = 59). Similarly, the mean pre-test practice score was 8.22 ± 3.11, and the mean post-test practice score was 15.65 ± 2.22, showing a mean difference of 7.43 (t = 19.49, df = 59). Both results were statistically significant at the 0.05 level. These findings indicate that the Health Promotion Program was highly effective in enhancing both the knowledge and practices of participants regarding HTN prevention.

Discussion

The pre-test findings revealed a significant gap in respondents' knowledge about the factors contributing to HTN and its prevention. Many participants had limited understanding of crucial topics such as the recommended daily sodium intake, stress and time management techniques, hidden sources of salt, and the distinction between saturated and unsaturated fats. Moreover, the study highlighted a lack of self-efficacy among participants when it came to adopting health-promoting behaviors, mainly due to insufficient awareness of the detrimental effects of unhealthy lifestyles. Factors like educational, social, and occupational stress were identified as key contributors to the daily habits of young adults, underscoring the growing challenge of empowering this demographic to prevent NCDs.

The Health Promotion Program focused on improving knowledge and lifestyle practices related to HTN prevention, and it showed a significant positive effect. Following the program, participants demonstrated a marked improvement in both their understanding and their lifestyle choices. Furthermore, they showed a strong commitment to implementing actionable plans for HTN prevention. These results suggest that Health Promotion Programs can be highly effective in improving health outcomes across large, diverse populations and settings.

Study Limitations

The study was conducted among adults aged 19–30 years; therefore, the findings cannot be generalized to other age-groups. The study was limited to selected urban areas, which may restrict generalizability of the findings to rural populations or other geographical settings. The study focused exclusively on the primary prevention of HTN and did not assess secondary and tertiary preventive measures, limiting the scope of its findings.

Conclusion

This research can help healthcare providers develop a systematic, problem-solving approach to enhance health outcomes and design effective strategies for promoting well-being among individuals. The researcher acknowledges that the full impact of health promotion on population health can only be fully assessed once it is widely implemented through community-based programs and services. As such, this Health Promotion Program focused on HTN prevention offers valuable insights into various health promotion strategies, which can play a crucial role in the development and implementation of similar programs and services.

Clinical Significance

In healthcare practice, this study provides valuable insights into health promotion strategies, especially for community health workers. Health promotion and disease prevention are more effectively implemented at the community level than programs that focus solely on treating existing conditions. In terms of health administration, the study underscores the importance of integrating health-promoting and illness-prevention strategies when planning and delivering healthcare services. From a research perspective, this study contributes to the growing body of knowledge on the effectiveness of health promotion programs in preventing HTN, offering useful recommendations for future initiatives in this field.

Recommendations

- A similar study could be conducted with a larger sample size to validate and generalize the findings.
- The same health promotion approach could be applied to develop programs aimed at preventing health issues that are influenced by environmental and behavioral factors.
- An experimental study could be carried out to evaluate the effectiveness of a Health Promotion Program on knowledge and lifestyle practices related to HTN prevention among adults in selected colleges.
- A study could be conducted to assess the effectiveness of a Health Promotion Program in the prevention of various NCDs.

Declarations

Ethical Approval

Ethical approval for this study was obtained from the institute-Level Ethical Approval Committee. The approval reference number is PNC/13-A dated 14 June 2023.

Clinical Trial Registration

Not applicable, as this study was not a clinical trial.

Data Availability Statement

The data generated and analyzed during the study are not publicly available due to participant confidentiality and ethical considerations but can be available from corresponding author on reasonable request, subject to appropriate permissions.

Artificial Intelligence (AI) Disclosure

No generative AI tools were used in the research process, data analysis, or the preparation of the manuscript.

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Authors' Contributions

The author(s) contributed to the study, data collection, data analysis and interpretation, preparation of the manuscript, and approval of the final version for publication.

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ORIGINAL ARTICLE

Emotional Intelligence and Job Satisfaction in the IT Sector: A Cross-sectional Study across Major Indian Technology Hubs

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Abstract

Background: Emotional intelligence (EI) has been identified as a significant psychological factor influencing employee behavior and workplace outcomes. However, its relationship with job satisfaction remains inconsistent across different professional settings.

Objective: The present study aims to examine the relationship between EI and job satisfaction among information technology (IT) professionals in major Indian technology hubs.

Methods: A cross-sectional research design was employed with a sample of 200 IT employees from Pune, Bengaluru, and Hyderabad. Data were collected using the Schutte Self-Report Emotional Intelligence Test (SSEIT) and the Job Satisfaction Survey (JSS). Statistical analyses included descriptive statistics, Pearson's correlation, and one-way analysis of variance (ANOVA).

Results: The findings revealed a negligible positive correlation between EI and job satisfaction ($r = 0.030$). No significant differences were observed across gender or geographic location. Age showed a significant relationship with EI but not with job satisfaction.

Conclusion: The results indicate that EI may not be a strong predictor of job satisfaction in the IT sector. Organizational and structural factors may play a more dominant role in influencing employee satisfaction. Other factors, like the hybrid model of work after the COVID pandemic and the role of emerging artificial intelligence (AI), may be affecting the dynamics.

Keywords: Cross-sectional study, Emotional intelligence, India, Information technology sector, Job satisfaction.

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Introduction

In today's modern workplace, where organizations are working to create inclusive, resilient, and high-performance cultures, emotional intelligence (EI) has become a critical driver of employee behavior and workplace outcomes.[1] It is commonly defined as the ability to perceive, understand, regulate, and utilize emotions effectively in oneself and others.[1] Subsequent models expanded this concept to include broader emotional and social competencies that support individuals in adapting to environmental demands.[2] Together, these perspectives position EI as an important factor in organizational functioning.

Job satisfaction refers to the positive emotional state resulting from an individual's appraisal of their job experiences.[3] It encompasses both intrinsic factors, such as meaningful work and achievement, and extrinsic factors, including pay, supervision, and work conditions. High levels of job satisfaction are associated with improved productivity, reduced absenteeism, lower turnover rates, and better overall well-being. Employees who experience satisfaction at work tend to display positive attitudes, higher motivation, and stronger organizational commitment. A substantial body of research has examined the relationship between EI and job satisfaction, which refers to an individual's overall evaluation of their job and work experiences.[4] Prior studies suggest that individuals with higher EI are better equipped to manage stress, maintain positive interpersonal relationships, and cope with workplace challenges, thereby enhancing their level of job satisfaction.[5]

Despite this, empirical findings remain inconsistent. Several studies report only weak to moderate relationships between EI and job satisfaction. For instance, Karimi et al. found that although EI contributes to overall employee well-being, its direct influence on job-related outcomes is limited and often mediated by factors such as stress and work environment.[6] Similarly, Miao et al. observed a positive but modest association, noting that the strength of this relationship varies across organizational and cultural contexts.[7]

Further research indicates that organizational and contextual variables may exert a stronger influence on job satisfaction than EI alone. Ealias and George demonstrated that demographic and situational factors significantly shape the EI–job satisfaction relationship, suggesting that EI does not function as a universal predictor.[8] Additionally, factors such as work climate, leadership style, and job stress have been consistently identified as more powerful determinants of employee satisfaction.

In certain professional settings, the relationship between EI and job satisfaction appears negligible or statistically insignificant. For example, Ghoreishi et al. reported no significant association among hospital employees, while Gill et al. found that EI did not significantly predict job satisfaction among faculty members in professional institutions.[9,10] These findings underscore the context-dependent nature of EI's influence.

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Within the information technology (IT) sector, research on this relationship remains limited, particularly in the Indian context. The IT industry is characterized by high job demands, rapid technological change, and intense performance pressure. In such environments, structural factors such as workload, compensation, and career advancement opportunities may play a more dominant role in shaping job satisfaction than individual emotional competencies. This raises questions about the extent to which EI can reliably predict job satisfaction in this sector.

Overall, the literature suggests that while EI is an important construct, its relationship with job satisfaction is complex, indirect, and highly context-dependent. The variability in findings highlights the need for further empirical investigation, especially within high-demand industries such as IT. Accordingly, the present study seeks to examine the relationship between EI and job satisfaction among IT professionals across major Indian technology hubs, such as Pune, Bengaluru, and Hyderabad. These cities represent significant technological and economic centers where employees work in highly competitive and dynamic environments. More specifically, the study aims to assess levels of EI and job satisfaction, compare these variables across cities and gender, and determine whether EI significantly predicts job satisfaction. The findings may provide practical interventions for organizational development, employee training programs, and human resource strategies aimed at enhancing employee well-being and productivity.

Objectives of the Study

- To assess the overall levels of EI and job satisfaction among IT sector employees working in the three major IT hubs—Pune, Bengaluru, and Hyderabad.
- To examine the relationship between EI and job satisfaction among IT sector employees.
- To determine the predictive role of EI in job satisfaction among IT sector employees, with special consideration to demographic factors such as age, gender, work experience, and job role.
- To examine gender dynamics in EI and job satisfaction among IT sector employees across the selected IT hubs.

Subjects and Method

Duration of the study was for six months from September 2025 to February 2026. The present study employed a quantitative, cross-sectional, and non-experimental research design to examine the role of EI in predicting job satisfaction among employees in the IT sector across three major Indian cities—Pune, Bengaluru, and Hyderabad. A correlational framework was used to assess the strength and direction of the relationship between EI and job satisfaction, along with a comparative component to explore differences across these IT hubs. The sample consisted of IT professionals aged 21 years and above with a minimum of 6 months of work experience, selected through a convenience sampling method. Data were collected using an online survey distributed via professional networks and social media platforms. Emotional intelligence was measured using the Schutte Self-Report Emotional Intelligence Test (SSEIT), while job satisfaction was assessed using Spector's Job Satisfaction Survey (JSS).[11,12] Demographic variables such as age, gender, work experience, job role, and location were also included. A pilot study involving 17 participants was conducted to ensure clarity, reliability, and feasibility of the instruments. Participation was voluntary, informed consent was obtained, and responses were screened for completeness, with incomplete data excluded to ensure accuracy and reliability of the analysis.

Table 1: Distribution of respondents according to Gender

Sex	*Number*	*Percent*
Female	88	42.30
Male	120	57.69
Total	208	100

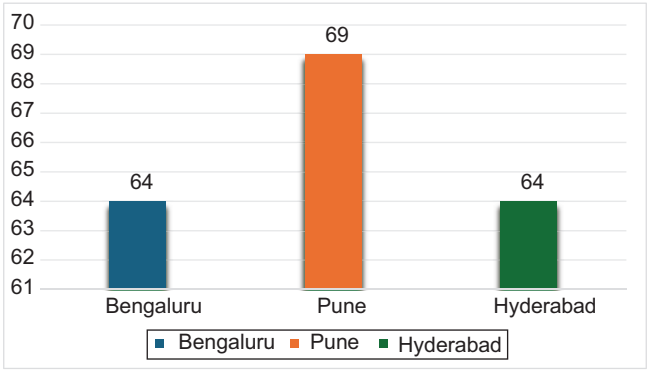

Fig. 1: Distribution of respondents across selected cities

Data Analysis

Data analysis was conducted using appropriate statistical techniques. Descriptive statistics such as mean and median were computed to understand the general levels of EI and job satisfaction. Pearson's product-moment correlation analysis was used to examine the relationship between EI and job satisfaction. One-way analysis of variance (ANOVA) were used to compare differences in EI and job satisfaction across gender and across the three IT hubs.

Data Management and Ethics

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

Results

The present study indicates that there is a total of 200 respondents, of which 57% of the respondents were male and 43% respondents were female (Table 1). Pune records the highest number of participants with 69 respondents, whereas both Bengaluru and Hyderabad have an equal number of 64 respondents each. Overall, Pune has a marginally higher representation, while Bengaluru and Hyderabad show identical and slightly lower levels of participation (Fig. 1).

Most of the respondents were equally distributed in the four age groups (Fig. 2), with most of them slightly higher in the age-group 20–25 years. Most of the respondents were contractual (54.81), and the permanent staff were 45.19 (Fig. 3). Most of the respondents earn below Rs 50,000, making up nearly half of the population. About one-third earn above Rs 1,00,000, which is a significant high-income segment. The middle-income group (50–100k) is the smallest, suggesting fewer people fall into this range. The distribution is somewhat polarized; many individuals are in the lower income bracket, a sizable group is in the high-income bracket, and comparatively fewer are in the middle range (Fig. 4).

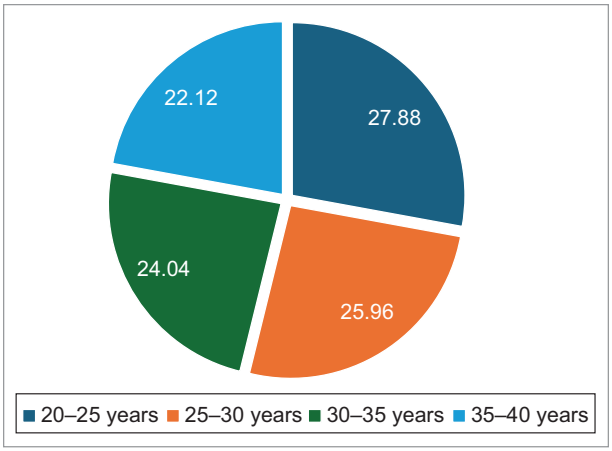

Fig. 2: Age-wise percentage distribution of respondents

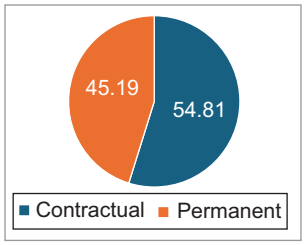

Fig. 3: Percentage distribution of employment type among respondents

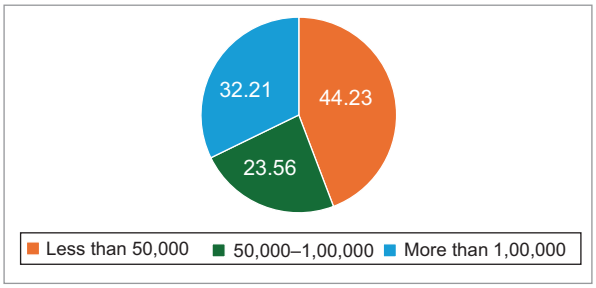

Fig. 4: Distribution of salary among the respondents

Table 2: Analysis of JSS and SSEIT scale

JSS scale interpretation		*SSEIT interpretation*	
36–108	Indicate dissatisfaction	33–76	Lower EI
108–144	Ambivalence	77–121	Moderate EI
144–216	Indicate Satisfaction	122–165	Higher EI

The JSS analysis was done by analyzing the questions related to JSS. The graph presents the interpretation of scores obtained from the JSS scale, categorizing respondents' levels of job satisfaction into three distinct ranges. Scores between 36 and 108 indicate dissatisfaction, suggesting that individuals within this range are generally unhappy with their job conditions and experiences. Scores from 108 to 144 reflect ambivalence, meaning respondents neither feel clearly satisfied nor dissatisfied, but rather hold neutral or mixed perceptions about their work. Finally, scores ranging from 144 to 216 indicate satisfaction, representing individuals who have a positive evaluation of their job and work environment. Overall, the graph (Table 2) provides a clear framework for classifying employee attitudes toward their job based on their JSS scores.

The graph (Fig. 5) presents the distribution of responses for the JSS across 36 items, categorized into six response options ranging from strongly disagree to strongly agree. Overall, the majority of responses cluster around the "slightly agree" and "agree" categories, indicating a generally positive but moderate level of job satisfaction among respondents. Many items show higher frequencies in "slightly agree," suggesting that while employees tend to lean toward satisfaction, their perceptions are not strongly positive.

At the same time, there is a noticeable presence of "slightly disagree" responses across several items, reflecting some degree of dissatisfaction or concern in specific aspects of the job. However, the counts for "strongly disagree" and "strongly agree" remain relatively low across most items, indicating that extreme opinions, either highly negative or highly positive, are less common among participants.

The variation in responses across different items suggests that job satisfaction is not uniform and may differ depending on specific job facets such as pay, supervision, or work conditions. Overall, the graph indicates a moderate level of job satisfaction, with a tendency toward mild agreement rather than strong endorsement, highlighting areas where organizational improvements may enhance employee satisfaction further.

Table 2 presents the interpretation of scores obtained from the SSEIT, categorizing individuals into three levels of EI. Scores ranging from 33 to 76 indicate lower EI, suggesting limited ability to perceive, understand, and manage emotions effectively. Scores between 77 and 121 represent moderate EI, where individuals demonstrate an average capacity to handle emotional situations and interpersonal relationships. Finally, scores from 122 to 165 indicate higher EI, reflecting a strong ability to recognize, regulate, and utilize emotions in both personal and social contexts. Overall, Table 3 provides a structured classification for assessing individuals' EI levels based on their SSEIT scores.

The graph illustrates (Fig. 6) the distribution of responses for EI across multiple items, measured using different levels of agreement. Overall, the majority of responses are concentrated in the "slightly agree" and "agree" categories, indicating that respondents generally perceive themselves as having a moderate to high level of EI. This suggests that most participants believe they are reasonably capable of understanding, managing, and expressing emotions effectively. The "slightly disagree" category also shows a noticeable presence across several items, reflecting that some respondents experience occasional difficulties in emotional regulation or perception. However, responses in the "strongly disagree" and "strongly agree" categories are relatively low, indicating that extreme perceptions of either very low or very high EI are less common. There is some variation across individual items, suggesting that different components of EI, such as emotional awareness, regulation, and utilization, may not be equally developed among all respondents. Overall, the pattern indicates a generally moderate level of EI, with a tendency toward positive self-assessment but not at a strongly high level (Table 4).

The ANOVA test was conducted to determine if there is a significant difference in job satisfaction levels among employees in the three cities. Pune reported the highest average job satisfaction (137.34), followed by Hyderabad (136.13) and Bengaluru (134.78). The calculated *p*-value is 0.205, which is greater than the standard significance level of 0.05. Additionally, the *F*-value (1.59) is less than the *F*-critical value (3.04). Since the *p*-value is high, we fail to reject the null hypothesis. This means there is no statistically significant

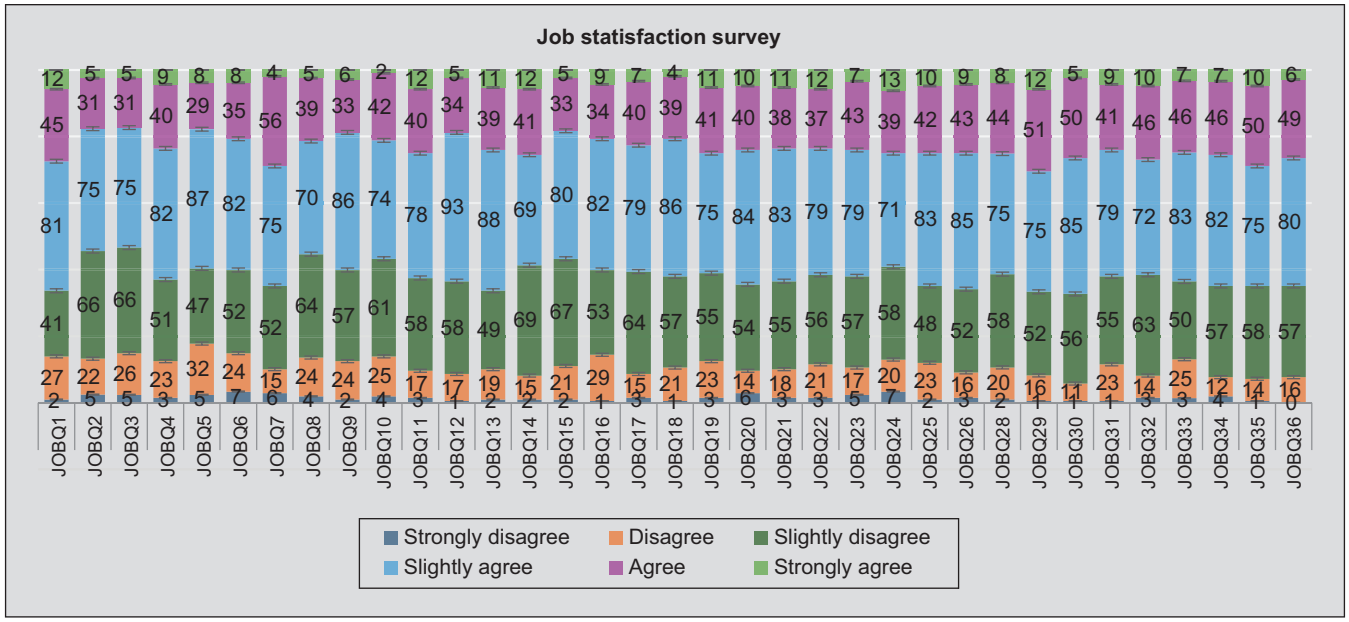

Fig. 5: The JSS analysis

Table 3: Variation in job satisfaction across the three cities

Groups	*Source of variation*	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Pune	Between groups	218.3158	2	109.1579	1.595686	0.205419	3.042472
Bengaluru	Within groups	13,271.18	194	68.40813	–	–	–
Hyderabad		–	–	–	–	–	–
	Total	13,489.49	196	–	–	–	–

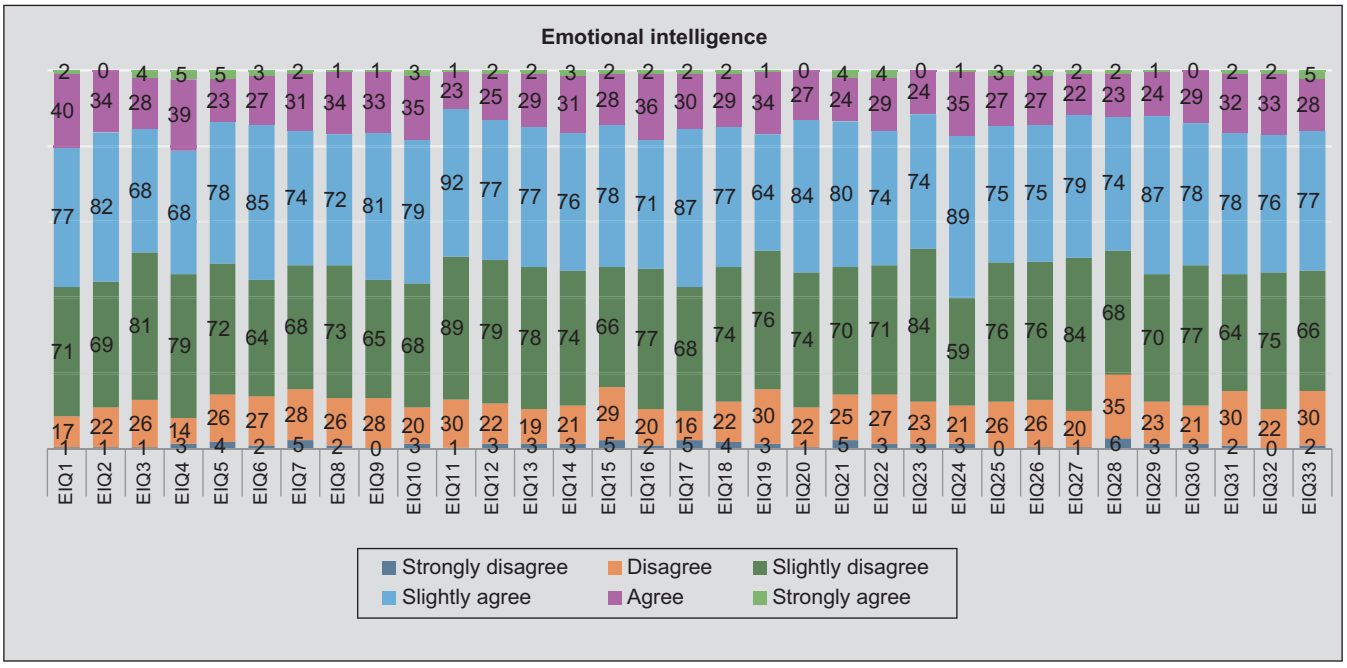

Fig. 6: Analysis of SSEIT

difference in job satisfaction across the three cities. Any observed differences in the averages are likely due to random chance rather than the location itself.

This analysis compared the EI scores (measured on a six-point Likert scale) across the same three locations. The average scores were very similar across all groups: Pune (117.03), Hyderabad (116.45),

Table 4: Variation in EI across the three cities

Groups	*Source of variation*	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Pune	Between groups	62.87785	2	31.43892	0.689931	0.502837	3.042472
Bengaluru	Within groups	8,840.239	194	45.56824	–	–	–
Hyderabad		–	–	–	–	–	–
	Total	8,903.117	196	–	–	–	–

Fig. 7: Association between EI and job satisfaction

and Bengaluru (115.66). The *p*-value is 0.503, significantly higher than 0.05. The *F*-value (0.69) is also much lower than the *F*-critical value (3.04). These results indicate that there is no significant difference in the EI of employees across Pune, Bengaluru, and Hyderabad. The variations in mean scores are statistically negligible.

The correlation coefficient (*r*) indicates the strength and direction of the relationship between two variables. In this case, a value of 0.030 suggests an extremely weak or negligible relationship. Since the correlation scale ranges from 0 (no relationship) to 1 (perfect relationship), a value this close to zero indicates that there is virtually no meaningful association between EI and job satisfaction in the given data (Fig. 7). While city and gender do not significantly influence EI or job satisfaction, EI itself is a major determinant of job satisfaction. Employees with higher EI tend to report significantly higher job satisfaction levels (Fig. 7).

Discussion

The present study aimed to examine the role of EI in predicting job satisfaction among IT sector employees across three major IT hubs in India, i.e., Pune, Bengaluru, and Hyderabad. The study further investigated differences in EI and job satisfaction based on city and gender. The findings provide important insights into the psychological dynamics of employees working in the highly competitive IT sector.

The findings revealed that EI levels were largely comparable across Pune, Bengaluru, and Hyderabad. The broader dataset, specific comparisons among these three cities did not reveal meaningful differences. This suggests that employees working in major IT hubs in India may experience similar work environments, organizational cultures, and professional demands, resulting in relatively uniform levels of EI.[4]

The absence of significant gender differences in EI further suggests that emotional competencies are not inherently influenced by gender within this professional context. Both male and female employees demonstrated nearly identical mean scores. This aligns with contemporary research suggesting that EI is shaped more by environmental exposure, organizational culture, and professional experience rather than gender alone. In high-performance sectors such as IT, both men and women may be equally required to develop emotional regulation, interpersonal effectiveness, and stress management skills to succeed.

However, the relatively low internal consistency of the EI scale (α = 0.567) must be considered when interpreting these findings. The poor reliability indicates that the items may not have consistently measured the construct within this sample. Cultural context, response style, or item interpretation differences may have influenced the reliability coefficient. Therefore, the overall findings suggest similarity across cities and gender.

Similar to EI, job satisfaction did not significantly differ across Pune, Bengaluru, and Hyderabad. The comparable median scores indicate that employees across these IT hubs experience similar levels of workplace satisfaction. This may reflect standardized organizational structures, similar corporate policies, and comparable compensation systems within the Indian IT sector.

The absence of gender differences in job satisfaction also suggests that male and female employees perceive their work environments in similar ways. Equal opportunities, structured promotion systems, and standardized performance evaluation methods within IT organizations may contribute to this parity. These findings are consistent with research indicating that job satisfaction is influenced more by organizational factors than by demographic characteristics such as gender.

The reliability coefficient for the job satisfaction scale (α = 0.647) was moderate but acceptable. While this suggests reasonable internal consistency, improvement in item refinement may strengthen measurement accuracy in future research.

Relationship Between EI and Job Satisfaction

Theoretically, this finding is consistent with existing models of EI, particularly those proposed by Mayer and Salovey and by Goleman. Emotional intelligence enables individuals to regulate stress, manage interpersonal conflicts, adapt to workplace challenges, and maintain positive workplace relationships. These abilities directly contribute to enhanced job satisfaction by reducing emotional strain and promoting psychological well-being.

However, the magnitude of the correlation is unusually weak in comparison to most empirical studies in organizational psychology, where correlations between EI and job satisfaction typically range from moderate to strong. Gill et al. also mentioned in their study that EI does not affect job satisfaction.[10] Same is supported by Ghoreishi et al., who mentioned that EI does not affect job satisfaction among Doctors in Kashan Hospital.[9]

The extremely weak correlation observed in this study may be partially influenced by methodological factors such as common

method variance, similar response formats, or overlapping item content between the two scales. Since both variables were measured using self-report questionnaires administered at the same time, participants may have responded consistently across items, thereby inflating the association.

While numerous studies have reported a positive association between EI and job satisfaction, the strength of this relationship has not been consistently supported across empirical investigations.[13,14] Several researchers have indicated that the direct impact of EI on job satisfaction is relatively limited, with organizational factors such as work environment, job stress, and leadership practices exerting a more substantial influence.[15] In addition, some studies have reported only moderate or component-specific relationships, suggesting that not all dimensions of EI contribute equally to job satisfaction.[13]

Furthermore, the relationship between EI and job satisfaction appears to be influenced by demographic and contextual variables, including age, experience, and occupational setting.[16] This variability implies that EI may not serve as a universal predictor of job satisfaction across different professional domains. In some contexts, the relationship is weak or statistically insignificant, further supporting this argument.[17] The inconsistencies observed in the literature underscore the need for further empirical exploration, particularly in high-pressure industries such as the IT sector, where structural and organizational factors may play a more dominant role in shaping employee satisfaction.

Additionally, the moderate reliability coefficients of both scales suggest that measurement limitations may have influenced the results. When internal consistency is not strong, correlations can sometimes appear artificially elevated due to shared measurement error. Therefore, while the results strongly support the predictive role of EI, the magnitude of the relationship should be interpreted cautiously.

The hybrid mode of work after the COVID pandemic has also altered the job satisfaction level of IT professionals by providing greater flexibility and improved work-life balance.[17] The impact of artificial intelligence (AI) on the job satisfaction of IT professionals is a dual-faceted, rapidly evolving phenomenon where AI is primarily seen as a tool to enhance productivity; it also introduces significant stressors when it replaces humans in jobs.

Implications of the Findings

Despite measurement considerations, the study highlights the importance of EI in the IT sector. The current study provides a strong conceptual background for researchers in the field of EI and job satisfaction. The findings of the study provide a strong need need to identify the various other antecedents of Job satisfaction among IT sector employees.[13] It is utmost important for the top official of the public sector to focus on the other factors that affect job satisfaction rather than simply focusing on EI.[18]

Furthermore, the absence of significant city-based differences indicates that EI development initiatives can be uniformly implemented across major IT hubs without requiring region-specific adaptation.

Limitations

Several limitations should be acknowledged. First, the relatively low reliability of the EI scale suggests that the instrument may not have functioned optimally within this sample. Future research should consider using scales with stronger psychometric properties or conducting item-level analyses.

Second, the cross-sectional design limits the ability to establish causal relationships. Although regression analysis suggests predictive power, longitudinal research would be necessary to confirm causality. Finally, convenience sampling limits generalizability. A larger and more diverse sample may yield more representative findings.

Conclusion

In summary, the study demonstrates that EI is positively associated with job satisfaction among IT sector employees, but the association is weak. While city and gender do not significantly influence these constructs, EI emerges as a central psychological factor contributing to workplace satisfaction. Despite certain methodological limitations, the findings underscore the importance of fostering emotional competencies within organizational settings to enhance employee well-being and performance.

Ethical Approval

Ethical approval number: DU/ZH/PSY/Ethical -2025.

Data Availability

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

Limitations

The study collected the data online, in person data collection would have given deeper understanding of the subject.

Artificial Intelligence (AI) Disclosure Statement

No AI or assisted technology was used .

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Authors' Contributions

Methodology, Validation, Writing – Original draft preparation: V Jaiswal, R Aggarwal; Writing – Review and Editing: V Jaiswal; Visualization: V Jaiswal; Supervision: R Aggarwal.

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ORIGINAL ARTICLE

Fertility, Urbanization, and Sanitation as Determinants of Life Expectancy in Association of Southeast Asian Nation Countries: A Panel Data Analysis (2004–2023)

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Abstract

Aim and background: Life expectancy at birth (LEAB) is a key metric of population health and development. This study investigates the determinants of LEAB across 10 Association of Southeast Asian Nations (ASEAN) member states from 2004 to 2023, focusing on economic growth, fertility, urbanization, and sanitation access.

Materials and methods: A balanced panel dataset of 200 observations (10 countries × 20-years) from the World Development Indicators (WDI) was analyzed. Variables included LEAB (dependent), gross domestic product (GDP) growth (annual %), [total fertility rate (TFR), births per woman], urban population (% total), and access to basic sanitation (%). Descriptive statistics and trend analyses were performed. Model selection used Breusch–Pagan Lagrangian multiplier (LM) test and Hausman test. Given detected heteroskedasticity ($p < 0.001$), a feasible generalized least squares (FGLS) model was employed for final inference.

Results: Feasible generalized least squares estimates showed that TFR (coefficient = −4.92, $p < 0.001$), urban population (coefficient = 0.093, $p < 0.001$), and access to basic sanitation (coefficient = 0.027, $p = 0.044$) were statistically significant determinants of LEAB. A reduction of one birth per woman was associated with a 4.92 years increase in life expectancy. Gross domestic product growth was not significant ($p = 0.257$).

Conclusion: Fertility reduction, managed urbanization, and improved sanitation infrastructure are the most robust determinants of longer life expectancy in ASEAN, whereas short-term GDP growth shows no measurable direct effect. Policies should prioritize voluntary family planning, "healthy city" urban planning, and sustained sanitation investments.

Keywords: ASEAN countries, GDP growth, Life expectancy at birth, Sanitation, Total fertility rate, Urban population.

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Introduction

Life expectancy at birth (LEAB) is widely recognized as a fundamental indicator of population health and overall national development, summarizing the mortality experience across all age-groups and reflecting the collective outcomes of economic prosperity, public health interventions, social progress, and environmental quality.[1–3] For the member states of the Association of Southeast Asian Nations (ASEAN), which have undergone profound economic, demographic, and social transformations over the past two decades, understanding the drivers of life expectancy is of paramount importance for sustainable development planning.[4–6]

Despite substantial global improvements in life expectancy, pronounced disparities persist across regions and countries.[7,8] Within ASEAN, these disparities are particularly striking. According to World Development Indicators (WDI), Singapore consistently ranks highest, with LEAB reaching 82.9 years in 2023, comparable to advanced economies. In contrast, Myanmar and Lao PDR have lagged considerably, with LEAB of approximately 66.9 and 69.0 years, respectively, in the same year—a gap of nearly 16 years. Such disparities translate into millions of preventable deaths and place unequal burdens on already strained health systems in lower-income ASEAN members. The COVID-19 pandemic temporarily interrupted progress across nearly all ASEAN countries, with Indonesia, Malaysia, and the Philippines experiencing the most pronounced declines during 2020–2021.[9]

The theoretical relationship between economic growth and health outcomes is well-established through the health production function framework.[10,11] However, the translation of economic growth into longevity gains is not automatic.[12,13] High-income ASEAN members like Singapore have completed the demographic transition with total fertility rates (TFRs) well below the replacement level (0.97 births per woman in 2023), while lower-income economies such as Lao PDR (2.42) and Myanmar (2.12) continue to experience higher fertility rates, which can strain household resources and increase maternal and child health risks.[14,15]

Rapid urbanization across ASEAN presents both opportunities—better access to healthcare and employment—and challenges, including congestion and pollution.[16,17] Access to basic sanitation services represents a foundational environmental determinant that directly reduces the transmission of fecal-oral pathogens responsible for diarrheal diseases and child mortality.[18–20] Yet, for

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many ASEAN member states, inadequate sanitation remains a major contributor to the preventable disease burden.[21]

This study aims to address gaps in the literature by: (1) Describing the trends of LEAB, gross domestic product (GDP) growth, TFR, urban population, and access to basic sanitation services in ASEAN countries from 2004 to 2023; and (2) examining the impact of these four variables on LEAB using appropriate panel data econometric methods.

Materials and Methods

Data Source and Variables

The requirement for individual informed consent was waived by the ethics committee due to the retrospective nature and use of de-identified data. This study employed a balanced panel dataset comprising all 10 ASEAN member states—Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam—over the 20-years period from 2004 to 2023. Data were obtained from the World Bank's WDI database. The balanced dataset comprised 200 observations (10 countries × 20-years).

The dependent variable was LEAB, measured in total years. The independent variables were: GDP growth (annual percentage), TFR (births per woman), urban population (percentage of total population), and access to basic sanitation services (SANI, percentage of population using at least basic sanitation facilities) (Fig. 1). These variables were selected based on their established roles in the health production function literature and data availability across all 10 ASEAN countries for the entire study period.

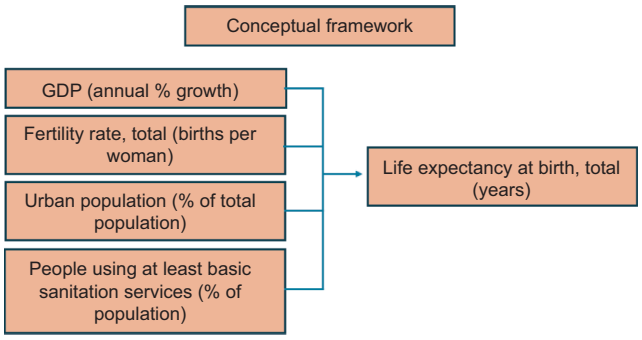

Fig. 1: Conceptual framework showing hypothesized relationships between independent variables (GDP growth, TFR, urban population, and sanitation) and LEAB

Statistical Analysis

All analyses were conducted using Stata software. First, descriptive statistics and a trend graph were generated for LEAB. Second, two panel regression models were estimated: The fixed effects (FE) model and the random effects (RE) model. Third, model selection was conducted using the Breusch–Pagan Lagrangian multiplier (LM) test to compare pooled OLS against RE, and the Hausman test to compare FE against RE. Fourth, diagnostic checks were performed: The Lagrange Multiplier test for group wise heteroskedasticity and the Wooldridge test for first-order autocorrelation. Fifth, although the Hausman test suggested that the RE specification was appropriate, significant group wise heteroskedasticity was detected. Because heteroskedasticity can result in inefficient standard errors and unreliable statistical inference, the feasible generalized least squares (FGLS) estimator was employed for final estimation. Feasible generalized least squares is designed to accommodate heteroskedastic error structures in panel data and provides more efficient estimates and more reliable statistical inference when heteroskedasticity is present. Therefore, FGLS was selected as the final model for inference.

Results

Descriptive Trends of LEAB

Over 2004–2023, LEAB exhibited a sustained upward trajectory across all ASEAN member states, yet pronounced disparities persisted. Singapore consistently ranked highest, increasing from 79.5 years in 2004 to a peak of 83.6 years in 2019, before a slight pandemic-related decline to 82.9 years in 2023. Lao PDR rose modestly from 60.1 years in 2004 to 69.0 years in 2023, while Myanmar, despite a sharp anomalous drop to 56.4 years in 2008 due to Cyclone Nargis, recovered to 66.9 years by 2023 (Fig. 2).

Descriptive Trends of Independent Variables

Over 2004–2023, GDP growth exhibited substantial volatility, ranging from Singapore's peak of 14.52% in 2010 to Myanmar's contraction of –12.02% in 2021. Total fertility rate declined

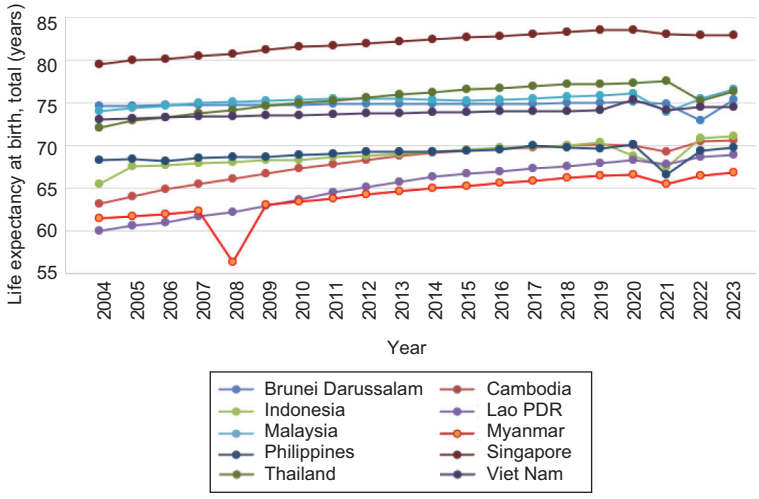

Fig. 2: Life expectancy at birth of ASEAN countries, 2004–2023

Table 1: Summary results for FGLS regression model of LEAB

Variable	*Coefficient*	*Std. error*	*p-value*
Constant	75.3326***	1.7581	0.000
GDP growth	0.0351	0.0310	0.257
TFR	–4.9195***	0.3428	0.000
Urban population	0.0930***	0.0068	0.000
Sanitation services	0.0266**	0.0133	0.044
Wald χ^2	2,823.68***		
p-value	0.0000		

**$p < 0.05$; ***$p < 0.01$. FGLS, feasible generalized least squares; GDP, gross domestic product; LEAB, Life expectancy at birth; TFR, total fertility rate

universally: Lao PDR fell from 3.90 to 2.42 births per woman, while Singapore dropped to 0.97 in 2023—below one child per woman. Urban population share increased in every country, most dramatically in Cambodia (from 18.98 to 40.63%) and Thailand (from 36.79 to 60.93%). Access to basic sanitation improved substantially, with Cambodia rising from 19.5 to over 80% and Lao PDR from 40.2 to 87.0%.

Model Selection and Diagnostic Checks

The Breusch–Pagan LM test rejected pooled OLS in favor of the RE model ($\chi^2 = 933.60$, $p < 0.001$), indicating significant country-specific heterogeneity. The Hausman test ($\chi^2 = 6.00$, $p = 0.1993$) failed to reject the null hypothesis, indicating that the RE model was preferred over FE.

Diagnostic checks on the RE model revealed violation of homoscedasticity. The Lagrange Multiplier test detected group wise heteroskedasticity ($\chi^2 = 12,800$, $p < 0.001$). The Wooldridge test provided no evidence of first-order autocorrelation ($F = 2.951$, $p = 0.1200$). Consequently, the FGLS estimator was employed to obtain efficient and consistent parameter estimates accounting for heteroskedasticity.

FGLS Model Results

The FGLS model was statistically significant overall (Wald $\chi^2 = 2,823.68$, $p < 0.001$). The FGLS estimates showed that TFR (coefficient = –4.9195, $p < 0.001$), urban population (coefficient = 0.0930, $p < 0.001$), and access to basic sanitation (coefficient = 0.0266, $p = 0.044$) were statistically significant determinants of LEAB. Gross domestic product growth was not statistically significant (coefficient = 0.0351, $p = 0.257$) (Table 1).

The TFR coefficient of –4.92 ($p < 0.001$) indicates that, holding all other variables constant, a reduction of one birth per woman is associated with an increase in life expectancy of approximately 4.92 years. The urban population coefficient of 0.093 ($p < 0.001$) indicates that a 1% point increase in urban population share is associated with a 0.09 years increase in life expectancy. The sanitation coefficient of 0.027 ($p = 0.044$) indicates that a 1% point increase in sanitation access is associated with a 0.03 years increase in life expectancy. Notably, a 10% point increase in sanitation access would yield only a 0.27 years (approximately 3 months) gain in life expectancy, a clinically modest but statistically significant effect.

Discussion

This study examined the determinants of LEAB across 10 ASEAN member states from 2004 to 2023. The FGLS model, which accounted for detected heteroskedasticity, identified TFR, urban population share, and access to basic sanitation as statistically significant determinants of LEAB.

The strong inverse association between fertility and longevity in ASEAN is consistent with previous studies documenting a negative relationship between fertility and life expectancy in developing countries.[22–24] The wide variation in TFR across the 10 countries—from below-replacement fertility (Singapore at 0.97) to still-elevated rates (Lao PDR at 2.42)—likely contributed to the precision of this estimate. The larger magnitude observed in this study (4.92 years per one-birth reduction) compared to earlier research may be explained by the exceptionally wide fertility transition gradient within ASEAN, the association of high fertility with shorter birth intervals and higher maternal and child health risks, and the pronounced demographic dividend effect in ASEAN countries.[14,15]

Each ASEAN country experienced increases in urban population share over the study period, and the positive association suggests that the region has managed urbanization more effectively than many other developing regions. This finding is consistent with previous studies that found urbanization exerts a positive effect on life expectancy globally.[25–27] Several mechanisms may explain this. First, more developed ASEAN economies have invested substantially in urban infrastructure, including public transport, water supply, sanitation, and waste management, mitigating the negative health consequences of crowding. Second, urban areas in ASEAN concentrate healthcare resources, including hospitals with specialized services and emergency care, reducing mortality from treatable conditions. Third, urbanization facilitates economies of scale in health service delivery and public health interventions, such as vaccination campaigns and disease surveillance. Fourth, cities offer greater educational and economic opportunities, leading to higher health literacy and better nutrition. The positive association in ASEAN contrasts with evidence from South Asia, where rapid, unplanned urbanization has been linked to adverse health outcomes, highlighting the importance of accompanying infrastructure investment.[23] However, ASEAN countries currently undergoing rapid urbanization—particularly Cambodia, Lao PDR, and Myanmar—may face emerging challenges similar to those seen in South Asia if infrastructure investment fails to keep pace with population growth.

Improvements in sanitation infrastructure continue to yield measurable health gains in ASEAN. By the end of the study period, several ASEAN countries had achieved very high sanitation coverage, with Cambodia achieving the most dramatic improvement from 19.5 to over 80% and Lao PDR rising from 40.2 to 87.0%. This finding is consistent with evidence from previous studies which showed sanitation services have a strong positive effect on life expectancy.[23,28,29] The statistically significant coefficient ($p = 0.044$), though modest in magnitude (0.027 years per percentage point), indicates that even as coverage approaches universal levels in some countries, continued sanitation investments still produce detectable longevity benefits. The statistical significance despite the small magnitude likely reflects the very large sample size (200 observations) and the dramatic improvements in sanitation coverage observed in several ASEAN countries, which provided sufficient variation to detect even modest effects. A systematic review of the South-East Asia Region further supports this, indicating that continued investments in sanitation infrastructure

yield health gains, particularly as the focus shifts from expanding access to improving quality and maintenance of existing services.[21] The effect may be partially mediated by urbanization, as urban areas systematically have better sanitation coverage than rural areas, which may explain why sanitation remained significant even after controlling for urban population share.

Short-term annual fluctuations in economic growth did not have a reliably measurable association with life expectancy in ASEAN after controlling for fertility, urbanization, and sanitation. This finding is consistent with previous studies that found GDP growth was not significantly associated with life expectancy.[23,30] The finding of no significant association likely arises because GDP growth captures short-term economic volatility rather than the long-run level of economic development, which is more relevant for sustained health investments. A more appropriate measure might be lagged GDP per capita or average income levels over longer periods, which capture cumulative economic development rather than annual fluctuations. Several explanations may account for the non-significant coefficient. First, as Tapia Granados documented in England and Wales, mortality rates can decline faster during recessions than expansions due to reduced workplace stress, traffic accidents, and air pollution, creating a counter-cyclical pattern that obscures any positive growth–longevity relationship.[30] Second, rapid economic expansion in some ASEAN countries has historically been accompanied by environmental degradation, including increased air pollution, which can adversely affect health. Third, the COVID-19 pandemic illustrated this phenomenon clearly: Countries with rapid pre-pandemic growth experienced sharp declines in life expectancy during the recession, suggesting that growth-driven health gains are not resilient to economic shocks. Thus, while economic development remains crucial for health systems, the direct and immediate impact of annual GDP growth on life expectancy appears weak relative to structural factors such as fertility reduction and urbanization.

Limitations

Several limitations should be acknowledged. First, omitted variable bias remains a concern; potentially important variables such as governance quality, nutritional indicators, health system performance measures, and lifestyle factors were not included due to data availability constraints. Second, the use of secondary data from the WDI is subject to cross-national differences in measurement consistency. Third, the panel data design identifies statistical associations rather than causal relationships. Potential endogeneity arising from reverse causality cannot be completely ruled out. Fourth, the COVID-19 pandemic during 2020–2021 may affect the generalizability of findings to non-pandemic periods. Fifth, the dataset contains an anomalous observation for Myanmar in 2008 (Cyclone Nargis) that was not explicitly controlled for. Sixth, this study uses national-level aggregates, which may mask within-country disparities (e.g., urban-rural differences in sanitation access or fertility rates). Seventh, the analysis does not explore potential interaction effects (e.g., sanitation improvements may have larger effects in urban than rural areas, which is partially but not fully captured by including urban population as a separate control). Eighth, the study is specific to the ASEAN region and 2004–2023 time frame, limiting extrapolation.

Conclusion

This study investigated the determinants of LEAB across 10 ASEAN countries from 2004 to 2023 using a balanced panel dataset and FGLS estimation to account for heteroskedasticity. Total fertility rate, urban population share, and access to basic sanitation emerged as statistically significant determinants, while GDP growth was not significant. Fertility reduction exhibited the largest marginal effect on life expectancy, followed by smaller gains from urbanization and sanitation improvements. These findings suggest that fertility reduction, managed urbanization, and sanitation infrastructure are more robust pathways to improved longevity in ASEAN than economic growth alone. Policymakers should prioritize voluntary family planning in higher-fertility countries, adopt "healthy city" urban planning in rapidly urbanizing nations, and continue sanitation investments in rural and underserved areas.

Ethical Approval

Ethical approval was not required for this study as it involved the analysis of publicly available, anonymized secondary data from the World Development Indicators, with no direct human or animal subjects. The study was conducted in accordance with relevant guidelines and regulations.

Artificial Intelligence (AI) Disclosure

No generative AI tools or large language models were used in any part of this work, including study conceptualization, literature search, data extraction, synthesis, interpretation, or manuscript writing. The author takes full responsibility for all content presented in this paper.

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Author's Contributions

Nay Aung: Conceptualization, Methodology, Formal analysis, Data Curation, Writing – Original Draft, Writing – Review and Editing, Visualization.

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REVIEW ARTICLE

Perceived Safety, Mental Well-being, and Quality of Life: A Review of Transit Experiences among LGBTQIA+ Commuters

Gayathri S[1], Paulose N Kuriakose[2]

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Abstract

Perceived safety in public transit spaces significantly influences the mental health and overall quality of life for LGBTQIA+ commuters, yet it remains underexplored. Transit systems, as essential daily pathways, expose many to visibility-related stigma, harassment risks, and persistent stress. While research on transport equity and health inequities has grown, the mental health consequences of transit insecurity, drawn from fragmented studies across fields, have seldom been synthesized. This article draws on interdisciplinary research from public health, mental health, transport planning, urban studies, and LGBTQIA+ health to explore how perceived safety in transit environments affects psychological well-being and everyday quality of life. It synthesizes evidence on harassment, anticipatory anxiety, hypervigilance, mobility avoidance, and minority stress tied to public transit use. Findings reveal consistent links to elevated anxiety, emotional exhaustion, eroded belonging, and curtailed travel freedom, with cumulative effects on everyday well-being. These impacts differ by gender identity, sexual orientation, visibility levels, and sociocultural settings. Ultimately, the evidence positions transit safety as a critical intersection of transport, mental health, and equity. It urges inclusive design and policy interventions to enhance LGBTQIA+ quality of life.

Keywords: LGBTQIA+ commuters, Mental well-being, Perceived safety, Public transit equity, Quality of life.

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Introduction

Public transit systems act as the primary infrastructure for urban residents to access employment, education, and social networks. Because these systems embed routine interactions within shared public spaces, researchers increasingly link them to individual mental well-being. Subtle perceptions of insecurity can generate sustained levels of anxiety, even when overt violence is absent.[1,2] Environmental psychology highlights this through the clear associations between stable communal spaces and overall life satisfaction.[3] However, much of the current literature treats the commuter experience as uniform and neglects critical differences. Safety perceptions diverge significantly for LGBTQIA+ individuals, who must constantly navigate the tension between their visibility and their vulnerability. For these users, routine trips involve a persistent risk of scrutiny or stigma. This transforms a simple daily commute into a source of ongoing psychological strain. Studies from North America, Europe, and Australia report elevated rates of verbal harassment, staring, misgendering, and intimidation among sexual and gender minority commuters in vehicles and stations.[4–6] Survey-based research suggests that between one-third and over half of LGBTQIA+ respondents report at least one incident of harassment or perceived threat in public transport settings, with transgender and gender non-conforming individuals reporting the highest exposure.[7] Even when incidents do not escalate into physical violence, the anticipation of hostility generates persistent vigilance, route and time avoidance, and emotional exhaustion.[8] These patterns align with *Minority Stress Theory*, which emphasizes how repeated exposure to stigma, discrimination, and threat in everyday contexts accumulates into adverse mental health outcomes, including anxiety, depressive symptoms, and reduced quality of life.[9]

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Despite this evidence, transit-related perceived safety remains weakly integrated into mental health and population health research concerning LGBTQIA+ communities. Much of the existing literature on LGBTQIA+ mental well-being focuses on family rejection, workplace discrimination, or healthcare access, while studies on public space safety often treat sexual and gender minorities as a peripheral or aggregated category.[10,11] Transport research, in turn, has historically prioritized efficiency, accessibility, and ridership metrics, with limited engagement with psychological well-being or identity-based vulnerability.[12] As a result, public transit systems are rarely conceptualized as sites of repeated psychosocial exposure that can exacerbate minority stress and shape everyday quality of life.

Mental well-being and quality of life extend beyond the absence of clinically diagnosable mental illness to include

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emotional security, sense of belonging, autonomy, and the ability to engage in daily activities without persistent fear or stress. Quality-of-life research demonstrates that routine anticipatory stress, even when individually moderate, can have cumulative effects on life satisfaction, emotional resilience, and social participation.[13] For LGBTQIA+ commuters, transit-related perceived safety influences not only immediate travel behavior but also broader patterns of mobility avoidance, social withdrawal, and disengagement from urban life. These effects are particularly pronounced in contexts where public transit is the primary or only affordable mode of transport, intensifying exposure and limiting coping strategies.[14]

Although policy discourses increasingly emphasize inclusive cities, safe transport, and equity in public services, empirical evidence linking transit-related perceived safety to mental well-being and quality of life among LGBTQIA+ commuters remains fragmented across disciplines. Existing studies vary widely in definitions, outcome measures, and methodological approaches, limiting their integration into coherent planning and health policy frameworks.[15] There is a lack of synthesized understanding of how perceived safety in transit settings operates as a determinant of mental well-being, how impacts vary within LGBTQIA+ communities by gender identity, sexual orientation, and visibility, and how these experiences intersect with broader transport and health inequities.

This paper addresses these gaps by conducting a narrative review of interdisciplinary literature on transit-related perceived safety among LGBTQIA+ commuters, with a focus on mental well-being and quality-of-life outcomes. It draws from public health, transport planning, and LGBTQIA+ health literature to investigate the intersections of harassment, hypervigilance, and chronic stress within the transit experiences of queer commuters. Rather than viewing transit systems strictly as mobility infrastructure, this analysis repositions them as social environments that directly influence mental health outcomes. By shifting the focus from purely physical design and operational efficiency to include holistic well-being, the following discussion argues for a broadening of transport planning priorities. The primary objective is to advocate for policy frameworks that integrate mental health protections, with a specific emphasis on the requirements of marginalized users.

Conceptual Framework: Transit-related Perceived Safety, Minority Stress, and Quality of Life

Perceived safety on transit serves as a critical psychosocial determinant of daily life, representing much more than a reaction to occasional discomfort. Because public transport necessitates extended proximity to strangers and involuntary visibility in enclosed environments, it presents a unique set of challenges. For LGBTQIA+ individuals, these specific spatial conditions dictate mobility choices and contribute to a cumulative internal stress load.

From a public health perspective, such spaces are increasingly recognized as sites where stress is not merely an occasional byproduct of exceptional events but is produced and reproduced through routine, everyday exposure.[16] For LGBTQIA+ commuters, these transit environments are particularly salient because they combine high visibility with the anonymity of a crowd. This combination often leads to an anticipation of identity-based threats even in the absence of overt harassment.

To understand how this environment penetrates mental well-being, *Minority Stress Theory* provides an essential foundational framework. This theory allows us to distinguish between distal stressors, such as direct discrimination, and proximal stressors, which include vigilance, identity concealment, and internalized stigma.[17] In the context of a commute, these proximal stressors take on a significant role. The act of monitoring one's appearance, posture, or behavior is not an episodic response to immediate danger but a form of sustained and exhausting emotional labor. These processes represent long-term adaptations to environments perceived as unpredictable or inherently hostile. Empirical research in mental health demonstrates that this state of chronic vigilance is a direct pathway to anxiety and emotional exhaustion across sexual and gender minority populations.[18]

This intersection of safety and stress is further complicated by the spatial and temporal constraints inherent to transit. Unlike many other public spaces, transit systems limit an individual's ability to use avoidance as a coping mechanism. Most commuters cannot simply choose an alternative route or time without incurring significant economic or social costs. This reduction in perceived control, which is a primary determinant of mental health, amplifies the stress response significantly.[19] For LGBTQIA+ commuters, especially those whose gender identity is highly visible, this lack of agency intensifies the minority stress process by forcing continued exposure to potentially threatening environments.

Furthermore, quality-of-life frameworks allow us to situate this mental well-being within the broader context of daily functioning and autonomy. Quality of life is defined not just by the absence of clinical illness but by the ability to participate in the world without a disproportionate psychological burden.[20] When a commute requires constant bandwidth for vigilance, the cumulative strain inevitably spills over into work performance, social connection, and leisure. This perspective is vital for population health research, which often overlooks subclinical but persistent stressors that degrade a community's overall health over time.

An essential contribution of this framework is its deliberate focus on the heterogeneity within the LGBTQIA+ community. It is critical to recognize that sexual orientation and gender identity do not represent identical dimensions of risk. Research consistently indicates that transgender, non-binary, and gender non-conforming individuals face higher levels of scrutiny and threat than cisgender sexual minorities.[21] Because visibility mediates exposure, safety is never distributed evenly. Intersectional factors, such as race, class, and age, further shape how risk is negotiated. Intersectionality theory reminds us that these factors do not simply add up; rather, they interact to produce distinct experiences of both vulnerability and resilience.[22] A framework that ignores this diversity risks reproducing the very invisibility it aims to challenge.

Finally, this conceptualization highlights a major gap in how we currently think about transport and health policy. While transit systems are usually judged by metrics of efficiency and crime statistics, health research often treats mobility as a neutral facilitator of access. By linking perceived safety directly to minority stress and quality of life, this framework reframes the transit system as a core public mental health environment.[23] This shift allows us to interpret LGBTQIA+ specific experiences through a robust lens of established stress research. It situates these personal narratives within structural conditions, including sociocultural norms and institutional responses to harassment. Ultimately, the framework

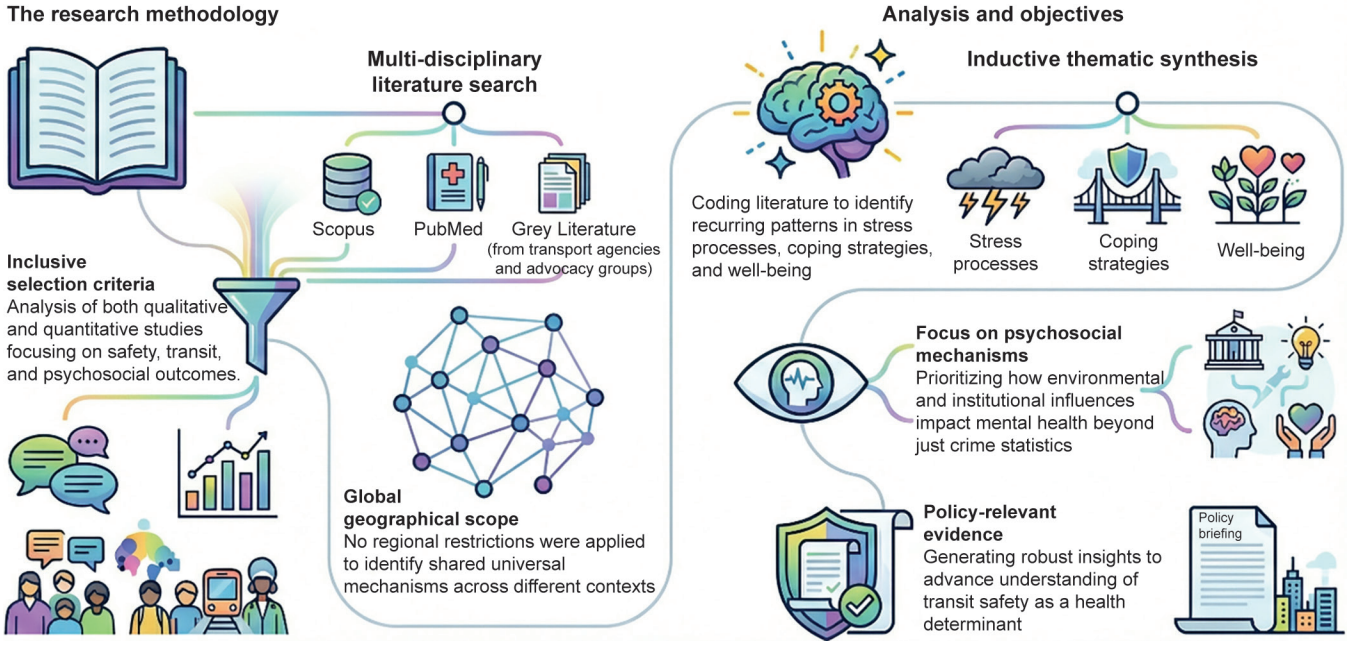

Fig. 1: Methodology adopted for review (*Source*: Author)

positions transit-related safety as a mediator between structural inequality and individual well-being, providing a coherent foundation for future research and targeted policy intervention.

Methodology

This study employs a narrative review design to synthesize interdisciplinary literature on transit-related perceived safety and its implications for mental well-being and quality of life among LGBTQIA+ commuters, as shown in Figure 1. A narrative approach was selected for this study because the relevant literature is currently limited, conceptually dispersed, and methodologically heterogeneous. The existing research spans diverse fields, including public health, mental health, transport planning, urban studies, and LGBTQIA+ scholarship. Narrative reviews are particularly suited to these contexts, as they enable an integrative analysis across various study designs and theoretical traditions. This method is preferable to a systematic review in this instance because it does not privilege narrowly defined outcomes or standardized measures, allowing for a more holistic interpretation of the evidence.[24]

Literature was identified via targeted searches in Scopus, Web of Science, PubMed, PsycINFO, and Google Scholar. Terms combined "perceived safety," "public transit," and "commuting" with "mental well-being," "quality of life," and LGBTQIA+ identifiers. Given evolving terminology across disciplines and time periods, we used multiple identity-related keywords for comprehensive coverage. Reference lists from key papers were hand-searched for further sources. Gray literature from advocacy groups, transport authorities, and global organizations added practical perspectives often missing in journal.[25]

Inclusion criteria targeted studies linking perceived safety, harassment, discrimination, or threats in public transit (or comparable mobility contexts) to mental health, stress, or quality-of-life outcomes for LGBTQIA+ groups. Both qualitative and quantitative work are qualified, as narratives and data each reveal distinct facets. We excluded studies limited to crime statistics or transit engineering without ties to perceptions or psychosocial impacts. No geographic restrictions applied. The goal was cross-contextual patterns over site-specific detail.

Analysis employed thematic synthesis. Full texts underwent inductive coding to pinpoint recurrent experiences of safety, stress manifestations, and coping or avoidance strategies. Themes coalesced into categories covering psychosocial dynamics, environmental factors, and community variations. Rather than mere frequency counts, the focus stayed on conceptual linkages across studies.[26] This approach suits this nascent area.

The review followed established narrative synthesis guidelines, with transparent reporting of search strategies, inclusion decisions, and analytic procedures.[27] It was not designed to be exhaustive or to produce causal estimates. Instead, the aim was to draw out conceptual linkages and policy implications. Taken together, the findings underscore the role of transit-related safety as a meaningful factor in shaping LGBTQIA+ mental health and everyday quality of life.

Findings

The reviewed literature indicates that transit environments are experienced by many LGBTQIA+ commuters as spaces of heightened vigilance rather than neutral conduits of mobility. Studies repeatedly identify public transit vehicles, stations, and transfer hubs as prime locations for harassment and perceived threats among sexual and gender minorities. These spots rank with streets and nightlife areas as especially risky for such groups.[28–30] Transit settings differ from optional public spaces due to their fixed schedules and routes. Commuters have little choice but to use them, embedding safety concerns in everyday travel.

Surveys from diverse cities confirm that LGBTQIA+ riders face far higher rates of verbal abuse, staring, misgendering, and intimidation on transit than cisgender heterosexual peers do. Transgender and gender non-conforming people report the most severe exposure.[31–33] These incidents occur across times and routes,

pointing to a pervasive rather than isolated risk. Crucially, research shows that the mental toll stems more from the unpredictability of encounters than from single events. This ongoing uncertainty fuels anticipatory stress on ordinary trips.[34]

A recurring finding across qualitative and mixed-method studies is the prominence of anticipatory vigilance as a central feature of LGBTQIA+ transit use. Commuters describe a continuous monitoring of their surroundings, strategic positioning within vehicles, and the modulation of their gender expression. They also report making calculated decisions regarding seating, boarding, and alighting points.[35,36] Participants often frame these strategies not as exceptional responses but as normalized adaptations to environments perceived as potentially hostile. Such vigilance has been linked to emotional exhaustion, anxiety, and a reduced sense of personal security, even among individuals who report relatively infrequent direct harassment.[37]

Transit-related perceived safety also shapes mobility behavior in ways that extend far beyond the commute itself. Evidence indicates that LGBTQIA+ individuals are more likely to alter their travel times, choose longer or less efficient routes, avoid certain modes of transport, or limit non-essential travel to reduce their exposure to risk.[38,39] These adaptations carry cumulative costs, including increased travel time, financial burdens, and reduced access to social and economic opportunities. Studies examining travel avoidance note that these constraints disproportionately affect individuals with limited transport alternatives, thereby reinforcing existing inequities in urban access and participation.[40]

The mental well-being implications of these experiences are clearly documented across the literature. Quantitative studies report strong associations between perceived safety in public transit and elevated levels of anxiety, depressive symptoms, and general stress among LGBTQIA+ commuters.[41] Qualitative research further illustrates how repeated exposure to vigilance and threat undermines emotional resilience and contributes to feelings of alienation and a diminished sense of belonging in urban environments.[42] These effects are often described as cumulative rather than acute. This aligns with broader mental health research showing that chronic, low-level stressors can have substantial impacts on well-being over time.[43]

Quality-of-life outcomes emerge as a distinct but related dimension in the reviewed studies. Transit-related perceived safety influences not only psychological states but also broader evaluations of daily life, autonomy, and satisfaction. When the simple act of moving through the city requires significant emotional and cognitive labor, the resulting exhaustion can limit an individual's capacity to engage fully in social and professional spheres. This suggests that the impact of transit safety is not just an individual health issue but a broader population health concern that affects the overall vitality and inclusion of LGBTQIA+ communities. LGBTQIA+ commuters report that fear or discomfort during routine travel constrains participation in social activities, limits engagement with urban amenities, and contributes to fatigue that spills over into work and personal life.[44] Studies drawing on quality-of-life frameworks highlight that the burden of constant vigilance reduces the perceived livability of cities, even when other indicators such as accessibility or service provision are favorable.[45] This suggests that technical efficiency alone cannot guarantee a high quality of life if the psychological cost of movement remains prohibitive. The literature also reveals substantial heterogeneity within LGBTQIA+ populations, noting that vulnerability is not experienced uniformly. Transgender, non-binary, and gender non-conforming individuals consistently report higher levels of perceived insecurity in transit settings than cisgender sexual minorities. This disparity reflects the specific role of visibility and the enforcement of gender norms in shaping an individual's exposure to threat.[33,46]

Intersectional analyses further indicate that race, class, disability, and age mediate these experiences, creating compounded vulnerabilities for individuals who occupy multiple marginalized positions.[47] Despite the importance of these overlapping identities, few studies disaggregate their findings systematically, which represents a significant gap in the current evidence base. Beyond individual identities, institutional and environmental factors emerge as critical modifiers of perceived safety. Research indicates that the presence of visible staff, clear reporting mechanisms, inclusive signage, and explicit anti-harassment policies can positively influence perceptions of legitimacy and support. These features provide a sense of security even in environments where incidents persist.[48] On the other hand, ambiguous or dismissive institutional responses serve to exacerbate feelings of vulnerability and actively discourage reporting. These findings suggest that perceived safety is shaped not only by interpersonal interactions but also by the symbolic and operational signals conveyed by transit authorities.

Across the reviewed literature, a consistent pattern emerges in which transit-related perceived safety acts as a mediating factor linking structural conditions to mental well-being and quality-of-life outcomes. Rather than functioning as an isolated or occasional exposure, perceived safety operates through repeated, everyday encounters that accumulate over time. While the empirical base specific to LGBTQIA+ commuters remains growing and relatively limited, the convergence of findings across transport studies, mental health research, and LGBTQIA+ scholarship provides a coherent evidence base. This synthesis supports the role of transit environments as significant sites of psychosocial stress and well-being inequity. Ultimately, the cumulative evidence suggests that addressing transit safety is a necessary step in reducing health disparities and fostering more inclusive urban environments.

Discussion

The findings of this review suggest that transit-related perceived safety functions as a meaningful determinant of mental well-being and quality of life for LGBTQIA+ commuters by embedding minority stress within everyday mobility, as shown in Figure 2. What distinguishes transit environments from other public spaces is their routine and unavoidable nature. Daily commuting transforms perceived threat from an episodic concern into a recurring psychosocial exposure, aligning with stress process models that emphasize the cumulative impact of repeated, low-intensity stressors on mental health.[49] This perspective extends transport research by positioning public transit not merely as infrastructure but as a setting where health inequities are routinely produced. A central interpretive contribution of this review lies in identifying perceived safety as a mediating mechanism between structural transit conditions and individual well-being. Transport planning literature has traditionally conceptualized safety through objective indicators such as crime rates, lighting, or surveillance, while mental health research has focused more heavily on interpersonal stigma and discrimination.[50,51] The reviewed evidence indicates that perceived safety connects these domains by translating environmental and institutional conditions into lived psychological experiences. This reinforces arguments from environmental

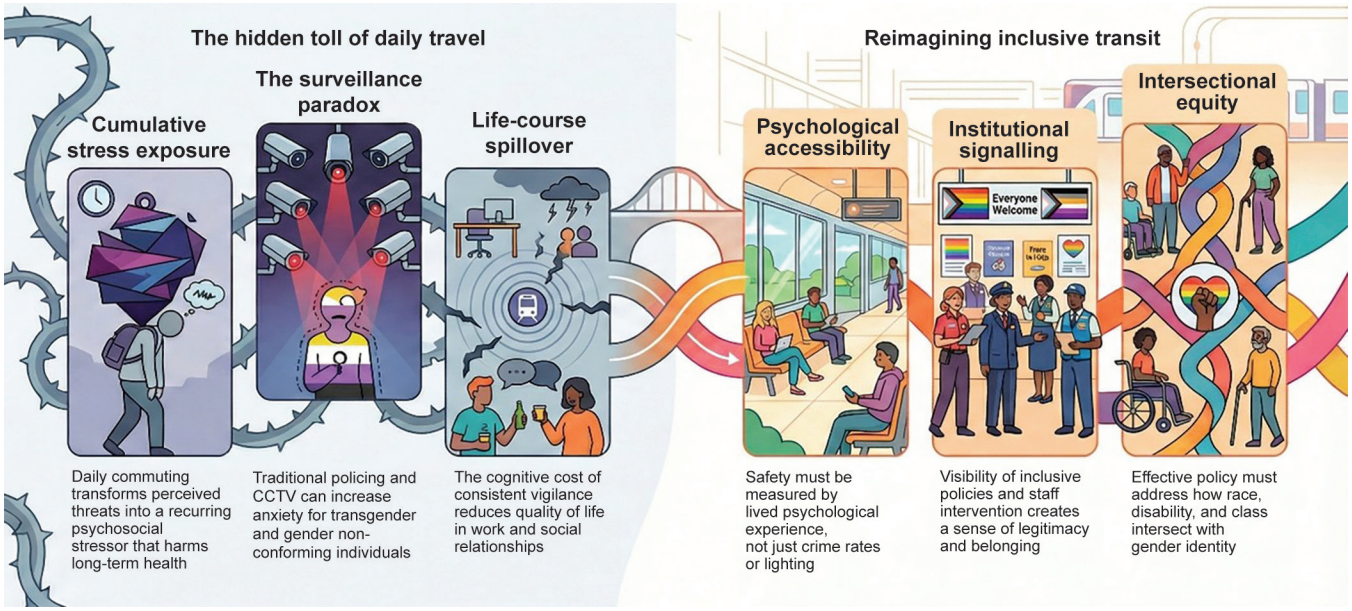

Fig. 2: Reconceptualizing urban mobility through an intersectional lens (*Source*: Author)

stress theory that perceived control and predictability are critical determinants of emotional regulation and well-being in shared spaces.[52]

The findings also challenge dominant assumptions within public safety discourse. Conventional safety interventions in transit systems often prioritize deterrence and surveillance, which are approaches that may reduce certain forms of crime but do not necessarily address identity-based threats or anticipatory stress. Feminist and queer scholarship has long argued that surveillance can itself be a source of anxiety for marginalized groups, particularly those whose bodies or expressions are already subject to excessive public scrutiny.[53] For LGBTQIA+ commuters, especially transgender and gender non-conforming individuals, increased surveillance without corresponding cultural competence or accountability may intensify rather than alleviate perceived insecurity. This highlights a critical mismatch between prevailing safety strategies and the lived realities of sexual and gender minorities.

From a mental health standpoint, the cumulative stress associated with transit-related vigilance aligns with evidence that chronic exposure to social threat contributes to anxiety, depressive symptoms, and emotional exhaustion, even in the absence of discrete traumatic events.[54] Minority stress research emphasizes that such outcomes arise not only from direct discrimination but also from the ongoing effort required to anticipate, manage, or conceal identity in potentially hostile environments.[55] The reviewed findings suggest that transit settings are a key but under-recognized context in which these processes unfold, particularly given the frequency and duration of commuting over the life course. Quality-of-life frameworks further illuminate the broader implications of these stress processes. Quality of life is shaped by autonomy, participation, and satisfaction with daily activities, and not solely by mental health status.[56] When routine mobility requires heightened vigilance or avoidance, it imposes cognitive and emotional costs that spill over into work, social relationships, and leisure. Urban studies research on livability has shown that such everyday frictions disproportionately affect marginalized groups, reducing the perceived inclusiveness of cities even where physical accessibility is high.[57] This underscores the importance of considering psychological accessibility alongside spatial and economic measures of equity.

The findings also underscore the need to account for heterogeneity within LGBTQIA+ populations. Intersectionality theory emphasizes that experiences of marginalization are shaped by the interaction of multiple social positions, producing distinct vulnerabilities rather than simply additive disadvantage.[58] Relatively few transit studies explore how race, class, disability, age, and immigration status intersect with sexual and gender identity to shape perceptions of safety. Yet these intersections matter. Transgender women of color, for example, face disproportionately high levels of both fatal and non-fatal violence globally. In the United States, recent data from 2024 suggest that nearly half of transgender individuals report experiencing harassment in public spaces, with even higher rates among racial minorities. The limited attention to these layered vulnerabilities weakens policy responses that assume a uniform commuter experience.

Institutional dynamics also shape how safety is perceived. Research on procedural justice and institutional trust shows that inclusive policies, visible staff support, and accessible reporting mechanisms contribute to a sense of legitimacy and belonging.[59] Within transit systems, seemingly small signals, such as inclusive signage or explicit equity commitments, can communicate recognition and protection. Their absence can signal the opposite. In this sense, perceptions of safety are shaped not only by direct encounters with other passengers but also by organizational culture and governance structures.

Overall, these insights call for reframing transit safety. Policy interventions must move beyond a narrow focus on crime control to prioritize equity, mental health, and the broader quality of urban life. By situating transit systems within the larger discourse on mobility justice and social inclusion, researchers can develop more comprehensive planning strategies. Currently, a significant disconnect exists between transport planning and mental health research; both investigate the impact of everyday environments on human behavior, but they rarely converge in practice or theory.

Limitations

This review has several limitations. As a narrative review, it does not provide the methodological rigor or quantitative synthesis of a systematic review or meta-analysis. The available evidence is heterogeneous in terms of study designs, definitions of perceived safety, outcome measures, and sociocultural contexts, limiting direct comparisons across studies. Furthermore, much of the literature originates from North America, Europe, and Australia, restricting the generalizability of findings to other regions. Many studies also rely on cross-sectional and self-reported data, making causal relationships difficult to establish. In addition, intersectional differences within LGBTQIA+ populations remain underexplored. Future research should employ longitudinal and mixed-methods designs, expand evidence from underrepresented regions, develop standardized measures of transit-related safety and well-being, and evaluate the effectiveness of inclusive transit policies and interventions across diverse LGBTQIA+ communities.

Conclusion

Perceived safety represents a critical yet frequently neglected determinant of mental health for LGBTQIA+ commuters. The impact of insecurity extends far beyond the immediate trauma of overt harassment; it manifests as persistent hypervigilance, the necessity of route diversion, and a narrowing of personal agency that reshapes daily mobility. Within this context, minority stress is effectively "spatialized," transforming transit environments into sites of cumulative psychological taxation.

Evidence across multiple disciplines suggests that even when physical access is technically adequate, these environments continue to sustain health disparities. Connectivity alone is an insufficient metric for progress, as it does not guarantee either psychological comfort or social inclusion. This review concludes with two primary findings. First, public transit functions as a structural determinant of mental health that operates independently of discrete violent incidents. Second, integrating minority stress and quality-of-life frameworks into transport scholarship is essential to accurately capturing and addressing the lived realities of LGBTQIA+ users. Third, it questions conventional safety indicators that focus primarily on crime statistics or service coverage while overlooking psychosocial inclusion. A system may meet technical benchmarks and still feel exclusionary to those who rely on it daily.

These findings have practical implications. Health and transport agencies need to reconsider assumptions that mobility is inherently neutral. Perceived safety influences whether urban access is meaningful or merely theoretical. Systems that are physically available but psychologically taxing risk reproducing inequities rather than alleviating them. Addressing this requires collaboration across sectors, including planners, transport authorities, public health institutions, and community organizations. Infrastructure improvements such as lighting and staffing can help, but they are only part of the solution. More durable change depends on governance measures: Clear antiharassment policies, staff training that addresses LGBTQIA+ experiences, accessible reporting mechanisms, and accountability structures. Incorporating safety perceptions and quality-of-life indicators into evaluation frameworks would provide a more accurate picture of inclusion. Ultimately, inclusive transit is not defined solely by coverage or efficiency, but by whether it offers mobility that feels safe, dignified, and sustainable for those who depend on it.

Artificial Intelligence (AI) Disclosure

Jenni AI and Google AI were used for language editing, manuscript refinement and priliminary graphic generation. The authors reviewed, verified, and revised all AI-assisted content and accept full responsibility for the manuscript's accuracy and integrity.

Authors' Contributions

Gayathri S : Methodology, formal analysis, writing – original draft, writing – review and editing, visualization.
Paulose N Kuriakose: Conceptualization, supervision.

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REVIEW ARTICLE

Oral Health and Quality of Life in Myanmar: Determinants, Disparities, and Policy Priorities—A Narrative Review

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Abstract

Background: Oral health-related quality of life (OHRQoL) reflects the functional, psychological, and social impacts of oral conditions. In Myanmar, despite the recent National Oral Health Plan (2024–2030), the synthesis of patient-centered oral health outcomes remains limited.

Objective: To synthesize and critically evaluate existing evidence on OHRQoL across population groups in Myanmar and identify key determinants and research gaps.

Methods: A structured narrative review was conducted using EBSCOhost, PubMed, Scopus, Google Scholar, and Myanmar Journals Online (2000–2025). Ten studies comprising 5,809 unique participants met the inclusion criteria. Findings were synthesized thematically.

Results: Dental caries in children (87% prevalence among 5-year-olds) was strongly associated with eating and sleeping difficulties. Among adults and elderly populations, tooth loss, periodontal disease, and depressive symptoms were consistently linked to impaired OHRQoL. COVID-19 hospitalization showed a synergistic interaction with psychological distress, which was associated with markedly higher Oral Health Impact Profile-14 (OHIP-14) scores. Prosthodontic rehabilitation [implant-retained overdentures and removable partial dentures (RPDs)] yielded large and clinically meaningful improvements in OHRQoL.

Conclusion: Poor oral health is associated with substantial functional and psychosocial burden across all age groups in Myanmar. However, evidence remains predominantly cross-sectional and geographically concentrated. Integration of OHRQoL into national surveillance and adoption of a biopsychosocial framework within the National Oral Health Plan are urgently needed.

Keywords: Dental caries, Myanmar, Oral health-related quality of life, Periodontal disease.

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Introduction

Oral health is a fundamental component of overall well-being, significantly influencing an individual's daily life, social interactions, perception of general health, and quality of life.[1] The concept of oral health-related quality of life (OHRQoL) emerged from the World Health Organization's paradigm shift in defining health as "a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity."[2] Oral health-related quality of life encompasses multiple dimensions including functional factors (chewing, biting), pain and discomfort, psychological factors (self-esteem, appearance satisfaction), and social factors (interactions with others).[3,4] This patient-centered approach recognizes that clinical indicators alone are insufficient to capture the true burden of oral diseases on individuals and communities.[5] This understanding is particularly critical when examining vulnerable populations globally who face barriers to dental care.[6,7]

Myanmar, a lower-middle-income country in Southeast Asia with a population exceeding 51 million, faces significant oral health challenges.[8] The first National Oral Health Survey (2016–2017) revealed that dental caries remains highly prevalent, with 85.3% of 6-year-old children having untreated caries and a mean DMFT of 5.7.[9] Among adults aged 35–44 years and elderly aged 65–74 years, periodontal disease and tooth loss are major public health concerns.[10] Despite these alarming clinical indicators, oral health has historically received limited attention in national health agendas, and the impact of these conditions on the daily lives of the Myanmar people has been poorly understood.[11] To date, no study has synthesized OHRQoL evidence across age groups, clinical conditions, and psychosocial determinants within a unified analytical framework in Myanmar.

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The healthcare landscape in Myanmar is characterized by significant disparities between urban and rural areas, a low dentist-to-population ratio, and limited public health expenditure on oral health.[12] The political and economic challenges following the 2021 military coup have further strained an already fragile healthcare system, creating additional barriers to accessing oral health services.[13,14] These structural factors likely compound the burden of oral diseases on quality of life, particularly among vulnerable populations such as children, the elderly, and those with chronic conditions.

The recent formulation of Myanmar's National Oral Health Plan (2024–2030) represents a pivotal step toward strengthening oral health governance and service delivery. Although regional analyses have examined the integration of oral health within Universal Health Coverage frameworks in South-East Asia, there remains a limited country-specific synthesis of patient-centered oral health

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Table 1: Summary of included studies on OHRQoL in Myanmar

Author (year)	*Location*	*Study design*	*Population*	*Sample size*	*OHRQoL instrument*	*Key focus*
Min et al. (2024)[16]	Mandalay	Cross-sectional	Children (5 years)	454	SOHO-5	Early childhood caries
Soe et al. (2004)[17]	Yangon	Cross-sectional	Adolescents (14 years)	543	OIDP, OHIP-14	Validation study
Thwin et al. (2024)[18]	National	Cross-sectional	15–18, 35–44, 60–74 years	3,513	WHO OHRQoL questions	National survey
Htun and Peltzer (2019)[19]	Magway	Cross-sectional	Adults (35–65 years)	633	OHIP-14	Community-dwelling adults
Tun et al. (2018)[20]	Thanlyin	Cross-sectional	Elderly (≥60 years)	146	OHIP-14	Institutionalized elderly
Htay (2022)[21]	Mohnyin	Cross-sectional	Elderly (≥60 years)	312	GOHAI	Community-dwelling elderly
Nyan et al. (2020)[22]	Mandalay	Before-after	Elderly (>60 years)	30	OHIP-14	Implant overdenture treatment
Htun et al. (2021)[23]	Mandalay	Quasi-experimental	Shortened dental arch patients	20	OHIP-14	RPD treatment
Thwin et al. (2024)[24]	Yangon	Cross-sectional	Adults (≥18 years)	158	OHIP-14	COVID-19 impact
Thwin et al. (2025)[25]	Yangon	Cross-sectional	Adults (≥18 years)	158	OHIP-14	COVID-19 and psychological interaction

outcomes in Myanmar.[15] Effective policy implementation requires not only epidemiological surveillance of disease burden but also a clear understanding of how oral conditions affect daily functioning and well-being. Oral health-related quality of life measures provide this essential perspective by capturing functional, psychological, and social impacts beyond clinical indices alone.[3]

This narrative review has three primary objectives: (1) To synthesize the existing evidence on OHRQoL across different population groups in Myanmar; (2) to critically evaluate the key clinical, psychological, and social determinants of OHRQoL; and (3) to identify critical research gaps to inform the implementation of the National Oral Health Plan (2024–2030) and guide future patient-centered research and policy.

Methods

Study Design

This study employed a structured narrative review design to synthesize existing evidence on OHRQoL in Myanmar. A narrative approach was selected due to anticipated heterogeneity in study populations, instruments, and outcome reporting, which precluded quantitative meta-analysis. Because this was a narrative rather than a systematic review, no formal risk-of-bias assessment or Preferred Reporting Items for Systematic Reviews and Meta-Analyse (PRISMA) flow diagram was performed, and the synthesis reflects thematic interpretation rather than quantitative pooling.

Search Strategy

A structured literature search was conducted across five electronic databases: EBSCOhost (Dentistry and Oral Sciences Source), PubMed, Scopus, Google Scholar, and Myanmar Journals Online. The search period covered January 2000 to December 2025. Search terms combined three domains: Oral health terms ("oral health," "dental health," "dental caries," "tooth loss," "periodontal disease"); OHRQoL terms ("quality of life," "oral health-related quality of life," "OHRQoL," "OHIP," "OHIP-14," "GOHAI," "SOHO-5," "OIDP"); and location terms ("Myanmar," "Burma"). Boolean operators (AND/OR) were used. Reference lists of retrieved articles were manually screened for additional relevant studies.

Study Selection

Articles were considered if they were conducted in Myanmar, reported original empirical research, assessed OHRQoL using a validated instrument, included human participants, and were published in English between 2000 and 2025. Case reports, editorials, commentaries, and methodological papers without outcome data were excluded. Although a formal risk-of-bias tool was not applied, methodological quality was critically appraised based on study design, sample size, representativeness, and instrument validity.

Data Extraction and Synthesis

From each included study, the following data were extracted: Author(s) and year, location, design, population, sample size, OHRQoL instrument, key outcomes, and reported determinants. Findings were synthesized thematically by population group (children/adolescents, adults, elderly), clinical determinants, psychological factors, intervention outcomes, and external shocks (e.g., COVID-19). Because of heterogeneity in designs and outcome measures, quantitative pooling was not performed.

Results

A total of 10 studies met the inclusion criteria and were included in this narrative review (Table 1). These comprised eight cross-sectional studies, one before-and-after study, and one quasi-experimental study. The studies were conducted across various locations in Myanmar, including Yangon, Mandalay, Magway, and Mohnyin, as well as one national survey. Sample sizes ranged from 30 to 3,513 participants. Oral health-related quality of life was assessed using several validated instruments including the Oral Health Impact Profile-14 (OHIP-14), the Geriatric Oral Health Assessment Index (GOHAI), the Scale of Oral Health Outcomes for 5-year-old children (SOHO-5), and the Oral Impacts on Daily Performance (OIDP).

OHRQoL in Children and Adolescents

The burden of poor OHRQoL begins early in life in Myanmar. Min et al.[16] studied 454 five-year-old children in Mandalay using the SOHO-5 instrument, which captures both child self-reports and parental proxy reports. The findings were striking: 87% of children had caries experience, with a mean DMFT score of 5.59 (SD 4.65). Approximately two-thirds of children (64.1%) and parents (70.5%) reported negative impacts on the child's OHRQoL. The most commonly affected items were difficulty eating and difficulty sleeping due to pain.

Among adolescents, Soe et al.[17] validated two OHRQoL instruments in 543 14-year-old students in Yangon. Despite relatively low clinical disease levels (mean DT 0.64), 53.0% of adolescents reported some degree of impact using the OHIP-14, compared to only 15.8% using the OIDP. This difference reflects the OIDP's focus on more severe, "ultimate" impacts, while OHIP-14 captures a broader range of less severe but more prevalent impacts. The physical pain and psychological discomfort subscales were most frequently affected. Dental caries was perceived as the most common cause of impact (34.0%), followed by the appearance of teeth (30.9%). Both instruments demonstrated good reliability (Cronbach's alpha: OIDP = 0.72, OHIP-14 = 0.86).

OHRQoL in Adults and the Elderly

The national oral health survey conducted by Thwin et al.[18] provided the first population-based estimates of OHRQoL across three age groups in Myanmar. Among 3,513 participants, the most prevalent oral health problems affecting quality of life were difficulty chewing (32.2%) and difficulty biting foods (30.8%). The mean OHRQoL score (based on WHO-recommended questions) was 2.46 ± 4.35, with older adults (60–74 years) reporting the poorest OHRQoL (mean 2.86 ± 4.79).

Htun and Peltzer[19] examined OHRQoL among 633 community-dwelling adults aged 35–65 years in Magway using OHIP-14. The mean OHIP-14 score was 8.1 ± 9.1, with 57.2% having impaired OHRQoL (any item scored ≥2) and 16.6% having frequent impairment (any item scored ≥3). The most prevalent domain was psychological discomfort (60.2%), followed by physical pain (51.7%) and physical disability (40.9%). Adjusted logistic regression analysis revealed that poor oral health status (tooth loss, cavities, poor perceived periodontal health) and depressive symptoms were positively associated with impaired OHRQoL, while protective factors included drinking fluoridated water, using fluoridated toothpaste, and—paradoxically—never having visited a dentist. This finding may reflect reverse causality, whereby individuals with symptomatic oral disease are more likely to seek dental care.

OHRQoL in Institutionalized and Community-dwelling Elderly

Tun et al.[20] assessed OHRQoL among 146 elderly residents of an elderly home in Thanlyin using OHIP-14. The mean OHIP-14 score was 18.7 ± 9.7 (range 0–40), indicating substantial impairment. The mean number of remaining teeth was 13.6 ± 8.6, with only 30.1% having more than 19 natural teeth. Linear regression revealed a significant negative relationship between the number of remaining teeth and OHIP-14 score (β = −0.558, 95% CI −0.828 to −0.496, $p < 0.001$), controlling for age. Elderly aged ≥70 years and those who were widowed or divorced had significantly poorer OHRQoL. Acceptable knowledge about oral health was associated with better OHRQoL (mean OHIP-14 16.9 vs 20.5 for those with unacceptable knowledge, $p = 0.022$).

Htay[21] studied 312 community-dwelling elderly in Mohnyin using GOHAI. The mean GOHAI score was 41.18 ± 5.7 (range 12–60), with 46.2% classified as having high OHRQoL (score ≥42) and 53.8% having low OHRQoL. Over half (56.1%) had at least 20 remaining natural teeth, but only 19.9% wore dentures, indicating substantial unmet prosthodontic need. Item-level analysis showed that the most frequently reported problems were limiting kinds of food (20.8% always), trouble biting or chewing (22.4% always), and using medication to relieve pain (25.0% sometimes).

Impact of Prosthodontic Rehabilitation on OHRQoL

Nyan et al.[22] evaluated the effect of single-implant retained mandibular complete overdentures in 30 edentulous elderly patients (mean age 65.8 years). Baseline OHIP-14 scores were very poor (mean 30.1 ± 12.0), reflecting the functional and psychosocial burden of edentulism with unstable conventional dentures. Following implant placement and conversion to implant-retained overdentures, OHIP-14 scores improved dramatically to 2.1 ± 2.5 ($p < 0.001$), with significant improvements across all seven OHIP-14 domains. Patient satisfaction, measured by the Prosthesis Evaluation Questionnaire, was 91%.

Similarly, Htun et al.[23] evaluated removable partial denture (RPD) treatment in 20 patients with shortened dental arches. Masticatory performance measured by glucose extraction improved significantly from 130.80 ± 26.78 to 177.48 ± 38.76 mg/dL ($p < 0.001$). Oral Health Impact Profile-14 total scores decreased from 15.85 ± 8.96 to 4.20 ± 4.21 ($p < 0.001$), with significant improvements in all domains except functional limitation. The effect size for OHRQoL improvement was large [effect size (ES) = −1.56], and the mean change (11.65 points) far exceeded the minimally important difference of five points, indicating clinically significant improvement.

Impact of COVID-19 and Psychological Factors on OHRQoL

Thwin et al.[24] conducted a series of studies examining the impact of the COVID-19 pandemic on OHRQoL in Myanmar. Among 158 participants in Yangon, 30.4% reported worsened oral health perception during the pandemic, and 27.8% reported negative changes in oral hygiene behaviors. These changes were significantly associated with a history of COVID-19 infection, depressive symptoms, and bleeding on probing.

In a subsequent analysis, the same research group demonstrated significant independent and interactive effects of COVID-19 hospitalization and psychological distress on OHRQoL. Hospitalized COVID-19 patients had dramatically higher OHIP-14 scores (median 18.1) compared to non-hospitalized (7.0) and uninfected individuals (3.2). Interaction analysis revealed synergistic effects: The combination of hospitalized COVID-19 infection with depressive, anxiety, or stress symptoms was associated with significantly worse OHRQoL than the sum of their individual effects.[25]

Across all population groups, OHRQoL impairment demonstrated a consistent gradient corresponding to clinical disease severity, psychological distress, and limited access to care. Intervention studies showed the largest magnitude of change, suggesting that OHRQoL measures are responsive to treatment effects and suitable for outcome monitoring in Myanmar's oral health system.

Discussion

This narrative review synthesizes the available evidence on OHRQoL in Myanmar, revealing a consistent and substantial burden across all age groups. The findings consistently show associations between oral diseases—particularly dental caries in children and tooth loss/periodontal disease in adults and the elderly—and poorer functional abilities, psychological well-being, and social interactions. The high prevalence of impacts, especially difficulty eating and sleeping among children and psychological discomfort among adults, underscores the urgent need to integrate patient-centered outcomes into oral health policy and clinical practice in Myanmar. However, because the majority of included studies are cross-sectional, the findings presented here reflect associations rather than causal relationships, and causal interpretations should be made with caution.

The magnitude of OHRQoL impairment in Myanmar children is particularly concerning. With 87% of 5-year-olds affected by caries and two-thirds experiencing negative impacts on daily life, early childhood caries emerges as a critical public health priority.[16] The impacts on eating and sleeping documented in this review have broader implications for child development, including nutritional status, growth, and school performance.[26] These findings align with global literature demonstrating that untreated caries in young children is consistently associated with pain, infection, and significant disruption of daily activities.[27] The substantial agreement between child and parent reports [intraclass correlation coefficient (ICC) = 0.78] validates the use of both perspectives and suggests that even young children can reliably report on their oral health experiences when appropriate tools are used.[28]

Among adolescents, the finding that 53% reported some OHRQoL impact despite relatively low clinical disease levels is noteworthy.[17] This discordance between clinical indicators and subjective experience highlights the importance of patient-reported outcomes in capturing the full burden of oral conditions. The prominence of psychological discomfort and appearance-related concerns in this age group reflects the developmental importance of body image and social acceptance during adolescence.[29] These findings suggest that school-based oral health programs in Myanmar should address not only clinical prevention but also the psychosocial dimensions of oral health.

In adults and the elderly, tooth loss emerges as a dominant determinant of poor OHRQoL. The consistent finding across multiple studies that having fewer than 20 teeth is associated with significantly worse OHRQoL supports the concept of the "shortened dental arch" as a functional threshold.[30] The psychosocial consequences of tooth loss—embarrassment, avoidance of smiling, social withdrawal—were frequently reported, particularly in the Magway study, where psychological discomfort was the most prevalent domain.[19] These findings challenge the notion that tooth loss is an inevitable and acceptable consequence of aging and highlight the potential importance of tooth preservation strategies.

The role of psychological factors, particularly depression, as determinants of OHRQoL merits special attention. This relationship likely operates through multiple mechanisms: Psychological distress may be associated with poorer self-care and oral hygiene practices, while poor oral health may be linked to social isolation and diminished self-esteem.[31,32] The COVID-19 pandemic appeared to intensify these relationships, with synergistic effects between severe infection and psychological distress.[25] These findings have important implications for clinical practice, suggesting that oral health providers should be alert to psychological distress in patients with poor OHRQoL, and that mental health support should be integrated into oral health care delivery.

The substantial improvements in OHRQoL observed following prosthodontic rehabilitation in before-and-after and quasi-experimental studies suggest that such treatment can meaningfully enhance daily functioning and well-being.[22,23] The magnitude of OHIP-14 reduction (mean change = 28 points) far exceeds established minimally important differences, indicating profound clinical relevance rather than merely statistical significance. The large effect sizes and satisfaction rates exceeding 90% suggest that even relatively simple interventions—such as single-implant retained overdentures—may improve function, comfort, and psychosocial well-being. These findings are particularly relevant for Myanmar, where economic constraints limit access to more complex and expensive treatments. The single-implant approach offers a cost-effective, minimally invasive option that could benefit many edentulous elderly patients.[33]

Several gaps in the evidence remain. The predominance of cross-sectional designs prevents temporal sequencing, thereby limiting causal interpretation of associations between oral disease and OHRQoL outcomes, and some studies were conducted in specific geographic areas with relatively small samples. Longitudinal research, evaluations of preventive interventions, and studies in vulnerable populations are needed to strengthen evidence for policy and clinical planning. The concentration of recent OHRQoL publications within a limited number of research groups suggests growing expertise in this field; however, expanding research capacity across additional academic institutions in Myanmar will be essential for generating nationally representative evidence.

The findings have clear implications for oral health practice and policy in Myanmar. Incorporating OHRQoL measures into routine assessment and national surveillance could improve understanding of patient needs beyond clinical indicators. Preventive programs targeting childhood caries, integration of psychosocial support within dental care, and expanded access to basic prosthodontic services may substantially improve population well-being. As Myanmar implements its National Oral Health Plan (2024–2030), a stronger focus on patient-centered outcomes will be essential to ensuring that oral health services enhance both health and quality of life.

Conclusion

Poor oral health is consistently associated with lower quality of life across all ages in Myanmar—impairing function, well-being, and social interaction. COVID-19 may worsen outcomes; prosthodontic rehabilitation shows benefit in before-and-after studies. Myanmar's National Oral Health Plan (2024–2030) should prioritize OHRQoL surveillance, child caries prevention, and restorative care access. However, evidence is predominantly cross-sectional. Longitudinal and intervention research is urgently needed. Without patient-reported outcomes, the true burden of oral disease in Myanmar will remain underestimated.

Artificial Intelligence (AI) Disclosure

The author used AI-assisted tools solely for proofreading, grammar checking, and language refinement during the preparation of this manuscript. No generative AI tools were used for study conceptualization, data extraction, synthesis, interpretation, or the core intellectual content of the work. The author takes full

responsibility for the accuracy, integrity, and originality of all content presented in this paper.

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REVIEW ARTICLE

Cuproptosis in Cancer: A Novel Metal-induced Cell Death Pathway

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Abstract

Cuproptosis is a recently identified form of copper-dependent regulated cell death that functions through a mitochondrial mechanism distinct from apoptosis, ferroptosis, and other canonical pathways. It is triggered when excess intracellular copper binds to lipoylated enzymes of the tricarboxylic acid (TCA) cycle, causing proteotoxic stress, collapse of iron–sulfur (Fe–S) cluster function, and mitochondrial failure. This narrative review synthesizes emerging evidence on the mechanistic basis of cuproptosis, key molecular regulators such as ferredoxin 1 (*FDX1*), and the increasing interest in utilizing this pathway for cancer therapy. Preclinical studies indicate that copper ionophores, copper chelators, and nanoparticle-based delivery systems can modulate cuproptosis to overcome drug resistance in several tumor types, although clinical results remain varied. Challenges include metabolic heterogeneity within the tumor, resistance mechanisms like adenosine triphosphate (ATP)/B-mediated copper export, and an incomplete understanding of downstream signaling. Despite these uncertainties, cuproptosis presents a promising therapeutic approach for cancers that depend heavily on mitochondrial metabolism. Ongoing mechanistic and translational research will be crucial for refining biomarkers, identifying effective drug combinations, and determining optimal contexts for cuproptosis-targeted treatments in oncology.

Keywords: Cancer therapeutics, Cancer, Copper chelators, Copper homeostasis, Copper ionophores, Cuproptosis, Drug resistance.

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Introduction

Cancer is an umbrella term for a broad range of diseases that can arise in almost any tissue of the body. In clinical settings, people often use related words such as malignant tumor or neoplasm. What distinguishes cancer from more benign growths is the emergence of cells that divide more rapidly than they should and eventually push past the boundaries that normally contain them. As these cells accumulate, many of them begin to infiltrate neighboring tissues. Some may even break away and travel to distant organs through the bloodstream or the lymphatic system, a process known as metastasis. When metastases become widespread, they disrupt the function of multiple organs at once, which is ultimately the major reason that cancer becomes life-threatening.[1] According to the American Association for Cancer Research's 2022 Cancer Progress Report, an estimated 18.1 million new cancer cases were recorded worldwide in 2020, and about 9.89 million people died as a result of the disease. Projections for the coming decades are not exactly reassuring. By 2040, global cancer incidence is expected to reach roughly 28 million new cases, a rise that reflects aging populations, changing lifestyles, and persistent gaps in prevention and early detection across many regions.[2,3]

Cuproptosis is a relatively new form of copper-dependent regulated cell death, first described in 2022, and it stands apart from the cell death pathways we were familiar with until then.[4] It does not fit neatly into the patterns seen in oxidative stress-driven mechanisms, where reactive oxygen species usually take center-stage. Instead, cuproptosis appears to unfold through a more targeted mitochondrial process that is initiated when copper builds up inside the cell. As researchers piece together the finer details, it has become clear that this pathway represents a genuine shift in how we think about metal-induced toxicity and cellular regulation.[5] Cuproptosis appears to be a genuinely separate mode of regulated cell death, working on principles that do not overlap much with apoptosis, necroptosis, pyroptosis, or even ferroptosis.[6] What makes it stand out is that the process does not hinge on reactive oxygen species or caspase activation, which are almost routine players in other pathways. Instead, the pathway ties cell death directly to mitochondrial respiration and the fate of lipoylated proteins. This tight link to mitochondrial metabolism gives cuproptosis a character that feels quite different from the better-known forms of cell death, although researchers are still sorting out some of the finer mechanistic details.[7] Cuproptosis begins when copper accumulates inside the cell and binds directly to a set of lipoylated enzymes in the tricarboxylic acid (TCA) cycle, most notably dihydrolipoamide S-acetyltransferase (*DLAT*) and dihydrolipoamide succinyltransferase (*DLST*). The interaction depends entirely on the lipoyl group, a small prosthetic moiety attached to specific lysine residues on these mitochondrial proteins. Experiments with purified *DLAT* and *DLST* show that they attach strongly to copper-charged resins, which makes the binding fairly easy to track. However, when lipoylation is disrupted by knocking out ferredoxin 1 (*FDX1*), the enzymes essentially lose their ability to bind copper. This loss of

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binding makes it clear that the lipoyl group is the critical point of contact between copper and these TCA-cycle proteins.[6] Copper is an essential transition metal that, under normal conditions, acts as a cofactor for several enzymes, which keep basic cellular processes running smoothly.[8] The problem arises when its homeostasis slips out of balance. Increasing evidence suggests that disrupted copper regulation does not merely disturb metabolism but can actively contribute to malignant transformation and support the progression of certain cancers.[9] The picture is complex, of course, but it is becoming clear that copper's role in cancer biology is more than a minor metabolic footnote. Copper is a crucial cofactor for cytochrome c oxidase, the terminal enzyme of the mitochondrial electron transport chain.[10] This metalloprotein uses its copper centers to transfer electrons from cytochrome c to molecular oxygen, a step that drives the formation of the electrochemical gradient needed for adenosine triphosphate (ATP) production. In practical terms, the cell begins to run short on energy, and many energy-dependent processes start to fail.[11] At the heart of cuproptosis is a copper-driven chain of events in which lipoylated mitochondrial enzymes begin to aggregate and overload the cell with proteotoxic stress.[12] This aggregation disrupts two systems that mitochondria rely on to function smoothly: The TCA cycle and the machinery responsible for building iron–sulfur (Fe–S) clusters. When both are compromised at the same time, mitochondrial activity collapses in a way that the cell cannot recover from. The result is a form of regulated cell death that hinges on this tightly linked metabolic breakdown.[12] The cuproptosis pathway is shaped by a tightly linked set of molecular regulators that manage copper levels, maintain proper protein lipoylation, govern the aggregation of lipoylated enzymes, and support mitochondrial metabolism. These systems do not operate in isolation. Instead, they influence one another in ways that ultimately decide how vulnerable a cell is to copper-induced death. In many cases, a small shift in one component of this network can tilt the balance toward either resistance or rapid collapse, which highlights how coordinated this pathway really is.[12] Ferredoxin 1 has emerged as the key upstream regulator of cuproptosis, and it operates through two related but mechanistically distinct routes. One of its central roles is to reduce Cu^{2+} to Cu^{+}, effectively converting copper into the more reactive form that can bind to lipoylated mitochondrial proteins.[13] This step is crucial, since only Cu^{+} can engage directly with those lipoylated components of the TCA cycle. Copper ionophores such as elesclomol can shuttle Cu^{2+} across the cell and into the mitochondria, but without *FDX1* performing this reduction step, the imported copper remains relatively inert. By generating Cu^{+} within the mitochondrial matrix, *FDX1* enables the toxic interactions that set the cuproptosis pathway in motion.[14] Dihydrolipoamide S-acetyltransferase and *DLST* are the main molecular targets that undergo copper-driven aggregation during cuproptosis. Both enzymes sit at the core of major mitochondrial dehydrogenase complexes. Dihydrolipoamide S-acetyltransferase functions as the E2 lipoyl transferase subunit of the pyruvate dehydrogenase complex, while *DLST* plays the analogous E2 role within the α-ketoglutarate dehydrogenase complex. Their lipoylated domains make them particularly vulnerable once copper accumulates in the mitochondrial matrix, placing them at the center of the cuproptotic cascade.[15] Recent research points to cuproptosis, a copper-dependent form of regulated cell death, as a potentially useful way to tackle cancer drug resistance. Because this pathway operates differently from apoptosis or other well-mapped death programs, it may provide an avenue to eliminate tumor cells that no longer respond to standard treatments.[16] Several copper-based strategies, including copper ionophores and various copper complexes, have shown the ability to slow tumor growth and kill cells that resist drugs such as cisplatin, 5-fluorouracil, and even targeted agents such as vemurafenib.[17] These compounds work by raising intracellular copper levels, which then accumulate in the mitochondria. Once that threshold is reached, copper promotes the aggregation of lipoylated TCA-cycle proteins, generating severe proteotoxic stress. This mitochondrial collapse appears sufficient to wipe out cells that have otherwise adapted to evade conventional chemotherapy.[15] Cuproptosis is a newly described form of regulated cell death in which excess copper drives the aggregation of specific mitochondrial proteins. The pathway operates in a way that is quite different from apoptosis or ferroptosis, which is partly why it has drawn so much attention. Many tumors show altered copper-handling and an unusually high dependence on mitochondrial metabolism, suggesting they might be especially vulnerable to this kind of copper-triggered toxicity. Yet, even with the burst of mechanistic studies that have appeared since 2022, the clinical relevance of cuproptosis in cancer is still only lightly charted.

A focused narrative review is therefore warranted to synthesize current knowledge, clarify the molecular basis of the pathway, and explore how interventions based on cuproptosis could lead to new therapeutic options in oncology.

Methodology

This article was developed as a narrative review synthesizing current evidence on the mechanisms, therapeutic relevance, and emerging challenges associated with cuproptosis in cancer. A comprehensive literature search was conducted between January 2022 and January 2025 using PubMed, Scopus, Web of Science, and Google Scholar. Key search terms included "cuproptosis," "copper-induced cell death," "*FDX1*," "lipoylated proteins," "copper ionophores," "copper chelators," and "tumor copper metabolism." Boolean operators (AND/OR) were applied to refine the search strategy. Both original research articles and review papers published in peer-reviewed journals were included. Priority was given to early-phase clinical trials relevant to copper-dependent cell death and its translational implications in oncology. Articles not available in English, conference abstracts without accessible full text, and non-scientific commentary pieces were excluded. Data extraction focused on mechanistic insights into cuproptosis, the roles of central regulators such as *FDX1* and lipoylated TCA enzymes, copper transporter biology, tumor metabolic adaptations, resistance pathways, and therapeutic interventions involving copper modulation. Clinical evidence from ongoing or completed trials of copper ionophores and chelators was also reviewed.

Mechanism of Action of Cuproptosis

Cuproptosis is a unique form of regulated cell death that begins when copper builds up inside the cell to levels it cannot safely manage. This excess can arise for several reasons, including heightened copper uptake, reduced copper export, or exposure to copper-carrying ionophores that shuttle the metal directly into cells. Once copper surpasses its normal physiological range, the conditions are set for the cuproptotic pathway to unfold.

Copper Accumulation and Mitochondrial Import

Inside the cell, copper in its reduced Cu^{+} form is directed toward the mitochondria, where a set of dedicated copper-handling proteins

ensures its safe delivery. Chaperones such as COX17 guide Cu^{+} to the inner mitochondrial membrane, passing it along to proteins such as *SCO1*, *SCO2*, and *COX11*. These components help position copper precisely where it is needed for the proper assembly of mitochondrial respiratory complexes.[14]

Copper Reduction by *FDX1*

Ferredoxin 1 plays a central role once copper enters the mitochondria. It reduces Cu^{2+} to the more reactive Cu^{+} state, the form that can actually interact with mitochondrial proteins. In parallel, *FDX1* supports the lipoylation of specific mitochondrial enzymes by working with lipoyl synthase (*LIAS*). This activity increases the pool of lipoylated proteins, which ultimately become the major binding targets for Cu^{+} during cuproptosis.[18]

Copper Binding to Lipoylated TCA-cycle Enzymes

Cu^{+} shows a strong preference for binding to the lipoylated subunits of the pyruvate dehydrogenase and α-ketoglutarate dehydrogenase complexes, particularly *DLAT* and *DLST*. The lipoyl groups attached to these enzymes serve as the key docking sites, allowing copper to engage directly with them and initiate the aggregation events characteristic of cuproptosis.[19]

Aberrant Aggregation of Lipoylated Proteins

When copper attaches to these lipoylated enzymes, it triggers abnormal aggregation and disulfide-linked misfolding of the mitochondrial proteins. This sudden build-up of misfolded material generates sharp proteotoxic stress that quickly outpaces the capacity of mitochondrial chaperone systems, including *HSP70*. Once these quality-control mechanisms are overwhelmed, the cell struggles to restore protein homeostasis, pushing it further along the cuproptotic pathway.[18]

Disruption of Fe–S Cluster Proteins

Copper also disrupts the formation and stability of Fe–S cluster proteins, which are crucial for mitochondrial electron transport and overall respiratory function. Excess Cu^{+} appears to destabilize the Fe–S assembly machinery itself, leading to impaired cluster formation and the progressive loss of Fe–S-containing proteins. As these components deteriorate, mitochondrial respiration becomes increasingly compromised, adding another layer of stress that pushes the cell toward cuproptotic death.[20]

Collapse of Mitochondrial Metabolism

The combined effect of lipoylated protein aggregation and the loss of Fe–S proteins severely disrupts the TCA cycle and undermines mitochondrial respiration. With these central metabolic pathways faltering, oxidative phosphorylation becomes less efficient, and the electron transport chain struggles to maintain its usual output. This metabolic collapse is a defining step in the progression toward cuproptotic cell death.[14]

Energy Failure

As mitochondrial respiration breaks down, ATP production drops sharply, leaving the cell with far less energy than it needs to sustain normal functions. This energy shortfall quickly affects processes that depend on a steady ATP supply, pushing the cell into a state where it can no longer maintain basic metabolic stability.

Proteotoxic and Metabolic Stress Amplification

The build-up of misfolded proteins sends strong stress signals within the mitochondria, amplifying the existing damage and making it increasingly difficult for the organelle to regain its normal function. Instead of easing with time, the stress tends to escalate, creating a feedback loop that pushes the cell further toward collapse.

Execution of Cuproptosis

Together, these layers of proteotoxic stress and metabolic breakdown activate a form of regulated cell death that does not rely on caspases or reactive oxygen species. This pathway, now recognized as cuproptosis, reflects a unique cellular response to overwhelming copper-driven damage.[13]

Cuproptosis is a unique mitochondrial metabolic cell death pathway initiated by excessive intracellular copper accumulation. Copper is imported into mitochondria, where *FDX1* reduces Cu^{2+} to the reactive Cu^{+} form. Cu^{+} then binds specifically to lipoylated TCA-cycle enzymes such as *DLAT* and *DLST*, inducing their aberrant aggregation and causing severe proteotoxic stress. Concurrently, copper disrupts Fe–S cluster protein stability, leading to mitochondrial respiratory chain dysfunction. The resulting collapse of the TCA-cycle and oxidative phosphorylation causes ATP depletion, amplifying metabolic and proteotoxic stress, which culminates in caspase- and ROS-independent regulated cell death termed cuproptosis (Fig. 1).

Detection and Biomarkers

Copper accumulates within the mitochondria, where it is enzymatically reduced from Cu^{2+} to its reactive Cu^{+} state by *FDX1*, a mitochondrial matrix reductase that is essential for rendering copper bioavailable to mitochondrial proteins such as cytochrome c oxidase.[21] This reduction step promotes the binding of copper to lipoylated mitochondrial enzymes, triggering toxic protein aggregation that ultimately results in mitochondrial dysfunction and the induction of cuproptosis.[22] Loss or inhibition of *FDX1* reduces mitochondrial copper levels, disrupts the biogenesis of cytochrome c oxidase, and impairs mitochondrial respiration. Thus, the essential role of *FDX1* in mitochondrial copper-handling and redox regulation directly links its function to the underlying mechanism of cuproptosis.[15]

Therapeutic Strategies

Therapeutic strategies designed to target cuproptosis primarily aim to modulate intracellular copper levels to either induce or suppress this regulated cell death pathway. By manipulating copper availability, these approaches seek to selectively trigger cuproptosis in susceptible cells, offering promising therapeutic potential, particularly in the context of cancer treatment.

Copper Ionophores

Agents such as elesclomol and disulfiram act as copper ionophores that promote the intracellular accumulation of copper, particularly within mitochondria of cancer cells. Elesclomol transports extracellular Cu^{2+} into the cell, where it is subsequently reduced to the cytotoxic Cu^{+} form by *FDX1*.[5] This Cu^{+} then binds to lipoylated mitochondrial enzymes, driving their aggregation and inducing mitochondrial metabolic collapse characteristic of cuproptosis. Both clinical and preclinical studies demonstrate that elesclomol

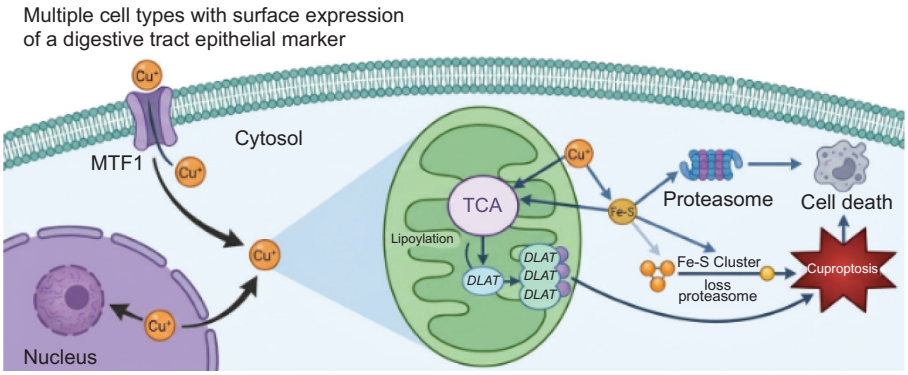

Fig. 1: Diagram of the mechanism associated with cuproptosis

enhances the therapeutic efficacy of chemotherapeutic agents such as docetaxel and sensitizes resistant tumors, including melanoma, lung, breast, and prostate cancers, by amplifying mitochondrial copper-dependent toxicity.[14]

Copper Chelators

Compounds such as tetrathiomolybdate, D-penicillamine, and trientine function as copper chelators that sequester free copper ions, thereby reducing intracellular copper availability. These agents are clinically employed in the management of copper overload disorders such as Wilson's disease and have also been explored for their anticancer potential, primarily through suppression of copper-dependent processes, including angiogenesis, tumor growth, and metastatic spread.[20] Within the framework of cuproptosis, copper chelators serve an additional role by mitigating excessive or pathological copper-induced cell death, offering therapeutic value in conditions where preventing mitochondrial copper toxicity is desirable.[23]

Combination Therapies

Several studies propose combination therapeutic regimens that integrate copper ionophores or chelators with standard chemotherapy, radiotherapy, or immunotherapy to enhance anticancer efficacy. Copper ionophores used alongside immune checkpoint inhibitors (such as anti-PD-1/PD-L1 antibodies) can potentiate antitumor immunity by inducing immunogenic cell death through cuproptosis.[24] Additionally, nanoparticle-based delivery platforms designed to release copper ions selectively within tumor tissues have been developed to improve the therapeutic window, enhance intracellular copper accumulation, and minimize systemic toxicity. Combination strategies that simultaneously target metabolic vulnerabilities and copper homeostasis further optimize cancer cell elimination and represent a promising direction for future cuproptosis-based therapeutics.[25]

Clinical Translation

Advances in elucidating the molecular mechanisms of cuproptosis have prompted the development of clinical trials that leverage copper modulation as a novel therapeutic strategy, particularly for drug-resistant and highly aggressive cancers.[25] By exploiting the distinct metabolic vulnerabilities associated with copper-dependent mitochondrial dysfunction, these emerging therapies hold promise for improving treatment responses and expanding precision oncology approaches.[26,27]

Translational and Clinical Evidence

Clinical and translational evidence supporting cuproptosis-targeting therapies is steadily expanding, with multiple ongoing and completed clinical trials evaluating copper-modulating agents, most notably copper ionophores such as elesclomol in diverse cancer settings. These investigations aim to determine the therapeutic utility of manipulating intracellular copper homeostasis to induce selective mitochondrial toxicity and enhance antitumor efficacy (Table 1).

Challenges Limiting Cuproptosis

Tumor cells rarely behave uniformly, and this metabolic heterogeneity creates a substantial challenge when attempting to induce cuproptosis in solid tumors. On top of that, the surrounding microenvironment often works against us. Regions of low oxygen, stiff or crowded tissue architecture, and other mechanical hurdles tend to interfere with the pathways that cuproptosis depends on. These conditions can shift mitochondrial metabolism in odd directions and, in many cases, dampen the expression of key regulators such as *FDX1*. The result is a frustratingly uneven response to treatment, where some cells are primed to undergo cuproptosis while others barely react.[28] Several resistance pathways are starting to emerge as researchers look more closely at why some cancers slip past copper ionophore therapy. One of the clearer trends involves the tumor cells ramping up copper export through transporters such as *ATP7A* and *ATP7B*. Cells increase expression of copper export proteins, thereby reducing intracellular copper accumulation. At the same time, many tumors seem to lean more heavily on antioxidant systems, which helps them cushion the oxidative stress that would otherwise push them toward cuproptosis. There is also a noticeable metabolic shift in some cancers. They move away from mitochondrial respiration and drift toward glycolysis, which essentially sidesteps the metabolic choke points that copper ionophores are trying to exploit.[28] A major roadblock in pushing cuproptosis-based treatments forward is that our molecular understanding of this process still feels a bit unfinished. Several of the downstream effectors remain unclear, and the way cuproptosis intersects with other cell death pathways is only partially mapped out. Because of these gaps, designing drugs or even thinking through sensible combination strategies becomes a bit of a guessing game. Many groups are arguing that we need deeper, more patient mechanistic work to fill in these missing pieces. Pinpointing new molecular players and clarifying how cuproptosis interacts with broader cellular networks could

Table 1: Summary of trials represents translation effect targeting copper metabolism and cuproptosis for cancer treatment

Study	*Design*	*Sample size*	*Outcome measures*	*Comparator*	*Conclusion*
An open-label, multicenter, single-arm phase 1/2 study to assess tolerability, safety and efficacy of CRC01 in adult patients with relapsed or refractory large B-cell lymphoma NCT04836507	An open-label, multicenter, single-arm phase I/II Study	91	Phase I study: MTD, which will be the RP2D. Phase II pivotal study: Overall response rate (ORR).	NA	Anbal-cel showed encouraging signs of effectiveness while maintaining a generally tolerable safety profile in this dose escalation study.
A randomized, double-blind, phase 3 trial of elesclomol (STA-4783) in combination with paclitaxel vs paclitaxel alone for treatment of chemotherapy-naïve subjects with stage IV metastatic melanoma NCT00522834 (SYMMETRY)	A randomized, double-blind, phase III trial	630	RECIST was used for efficacy assessment with specifications in the protocol to allow for the recording of up to five skin lesions (beyond the maximum of 10 permitted per RECIST) and to account for missing data.	Paclitaxel	The study did not achieve its primary endpoint. Prespecified and exploratory analyses suggest that baseline LDH levels may predict treatment outcomes for elesclomol.
A phase Ib study of intravenous copper loading with oral disulfiram in metastatic, castration resistant prostate cancer NCT02963051	A phase Ib, open-label study	9	Safety (NCI CTC v4.0) and tolerability of IV $CuCl_2$ and DSF in men with mCRPC.	NA	Oral DSF is not an effective treatment for mCRPC because it is quickly metabolized into the noncytotoxic inactive metabolite, MeDDC.
A study of tetrathiomolybdate (TM) plus capecitabine NCT06134375	Phase Ib open-label	18	To establish the safety of the combination of adjuvant tetrathiomolybdate with capecitabine and pembrolizumab by the number of doses and limiting toxicities.	NA	Ongoing.
Safety and superiority of penicillamine in radiosensitization of recurrent head and neck cancer NCT06103617	Single-center, single-arm, phase II clinical trial	10	The ORR is the proportion of patients who achieve a prespecified reduction in tumor volume that is maintained for a minimum duration.	NA	Ongoing.

DSF, disulfiram; IV, intravenous; LDH, lactate dehydrogenase; mCRPC, metastatic castration-resistant prostate cancer; MTD, maximum tolerated dose; RECIST, response evaluation criteria in solid tumor; RP2D, recommended phase II dose

Note: All clinical trials listed in this table can be accessed using their respective ClinicalTrials.gov identifiers (NCT numbers)

open the door to more precise targeting and, ultimately, more reliable therapeutic approaches (Fig. 2).[29–31]

Discussion

Cuproptosis has quickly moved from an intriguing biochemical observation to a pathway with genuine therapeutic promise. The mechanistic landscape of this pathway remains incompletely defined. The past few years have given us a clearer sense of how copper overload destabilizes mitochondrial metabolism and pushes cells toward a very specific form of regulated death. Even so, when we step back and look at the broader landscape of cancer biology, the picture becomes more complicated.[2] Tumors do not operate under clean, uniform metabolic conditions. They grow in pockets of hypoxia, shift between nutrient states, and constantly remodel their stroma. All of this means that the elegant mechanistic model built in controlled lab systems rarely plays out as neatly in the chaotic setting of a solid tumor. One recurring challenge is the sheer metabolic diversity within and across tumors. Two regions in the same tumor can behave as completely different organisms.[3] Some cells rely heavily on oxidative phosphorylation and seem almost primed for copper-induced mitochondrial collapse. Others survive comfortably on glycolysis and barely register mitochondrial stress at all. This metabolic unevenness makes it difficult to predict where cuproptosis-inducing therapies will work well and where they will quietly fail. The tumor microenvironment only intensifies this unpredictability. Dense extracellular matrices, abnormal vasculature, and chronically low oxygen levels tend to suppress expression of regulators such as *FDX1*, weakening the very machinery that cuproptosis depends on.[5] Many tumors exhibit intrinsic features that confer partial resistance even before therapeutic intervention. Beyond these intrinsic barriers, cancer cells appear surprisingly adaptable when exposed to copper ionophores. Several resistance pathways have now surfaced. Many tumors increase the activity of *ATP7A* and *ATP7B*, essentially pumping out copper as fast as the drugs bring it in.[4] Others bolster antioxidant defenses or shift toward glycolysis to escape mitochondrial reliance altogether. Although these strategies are not

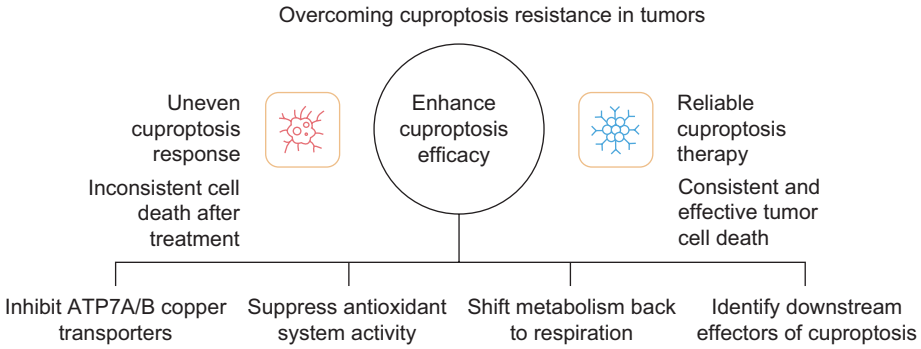

Fig. 2: Challenges limiting the therapeutic exploitation of cuproptosis

mechanistically complex, they are sufficiently effective to diminish the therapeutic impact of copper-based agents. The difficulty is that each resistance mechanism hints at a different therapeutic vulnerability, making it hard to design a single "best" combination approach. Some tumors may respond to copper ionophores plus metabolic inhibitors, while others may require blocking copper exporters or rewiring antioxidant signaling. This diversity places a heavy burden on translational research: We need to know which tumors fall into which resistance category before clinical strategies can become reliably effective.[32]

A deeper issue sits beneath these practical concerns. The molecular map of cuproptosis is still incomplete. We know the core players well enough to sketch the pathway, but we do not yet understand the full set of downstream events or how this mode of death interacts with apoptosis, ferroptosis, or other stress responses.[17] For example, some studies hint at subtle cross-talk with Fe–S cluster biogenesis pathways or stress-induced proteostasis networks, but it is difficult to say whether these represent true regulatory nodes or just collateral damage from copper overload. Without answering these mechanistic questions, drug design remains a little speculative.[18] There is a tendency to rely on copper modulation alone; however, evidence suggests that the most effective therapeutic approaches will require rationally designed combination strategies. Understanding those matches requires molecular clarity that the field is still working toward. Even with all these uncertainties, the translational progress so far is encouraging. Early-phase trials using copper ionophores, copper chelators, or engineered copper-delivery systems show that cuproptosis can be manipulated in patients, even if the clinical benefits vary. Some failures, such as the "SYMMETRY" trial with elesclomol, have been more instructive than disappointing, because they hint that factors such as baseline lactate dehydrogenase (LDH) levels or metabolic dependencies may strongly influence outcomes.[29] Newer approaches, including nanoparticle-based copper carriers or combinations with immunotherapy, reflect a shift toward more rational, metabolism-focused strategies rather than blanket copper loading. Taken together, the current body of evidence suggests that cuproptosis is neither a miracle pathway nor a passing scientific curiosity.[28] It sits somewhere in between: A promising but still-maturing concept that requires more rigorous mechanistic work before it can genuinely reshape cancer therapy. The next steps will involve refining biomarker signatures, mapping resistance trajectories in greater detail, and designing trials that do not treat many tumors as metabolically equivalent. With a clearer understanding of the molecular "gray zones" that still surround cuproptosis, researchers may eventually be able to use this pathway not just as an experimental curiosity but as a precise therapeutic tool.[31]

Limitations

However, the said review is only dependent on the available published literature database and does not embrace a systematic methodology for study selection. Additionally, most of the current evidence on cuproptosis is derived from early phase clinical trials, while clinical data remain limited. Future research should focus on validating cuproptosis-related biomarkers, demonstrating downstream molecular mechanisms, and conducting well-designed clinical studies to achieve the therapeutic and scientific validity of cuproptosis-targeted interventions in cancer.

Conclusion

Cuproptosis has emerged as a genuinely distinct form of regulated cell death, and although the field is still piecing together several mechanistic gaps, the progress so far suggests real therapeutic potential. Copper-dependent mitochondrial stress offers a way to target tumors that have learned to sidestep more familiar death pathways. At the same time, the complexity of tumor metabolism, the adaptive resistance seen with copper ionophores, and the limited clinical data all remind us that this approach is far from ready-made. What seems most promising is not a single copper-based drug but a more thoughtful integration of cuproptosis with metabolic profiling, biomarkers, and combination strategies. As mechanistic studies continue to sharpen our understanding, cuproptosis may well become a useful addition to the cancer therapy toolkit, especially for tumors that rely heavily on mitochondrial metabolism or resist conventional treatments.

Artificial Intelligence (AI) Disclosure Statement

During the preparation of the manuscript, authors used Grammarly and Quillbot apps to improve language, grammar, and readability. After using these tools, authors reviewed and edited the content as needed and takes full for final content of the publication.

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Authors' Contributions

Mr Nalin Pathak performed conceptualization, literature search, data interpretation, and drafted the initial manuscript. Mr Jayashis Banerjee contributed to methodology, content review, and major

editing. Mr Nomaan Mehdi supervised the work, validated scientific accuracy, and provided critical revisions. All authors approved the final manuscript.

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REVIEW ARTICLE

The Midwifery Approach to Primary Healthcare: From Survival to Dignity

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Abstract

The maternal mortality ratio (MMR) is a critical indicator of a country's health status and progress toward universal health coverage. As the maternal mortality of India continues to reduce, showing the remarkable progress in health service delivery, regional disparities persist. It becomes even more pronounced among women from marginalized social groups. As survival has improved, focus should now shift to improving the qualitative aspects of care: Respecting the dignity of women, ensuring equal treatment across all social groups, enhancing childbirth experiences, and reducing morbidity. This paper reviews the role of midwifery-led care in improving the quality of maternal health and offering a continuum of care, particularly for the vulnerable population. It tries to explore different models of midwifery care across different aspects and the way they can be replicated in a lower-middle-income setting. Beyond clinical practice, it also highlights the importance of strengthening the quality of midwifery education and greater representation within the health system. This becomes more relevant given the Indian Government has recently introduced the National Nursing and Midwifery Commission (NNMC) Bill, 2023. Along with that, the World Health Organization (WHO) also acknowledges midwives' indispensable role in improving the maternal health of a country. When positioned as leaders of maternal primary healthcare, midwives can accelerate our progress toward sustainable development goals (SDG) 3 and 5 by providing crucial services required in reducing maternal and infant mortality rates.

Keywords: Health policy, Maternal health, Maternal mortality ratio, Nursing and midwifery, Primary healthcare.

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Introduction

One of the critical indicators used to measure the performance of the health system and gender equality in a country is maternal mortality. Maternal mortality, as per World Health Organization (WHO), has been defined as "The annual number of female deaths from any cause related to or aggravated by pregnancy or its management (excluding accidental or incidental causes) during pregnancy and childbirth or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy."[1]

India has made remarkable progress in improving its maternal mortality ratio (MMR).[2] The MMR of the country has reached 93 in 2025 and is expected to achieve the target of sustainable development goal (SDG) of below 70 by 2030. Alongside that, the country's sex ratio has also improved, and the fertility rate has reached the replacement level.[3] Over the last three decades, while the reduction of MMR around the world has been 48%, India's MMR reduction has impressively been 86%.[3] This has been possible due to years of initiative and target-focused care to increase institutional births by conditional cash transfer scheme, providing services to women and their new-borns free of cost in all public healthcare facilities, and assigning a specific day of the month for identification and management of high-risk pregnancies, among many others.

However, this national data masks regional and social disparities in MMR data. Although most of the southern and western parts of the country has already achieved the SDG goal of MMR less than 70, there are parts of northern and north eastern region, still having MMR more than 100. This has been more concerning in the remote parts of these states.[4] Social inequities have been widely pronounced for maternal death among different social groups of the country, with maternal mortality among the country's Scheduled Tribes and Castes being about two times higher, while for the Muslims and Other Backward Castes, it is 1.5 times higher when compared to women belonging to upper castes.[1] A possible reason can be the deep-rooted prejudice and bias against people from different classes and castes within the society and the health workforce as well. However, there is a lack of study to identify all the potential drivers causing this disparity across the country and can be a future scope of research.

In a deeply patriarchal society, women are already facing the burden of gender bias and sexual abuse. Things grow worse for marginalized women, who have to face the dual burden of discrimination. These forms of bias have been so normalized by the people of the society that they have filtered into the healthcare system as well. Women inside the labor room have to face traumatic experiences during birth – physical and verbal abuses. This becomes more pronounced among those women with little agency and decision-making authority. Such experiences are a key driving factor in whether the woman and her family are going to choose public

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healthcare for future pregnancies and other illnesses and whether they are going to recommend it to others.

Midwives can play a transformative role in this landscape. Professional midwives are the ones who are designated to provide care during pregnancy, childbirth and the post-partum period in a woman-centric approach. They reduce the economic burden of medicalized care and bridge the gap between the couple and the healthcare system.[5] Apart from the positive birthing experience, midwives can actually play a significant role in reducing the mortality of women due to pregnancy-related reasons. Around 4.3 million lives can be saved annually by 2035, simply with the access of a skilled midwife.[6] In low- and lower-middle income regions, midwives can take care of uncomplicated pregnancies at the primary and secondary level, freeing up the time of specialists for handling complicated and emergency cases. Both the specialist and midwife can act in partnership, like a collaborative model instead of a hierarchical one, making the caregiving process more respectful and safer.

A lot of work has been done to address the outcome of pregnancies and reduce preventable death. Now that we have been able to reduce the burden of maternal death to quite some extent, it's time to focus on the qualitative aspect of care. There has been evidence around the world on how midwives can improve a woman's birthing experiences. This review article is an effort to look into the vital roles of midwives in the Indian healthcare system, successful models of midwifery around the world and their applicability to the South Asian context.

Methodology

A secondary search of data has been done from PubMed and Google Scholar using keywords: Health system, maternal health and policy, maternal mortality, nursing and midwifery, midwifery education, obstetric violence, successful midwifery model. Along with this, news articles, WHO guidelines and newsletters, policy documents from the Ministry of Health and Family Welfare (MoHFW) and National Nursing and Midwifery Commission (NNMC) Bill, has also been referred while preparing this article. All the reviewed articles and documents had been no older than 2015. Both primary and secondary research has been considered during the search of article. While the primary focus has been on articles focussed in India and on South-Asian context, several successful stories and models from other developing and developed countries has also been included.

Global Midwifery Landscape

The practice of midwifery is not new to the world and has deep roots across cultures. For centuries women in different communities were designated to assist women during the process of labor and after birth care and were called by different names in different parts of the world. This craft of midwifery was passed down to these women across different generations by word of mouth, and it was only in the 20th century when midwifery as a profession started to gain pace on the European continent.[7] Though the midwives in those era performed a holistic task of taking care of pregnant woman from late pregnancies to caring the new-born along with the new mother, their practices were largely unscientific. That was a time when the concept of sanitary awakening and importance of hygiene was still an evolving process. Maternal and new-born mortality was high, which rendered the population relatively stable even after a high birth rate. It was in the 1770s, when the need for safe and clean birth was realized and midwifery courses started coming up to address this issue of childbirth in remote parts of Europe, thereby gradually emerging as a respectable profession. It is very recently that in the mid-20th century with specialization and medicalization of childbirth, obstetricians started taking a greater role and midwives are losing their autonomy.[7]

As we stepped into the 21st century, the importance of hygiene has become clearer to us in every aspect of health. There is ample research done and activities undertaken to improve the sanitation and hygiene not only in developed but also developing countries as well. The shift of dialogue, in maternal care, is gradually to a more positive experience of childbirth with protection of women's rights and dignity. The midwifery model of care is a solution for that. It not only provides a personalized and positive birthing but also manages and does timely referral in case of any complications. Evidence has shown that deliveries under the supervision of midwives have a lower rate of intervention and a higher number of normal births.[6] In rural areas, where midwifery care has been passed on from generations in a family, midwives are a part of the community/village itself, a woman find them more approachable than any general physician. Under such circumstances, midwives can be effectively deployed as the primary care provider. In fact, studies around the world have shown how the midwives were conducting screening and counselling related to weight gain, smoking cessation and vaccinations.[8] This model, when deployed in a low-resource country, can address the problem of physician shortages.

Looking into the current context, the numbers of healthcare professionals vary across different parts of the world and are equally applicable here in the midwifery context. Lower- and lower-middle-income countries of Africa and Southeast Asia have only 2% of the world's total supply of midwives, despite the fact that these regions are some of the most deprived regions of the world in terms of healthcare.[9] If we take a closer look at this 2% of data, most of the midwives in Africa are full professional midwives, while those in Southeast Asia are associate professionals, i.e., they perform additional duties along with midwifery duties. When asked to demonstrate their services, African midwives showed a more promising result in terms of continuum of care compared to their South-Asian counterparts.[9] Midwives have the potential to change the landscape for primary maternal healthcare, but to do so, they need good conducive work environment, a career flow chart, regulatory policies and autonomy to practise on their own. Many of the European midwifery care model has been addressing this quite effectively, which is also one of the regions having high midwife density.

Evolution of NPM in India

Traditional dais has been a part of the South Asian culture for a long-time. They were closer to communities and to families and performed a wide range of tasks related to childcare along with assisting in childbirth. In India, these tasks were often considered polluted and reserved for women belonging to lower castes.[10] Post-independence, with the high maternal mortality in the country and India's commitment towards the Alma Ata Declaration of ensuring universal healthcare, did the government realize the need for formalizing this cadre. Formal trainings were given and trained dais were renamed to what they are called today as "Trained Birth Attendants." The aim was to have the access of healthcare providers as close to people as possible, similar to what the Alma Ata stated. But in doing so, their geographical boundary has been restricted,

thereby limiting the handling of a number of complicated cases of childbirth. Studies, over two decades after their introduction, have shown that they were largely inefficient in handling emergency cases and their trainings were not very impactful in reducing the MMR.[10]

To address this concern and improve the outcome of childbirth, the government gradually started shifting its focus towards institutional birth under trained health workers (doctors and nurses). Several initiatives like Janani Suraksha Yojana (JSY) and Janani Sishu Suraksha Karyakarm (JSSK) have been introduced to increase the demand for institutional birth by providing cash incentives and free stay, drug and diagnostic services in public hospitals. The community health workers of India (ASHAs) were tasked with ensuring antenatal and postnatal care in the community and reinforcing to the families to seek birth in a health facility. Despite all these efforts, a segment of the population remained who continued with home birth under unsupervised care, citing the primary reason being socio-cultural practices, previous institutional experiences or the higher opportunity cost of staying in hospital.[11]

This is where midwives are supposed to play a significant role in filling this gap of practice between the provider and the care-seeker. Efforts to integrate the midwives into India's public health cadre have been tried since the early 2000s in a collaborative partnership, first with Australia and then Sweden. Although a lack of future career progression, role clarity and absence of legal framework led to a failure of these projects, the concerned authorities seem to have learnt from their past mistakes and have introduced a newer guideline for midwifery-led care in consultation with international experts.[12] The NNMC Bill, introduced in 2023 as an amendment to the Indian Nursing Council Act, 1947, provides a guideline for setting-up Nursing and Midwifery Commissions at national and state levels. The bill also states the formation of different autonomous boards to supervise their education, periodic assessment of educational institutions and upholding the professional code of ethics (NNMC bill review). By doing this, India has taken a landmark step in regularising midwifery education and practice and identifying it as an independent cadre.

Nursing, in India, has long been considered subsidiary to the public health system, let alone midwifery. The quality of education has long been compromised due to the large number of private institutions, which are primarily located in urban areas. Similarly, in practice, the lack of enough representation in policymaking and leadership roles kept their issues from being addressed. Despite comprising one of the largest cadres of the healthcare system, the nurses and midwives of India have felt powerlessness at different levels. This has resulted in a large number of migrations to the Western lands.[13] Being the second largest country for migration of nurses, this might put a strain on India's own healthcare system, more so in remote areas, and will provide a ground for untrained health professionals to grow and practice. The NNMC 2023 bill is an initial effort in addressing this challenge. However, it's too early to evaluate its effectiveness and can be a possible area of research in the next 5 years.

Global Model and Lessons for India

Model	*Key features*	*Strengths*	*Limitations*	*Lessons learnt*
The Danish model (high-income country)[14]	• A midwifery-led continuity-of-care model operating in a tertiary care hospital. • The philosophy behind it is pregnancy and childbirth being natural events requiring some assistance. • Screening of pregnant woman done during ANC period and any obstetric complication arising at any stage is referred for obstetrician-led care. • Care starts from the antenatal period and continues till birth. • On-call service available 24/7 for any query.	• Starting the care from the antenatal period builds a trusting and familiar environment for the couple, instead of directly meeting them in the labor rooms. • By sorting out complicated cases for the OBGYN, effective task shifting has been done. • Effective use of technologies like webinars, online chats and helpline numbers prepares the woman for her birth.	• The continuity-of-care model not extending to the post-natal period keeps the post-natal complications being not addressed by midwives. • A shortage of midwives resulting in long and stretched working hours.	• Inside a low-resource setting, trained midwives can reduce the workload of doctors, giving them more time to attend to complicated cases. • Setting-up a 24/7 helpline number, to be attended by an on-duty midwife, to address any query, identify emergencies and follow-up until the woman seeks care from the nearest health facility.
The Kenyan model (low-middle-income country)[15]	• A community-led midwifery model operating in rural Kenya. • All community midwives (CM) were trained in emergency obstetric and new-born care (EmOC) along with monthly supportive supervision at their facilities.	• Increased community participation – Community Health Volunteers, BCs, and Community Health Extension Workers (CHEWs) working alongside the CM. • Continuous capacity building of the CM through monthly supervision.	• The CMs in the project are experienced, retired professionals. Results of such project might be different when freshly trained midwives are recruited.	• The midwives in India need to engage with other community health workers, leaders and volunteers to understand the local context and tailor services accordingly.

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Model	*Key features*	*Strengths*	*Limitations*	*Lessons learnt*
	• The traditional birth attendants were renamed as birth companions (BC) and tasked with health education and referring women to CM. • Complicated obstetric cases got referred to other facilities. • Postpartum observation and home visits for new-born care by CM.	• Complete package of continuum of care starting from the antenatal period to extending up to a few days of the postpartum period. • A resource-limited setting proves a wide scope of practice and development of skills to identify complications.	• The project runs parallel to the already existing public health infrastructure. The challenges of integrating the system into the regular health service are yet to be explored.	• Being a relatively new cadre, the midwives need continuous support, hand-holding and training from the health officials.
The Bangladesh model (a lower-middle-income context)[16]	A two-phased integration model of midwifery-led care: Reorientation of midwifery education • Renaming the nursing council as the Nursing and Midwifery Council, along with the establishment of a Midwifery Society for representation of the newly formed cadre. • Laying out a professional code of ethics and guidelines for licensing and practising. • Partnership with international bodies to deliver evidence-based education in the classroom and upskilling of knowledge for those in practice. • Clear pathway for growth in career with opportunities for pursuing master's and doctoral degrees. Integration of midwives in the health system • Midwives were first placed in primary and secondary health facility before being scaled up to tertiary levels. • The Directorate of Health has been given the responsibility to oversee their working environment along with interactions with other team members.	• The two-way approach of realigning the education followed by clinical practice, though it took a long 20 years time period, established a strong foundation for this upcoming cadre. • Representation through different governing bodies ensures their challenges are heard and addressed. • Use of social media groups to connect with each other, resolve queries related to clinical practice. • Deploying the cadre during any humanitarian crisis to address maternal and new-born needs at that time.	• Strong resistance from the existing cadre of doctors, nurses and managers limited their scope of practice in many areas, viz., use of emergency drugs and other interventions. • While midwives have started working in primary and secondary units, the challenges of their working in a tertiary hospital, where other health professionals are also present, remain unexplored.	• Laying a clear groundwork of education for midwifery, followed by their gradual introduction to the health system starting from primary health care and promoting the senior cadre to tertiary units. • Taking into confidence other health professionals (primarily the doctors and nurses) to identify midwives as co-workers instead of competitors.

Integration of Midwives into Public Health System

People widely acknowledge nursing as an integral part of the health system. In the Indian context, midwives have been considered an integral part of nursing, although the nature of the job varied. A six months training in maternal and new-born care is what midwifery training offered to the nursing students, unlike the 18 + 6 months curriculum suggested by the ICM. Now that the government has started recognising midwifery as a separate profession with a special reorientation of midwifery training and education, it is equally important to integrate and assert their roles in the public health system. Evidence has shown that a separate midwifery association has not only been helpful in increasing their visibility but also helped midwives start a dialogue, support students and young professionals, negotiate good working conditions and increase advocacy for sexual and reproductive health.[17]

Midwives are supposed to be the first point of contact for maternal and new-born care and provide the entire continuum of care. This is more relevant for vulnerable and marginalized populations who otherwise might be reluctant to approach higher units of healthcare. The process of integration in the public health system starting from the primary level and then gradually moving to the secondary and tertiary levels has proven to be effective in the

Bangladesh Model.[16] That way the system becomes more familiar with this new cadre and has a better acceptability.

Midwives are not only providing care but actually contributing significantly to achieving the country's universal access to healthcare and health equity.[18] They are the ones bringing healthcare to the last mile. They lead the community. They are the ones who know the cultural contexts and challenges of the community. However, having all of these means the need to have a good team, as a midwife can't achieve everything on her own. They need to collaborate with other cadres, and this can be achieved through constant communication and collaboration with doctors and nurses.[19] At the same time, midwives should also be encouraged to document their work, challenges and ground realities. This way they are contributing to the body of knowledge that can be studied by policymakers, academicians, and other fellow midwives in some other part of the world.[18,20]

Limitation of the Study and Scope for Future Research

While this review paper has given a historical detail on how midwifery has emerged as an indispensable part of health system and it's role in reducing the maternal mortality, especially resource-constraint LMICs, the paper lacks field data to depict the current state of midwifery-led care in the Indian public healthcare system. Primary research is needed on how the public healthcare system has evolved and adapted to this new cadre following the introduction of NNMC, 2023 bill.

Conclusion

The paper has been an effort to reflect on India's current stand on midwifery-led care amidst the WHO's call for strengthening the midwifery services to reduce MMR. Evidence around the world has shown how midwifery can not only reduce maternal death but also provide quality care. Successful models from countries around the world with different income groups have been studied, and best practices are identified to enhance India's midwifery model further. Introducing the cadre has been a bold step towards India's goal of achieving SDG 3 and 5 in the near future.

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Authors' Contributions

Ipsita Maiti – Initial search for literature, selection of relevant review articles, compilation of the initial draft and final editing.
Prof Nanthini Subbaiah – Oversight of the initial draft, critical review and editing of the initial draft.

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REVIEW ARTICLE

Evolution of the Women's Questionnaire in India's National Family Health Survey (1992–2024): Expanding Dimensions of Women's Health and Autonomy

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Abstract

Background: The National Family Health Survey (NFHS) is India's largest nationally representative health survey and a major source of evidence for population health, reproductive health, nutrition, and gender-related policy formulation. Since its inception in 1992–1993, the Women's Questionnaire has evolved substantially in response to changing public health priorities, demographic transitions, technological transformations, and emerging gender concerns.

Objective: This paper critically examines the evolution of the NFHS Women's Questionnaire from NFHS-1 (1992–1993) to NFHS-6 (2023–2024), with particular attention to changes in thematic scope, respondent inclusion, and policy orientation.

Methodology: A narrative comparative review was conducted using official NFHS questionnaires and reports published by the International Institute for Population Sciences (IIPS), Ministry of Health and Family Welfare (MoHFW), and the Demographic and Health Surveys (DHS) Program. Thematic domains, respondent eligibility, survey innovations, and methodological shifts were systematically extracted and compared across six NFHS rounds and against DHS-8 model questionnaires.

Results: The analysis demonstrates a progressive transition in the NFHS Women's Questionnaire from a predominantly fertility- and family planning-oriented instrument to a multidimensional framework encompassing maternal health, nutrition, domestic violence, financial inclusion, menstrual health, non-communicable diseases (NCDs), and digital access. Since NFHS-3, the inclusion of all women aged 15–49 years broadened the representativeness of the survey. Recent rounds introduced modules on menstrual hygiene, digital access, reproductive health services, and women's autonomy. National Family Health Survey-6 further reflects India's post-pandemic and digital governance landscape through expanded questions on digital and financial inclusion, tele-health, and reproductive healthcare access.

Conclusion: The evolution of the NFHS Women's Questionnaire reflects broader transformations in India's public health priorities and gender policy discourse. While the increasing breadth of the survey strengthens its policy relevance, it also raises important methodological considerations regarding questionnaire burden, comparability across rounds, and ethical management of sensitive data. Future NFHS rounds may benefit from integrating climate-health vulnerability, adolescent mental health, unpaid care work, and digital misinformation exposure within a robust methodological framework.

Keywords: Digital inclusion, Gender, India, National Family Health Survey, Reproductive health, Women's questionnaire.

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Introduction

The National Family Health Survey (NFHS), coordinated by the Ministry of Health and Family Welfare (MoHFW), Government of India, and implemented by the International Institute for Population Sciences (IIPS), is one of the most significant population-based health surveys in the world.[1] Since the first round in 1992–1993, the NFHS has generated nationally representative data on fertility, mortality, reproductive health, nutrition, family planning, gender, and health service utilization. The survey has played a central role in evidence-based policy formulation and program monitoring in India.

The NFHS forms part of the broader Demographic and Health Surveys (DHS) framework supported internationally by ICF and United States Agency for International Development (USAID).[2] While the NFHS follows the core DHS methodology to maintain comparability, successive rounds have increasingly incorporated India-specific modules reflecting local public health priorities, socio-cultural realities, and policy needs.

The Women's Questionnaire is the central component of the NFHS. It captures extensive information related to women's demographic characteristics, reproductive history, maternal healthcare, contraception, nutrition, domestic violence, and household decision-making. Over time, the questionnaire has expanded substantially in thematic scope. Earlier rounds primarily focused on fertility regulation and maternal-child health, whereas recent rounds include dimensions related to menstrual hygiene,

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digital access, financial inclusion, non-communicable diseases (NCDs), and reproductive healthcare access.

The evolution of the Women's Questionnaire mirrors broader transitions in India's health and development priorities. The expansion from a narrow demographic approach toward multidimensional indicators of women's autonomy and well-being reflects changing understandings of gender, health, and social development. Simultaneously, the increasing complexity of the questionnaire raises important methodological questions related to comparability across rounds, respondent burden, privacy, and the ethical management of sensitive information.

Despite the extensive use of NFHS data in public health research and policy analysis, limited scholarly attention has been paid to the evolution of the survey instrument itself. Most existing studies utilize NFHS datasets for epidemiological or demographic analyses without critically examining how changing questionnaire structures shape the production of health knowledge.

This paper aims to address this gap by:

- Tracing the evolution of the NFHS Women's Questionnaire from NFHS-1 to NFHS-6;
- Examining shifts in thematic priorities and respondent inclusion;
- Comparing the NFHS framework with the DHS model questionnaires; and
- Discussing the methodological and policy implications of questionnaire expansion.

The paper adopts a gender-sensitive and public health systems perspective to understand how the changing structure of the Women's Questionnaire reflects evolving state priorities in women's health governance in India.

Methodology

Study Design

This study employed a structured narrative review and comparative document analysis to examine the evolution of the Women's Questionnaire in the NFHS across six survey rounds conducted between 1992–1993 and 2023–2024. The objective was to assess changes in questionnaire structure, thematic domains, respondent eligibility, and policy orientation over time.

Data Sources and Document Selection

The review included official NFHS survey reports and Women's Questionnaires from NFHS-1 (1992–1993) through NFHS-5 (2019–2021), the NFHS-6 (2023–2024) phase I Women's Questionnaire, and the DHS-8 Model Women's Questionnaire along with associated methodological guidance documents. Documents not directly related to questionnaire content, design, or implementation were excluded from the review.

Data Extraction and Analytical Framework

A structured thematic framework was developed to facilitate systematic comparison across survey rounds. Relevant questionnaire components, modules, and indicators were extracted and categorized into major thematic domains, including: Respondent eligibility and demographic characteristics; fertility and reproductive health; maternal and child health; nutrition and biomarker assessments; domestic violence and gender-related indicators; women's autonomy and financial inclusion; media exposure and digital access; menstrual health and reproductive healthcare access; NCD indicators; and mental health and tele-health components.

The evolution of the NFHS Women's Questionnaire was examined through four interrelated transitions: (i) demographic transition and changing reproductive health priorities; (ii) epidemiological transition from communicable diseases to broader nutrition and NCD surveillance; (iii) expansion of gender and autonomy-related indicators; and (iv) incorporation of digitalization, financial inclusion, and emerging health-system dimensions.

Ethical and Methodological Considerations

As this study was based exclusively on secondary analysis of publicly available survey instruments and reports, no human participant involvement or ethical clearance was required. However, the review critically examined methodological and ethical issues associated with questionnaire expansion, including respondent burden, privacy concerns, comparability across survey rounds, and challenges related to the reliability of self-reported and biomarker data.

Limitations

The review has certain limitations. First, the analysis was restricted to questionnaire instruments and official survey documentation and did not assess field implementation processes or psychometric performance of indicators. Second, the study adopts an interpretive comparative approach and does not involve quantitative statistical analysis of NFHS datasets.

Major Components of the Women's Questionnaire

The Women's Questionnaire has progressively expanded from a predominantly reproductive-health-oriented instrument to a multidimensional framework assessing social, economic, behavioral, and health-related determinants.

- Respondent background: This section captures demographic and socio-economic information including age, education, occupation, religion, caste, household characteristics, media exposure, and digital access.
- Marriage and fertility: This module includes marital history, age at marriage, birth history, pregnancy outcomes, fertility preferences, and reproductive intentions.
- Family planning and contraceptive use: Questions assess contraceptive knowledge, current and past use, source of supply, discontinuation, and reasons for non-use.
- Maternal and child health: This section includes antenatal care, institutional delivery, immunization, postnatal care, breastfeeding, and child health indicators.
- Nutrition and biomarkers: Over time, this component expanded to include anthropometric measurements, anemia testing, blood pressure, and blood glucose assessments.
- Domestic violence module: The domestic violence module collects sensitive information regarding emotional, physical, and sexual violence using internationally accepted confidentiality protocols.
- Menstrual health and hygiene: Introduced in recent rounds, this section examines menstrual product usage, access barriers, sanitation facilities, and hygiene practices.
- Women's autonomy and financial inclusion: Recent rounds include indicators related to household decision-making, bank account ownership, mobile phone access, and financial participation.

- Reproductive healthcare access: Recent questionnaires expanded information on abortion care, healthcare providers, and access pathways.
- Digital access and tele-health: NFHS-6 introduced additional questions on internet access, digital engagement, and utilization of online healthcare services.

Evolution of Respondent Coverage in the NFHS Women's Questionnaire

The target population of the NFHS Women's Questionnaire has undergone a significant transformation across successive survey rounds, reflecting evolving demographic priorities and broader conceptualizations of women's health. In NFHS-1 (1992–1993), the survey interviewed ever-married women aged 13–49 years, consistent with the policy emphasis of the period on fertility regulation, family planning, and maternal-child health within marital unions.[3] NFHS-2 (1998–1999) standardized the eligibility age range to 15–49 years; however, the survey continued to remain restricted to ever-married women.[4] A major methodological and conceptual shift occurred from NFHS-3 onwards, when the eligibility criteria were expanded to include all women aged 15–49 years irrespective of marital status.[5] This transition substantially broadened the representativeness and analytical scope of the survey by enabling the inclusion of adolescent and never-married women. Consequently, the NFHS became better equipped to capture dimensions such as adolescent reproductive health, sexual health awareness, nutritional status among unmarried women, healthcare access, educational and employment characteristics, and broader indicators of women's autonomy and social participation. The substantial increase in sample size beginning with NFHS-4 enabled district-level estimates and strengthened the survey's utility for decentralized planning and monitoring.[6] The number of women interviewed across NFHS rounds is presented in Table 1.

Evolution of the Women's Questionnaire across NFHS Rounds

The NFHS Women's Questionnaire has evolved progressively from a predominantly fertility-oriented demographic instrument into a multidimensional framework addressing broader determinants of women's health and autonomy. NFHS-1 (1992–1993) primarily focused on fertility behavior, family planning, maternal and child health, and infant mortality, reflecting the population stabilization priorities of the early 1990s.[3] National Family Health Survey-2 (1998–99) expanded the scope to include women's education, employment, nutritional status, and domestic violence, indicating increasing recognition of gender and socio-economic determinants of health.[4]

A major epidemiological and behavioral transition occurred in NFHS-3 (2005–2006) through the incorporation of HIV/AIDS awareness, sexual behavior indicators, anemia assessment, and expanded domestic violence modules.[5] National Family Health Survey-4 (2015–2016) substantially increased sample size and introduced district-level estimates alongside biomarker assessments such as blood pressure and blood glucose measurements, thereby strengthening the role of NFHS as a decentralized public health surveillance system.[6]

Subsequent rounds increasingly incorporated dimensions related to gender, technology, and chronic disease epidemiology. National Family Health Survey-5 (2019–21) introduced menstrual hygiene indicators, mobile phone ownership, and expanded NCD assessments, reflecting growing attention to digital access and gender disparities in technology use.[7] Based on the available phase I questionnaire, NFHS-6 (2023–2024) further expanded the survey framework to include digital and financial inclusion, tele-health utilization, reproductive healthcare pathways, healthcare financing, and expanded menstrual health indicators.[8] These additions illustrate the growing convergence of public health surveillance with digital governance and social protection systems in India.[9,10] The evolution of major thematic domains across survey rounds is summarized in Table 2.

Methodological and Ethical Considerations in Questionnaire Expansion

The progressive expansion of the NFHS Women's Questionnaire has considerably enhanced the availability of multidimensional and policy-relevant data on women's health, nutrition, autonomy, and healthcare access in India. However, the increasing breadth and complexity of the survey instrument also introduce several methodological, operational, and ethical challenges that warrant careful consideration.

One major concern relates to questionnaire burden and respondent fatigue. As the duration and complexity of interviews increase, there may be adverse implications for interview completion rates, respondent attention, and the reliability of self-reported information. This is particularly relevant for sensitive modules relating to domestic violence, abortion, sexual behavior, and reproductive health, which require careful sequencing, privacy safeguards, and extensive interviewer training to minimize distress and reporting bias.[11]

The expansion of survey domains across rounds also raises issues of longitudinal comparability. Changes in respondent eligibility criteria, question wording, indicator definitions, biomarker methodologies, and sampling approaches may affect the consistency of trend analyses over time. For instance, the inclusion of never-married women from NFHS-3 onwards represents an important methodological shift that complicates direct comparisons with earlier rounds restricted to ever-married women.

Ethical and privacy-related concerns become increasingly significant as the questionnaire incorporates more sensitive personal, behavioral, and digital information. Modules addressing domestic violence, reproductive decision-making, abortion, sexual behavior, and digital access require robust confidentiality protocols and culturally sensitive field procedures, particularly in socially conservative settings where disclosure may carry social risks for respondents.

Table 1: Number of women interviewed across NFHS rounds

NFHS round	*Women interviewed*
NFHS-1	89,777
NFHS-2	89,199
NFHS-3	1,24,385
NFHS-4	6,99,686
NFHS-5	7,24,115
NFHS-6	7,16,397

NFHS, National Family Health Survey

Source: Compiled from NFHS-1 to NFHS-6 survey reports and questionnaire documents[3–8]

Table 2: Comparative evolution of major themes across NFHS rounds

Thematic area	*NFHS-1*	*NFHS-2*	*NFHS-3*	*NFHS-4*	*NFHS-5*	*NFHS-6*
Fertility and family planning	Yes	Yes	Yes	Yes	Yes	Yes
Maternal and child health	Yes	Yes	Yes	Yes	Yes	Yes
Nutrition indicators	Limited	Expanded	Expanded	Expanded	Expanded	Expanded
HIV/AIDS awareness	No	No	Yes	Yes	Yes	Yes
Domestic violence	No	Yes	Yes	Yes	Yes	Yes
Women's autonomy	Limited	Yes	Yes	Yes	Yes	Yes
Biomarker collection	No	Limited	Expanded	Expanded	Expanded	Expanded
Menstrual health	No	No	No	No	Yes	Expanded
Digital access	No	No	No	No	Limited	Expanded
Financial inclusion	No	No	No	No	Limited	Expanded
Tele-health	No	No	No	No	No	Introduced
Detailed reproductive healthcare access	Limited	Limited	Limited	Limited	Moderate	Expanded
NCD indicators	No	No	Limited	Yes	Expanded	Expanded

NCD, non-communicable disease; NFHS, National Family Health Survey

Source: Derived from NFHS-1 to NFHS-6 Women's Questionnaires[3–8]

Table 3: Comparative context: NFHS and DHS frameworks

Dimension	*NFHS (India)*	*DHS (Global)*
Implementing structure	MoHFW and IIPS	USAID-supported DHS program
Geographic coverage	India	More than 90 countries
Core focus	Fertility, maternal health, nutrition, gender	Fertility, maternal-child health, HIV/AIDS
Domestic violence module	Comprehensive and routinely included	Optional in many countries
Menstrual health	Expanded in recent rounds	Limited in many DHS surveys
Digital access indicators	Included in recent rounds	Limited availability
Financial inclusion	Included in NFHS-5 and NFHS-6	Not commonly included
Tele-health questions	Introduced in NFHS-6	Rare in standard DHS models

DHS, Demographic and Health Surveys; IIPS, International Institute for Population Sciences; MoHFW, Ministry of Health and Family Welfare; NFHS, National Family Health Survey

Source: Compiled from NFHS-6 Women's Questionnaire and DHS-8 Model Women's Questionnaire[2,7,8,12] USAID, United States Agency for International Development

Additionally, the reliability of self-reported indicators remains an important challenge. Data related to abortion, domestic violence, sexual practices, and mental or reproductive health may be influenced by stigma, recall bias, underreporting, and interviewer effects, potentially affecting data validity.

Biomarker collection also presents methodological challenges. Recent debates surrounding anemia estimation methods have highlighted the importance of standardized measurement protocols, equipment calibration, quality assurance systems, field-level technical training, and transparency in biomarker methodologies.[12] As the NFHS continues to evolve into a more comprehensive health surveillance platform, maintaining a balance between thematic expansion and methodological rigor will remain critical for ensuring data quality, reliability, and policy utility.

Comparative Context: NFHS and DHS Frameworks

The NFHS was originally designed within the broader methodological architecture of the global DHS Program. Over successive rounds, the NFHS has increasingly incorporated India-specific modules and contextual adaptations in response to evolving national health priorities, epidemiological transitions, welfare programs, and gender policy frameworks. A comparison between NFHS and DHS frameworks is presented in Table 3.

The progressive expansion of the NFHS illustrates the transition from a predominantly demographic survey toward a broader health and social policy surveillance system and reflects India's changing epidemiological and governance priorities. While this localization has enhanced the survey's relevance for domestic policy planning, it has also introduced challenges related to longitudinal and cross-national comparability.

Future Directions for NFHS-7

Future NFHS rounds may consider strengthening indicators in the following areas:

- Adolescent mental health: India currently lacks nationally representative mental health indicators among adolescent girls and young women. Questions on emotional well-being, stress, and psychosocial support among adolescents may improve understanding of emerging mental health concerns. This will help to inform Rashtriya Kishor Swasthya Karyakram (RKSK) and School mental health programs.
- Unpaid care work: Women's unpaid domestic and caregiving labor remains largely invisible in health surveys. Measurement of unpaid domestic and caregiving labor may improve understanding of gendered time burdens. This will be useful for gender budgeting, women's labor force participation policies, and social protection planning.
- Digital information ecosystems: As India rapidly digitizes healthcare delivery, NFHS-7 should move beyond device ownership toward meaningful digital engagement. Future

surveys may examine digital health literacy; exposure to misinformation; online safety; access to tele-health services. This would support the Digital India Mission and Public health communication strategies.

- Elderly women and healthy ageing: NFHS focuses heavily on reproductive age women but insufficiently captures ageing-related vulnerabilities. Future surveys may consider elderly females to capture indicators like functional disability, social isolation, care dependency, financial dependence, chronic disease management, etc. It would help to support healthy ageing policies, geriatric care planning, and long-term care systems.

Any future expansion should carefully balance comprehensiveness with feasibility, respondent burden, and data quality considerations.

Conclusion

This review demonstrates that the NFHS Women's Questionnaire has progressively expanded from a predominantly fertility- and family planning-focused instrument to a broader framework encompassing nutrition, gender-based violence, women's autonomy, NCDs, menstrual health, financial inclusion, and digital access. These changes broadly reflect evolving public health priorities and social policy concerns in India.

However, the findings should be interpreted with caution. The study is based on a structured review of questionnaire instruments and official documentation rather than empirical analysis of NFHS datasets or field implementation experiences. Furthermore, observations relating to NFHS-6 are based primarily on the currently available phase I questionnaire and may require reassessment when complete national datasets and final reports become available.

Rather than evaluating the effectiveness or impact of specific questionnaire components, this review highlights major trends in the evolution of the survey instrument and identifies emerging areas for future consideration. Further research using systematic review methods, psychometric evaluation, and empirical analysis of NFHS data would provide a stronger basis for assessing how questionnaire changes influence data quality, policy relevance, and understanding of women's health and autonomy in India.

Artificial Intelligence (AI) Disclosure

The authors confirm that no AI tools were used in the preparation, analysis, or writing of this manuscript.

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Authors' Contributions

Deepak J Londhe: Conceptualization, methodology, literature review, data collection, formal analysis, interpretation of findings, and manuscript drafting. Shital Chinchalkar: Literature review, data collection, analysis, and critical review of the manuscript. Shobhit Kumar: Methodological inputs, data interpretation, and critical revision of the manuscript. Shrestha Hazra: Data verification, literature review, interpretation of findings, and critical revision of the manuscript. All authors contributed to the development of the manuscript, reviewed and approved the final version, and agreed to be accountable for all aspects of the work.

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REVIEW ARTICLE

The Dual Challenge: Building Climate-smart Healthcare Facilities While Mitigating the Sector's Environmental Impact in India

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Abstract

Climate change threatens health service continuity through extreme heat, floods, cyclones, and water stress, while the health sector's own operations contribute to environmental impacts. We assessed selected infrastructure proxies of climate-smartness in India's public health facilities using Indian Public Health Standards (IPHS) self-assessment data across five facility types [district hospitals (DH), sub-district hospitals (SDH), community health centers (CHC), primary health centers (PHC), and sub-health centers (SHC)]. We constructed a composite index (0–100) across three domains—environment-friendly measures, drainage and sanitation, and garden/landscaping—based on the percentage availability of defined line items. District hospitals achieved the highest score (87), while SHC scored the lowest (60), indicating major gaps at the frontline. Across facility types, common gaps are clustered around a triad: Limited availability of solar power, rainwater harvesting, and computerized registration. Findings highlight the need to prioritize basic resilience and service continuity measures at peripheral facilities alongside higher-leverage mitigation upgrades in energy-intensive hospitals.

Keywords: Climate-smart healthcare, Greenhouse gas emissions, India, Indian Public Health Standards, Public health infrastructure, Resilience.

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Introduction

India is experiencing more frequent and intense heatwaves, heavy rainfall events, floods, cyclones, and water stress. These hazards disrupt service continuity, damage infrastructure, and increase demand for care. Health facilities must therefore become climate-smart: They must protect essential services during climate shocks (adaptation/resilience) and reduce the environmental footprint of care delivery (mitigation).

The health sector faces a dual challenge. On one hand, it must maintain safe, quality services for a growing and aging population. On the other hand, it must reduce energy use, emissions, and waste, and use water more efficiently.

"Health Care without Harm"– September 2019 report has reflected that the health sector alone contributes 4.4% to global greenhouse gas (GHG) emissions, equivalent to the annual GHG emissions from 514 coal-fired power plants. In India, the healthcare sector ranks seventh globally, generating about 38.8 million metric tons of carbon dioxide annually, roughly equivalent to the emissions of 187 coal-fired power plants. There are many carbon-intensive activities in the healthcare system, ranging from heating, ventilation, and air conditioning (HVAC) systems in hospitals to supply chains, procurement of medical products and technologies, and biomedical waste management.[1]

The effects of the healthcare industry on the environment go beyond carbon emissions. Increased emissions worsen respiratory conditions and have an impact on public health by contributing to air pollution. In many regions of India, water shortages are a result of inefficient water use in healthcare facilities, which puts additional demand on already scarce water supplies. Improperly disposed healthcare waste can contaminate land and water, endangering human health and the environment.[2] The potential health impacts are staggering: Increased mortality from heat stress, rising child stunting rates, and a projected 2,50,000 additional global deaths annually from 2030 to 2050 due to climate threats.

The World Health Organization (WHO) estimates that between 2030 and 2050, climate change is expected to cause approximately 2,50,000 additional deaths per year, resulting from malnutrition, malaria, diarrhea, and heat stress. Diseases such as malaria, yellow fever, dengue, and cholera are all sensitive to climate change due to effect on the viability and the geographical distribution of the mosquitoes and microorganisms, which prefer a wetter, warmer world. Climate change could push 132 million into extreme poverty by 2030, with health impacts driving one-third of this increase and could cause 1.5 million deaths due to heat-related mortality by 2100 in India alone.[3]

The Council on Energy, Environment and Water (CEEW) in its study to determine the climate health risk index, found that over

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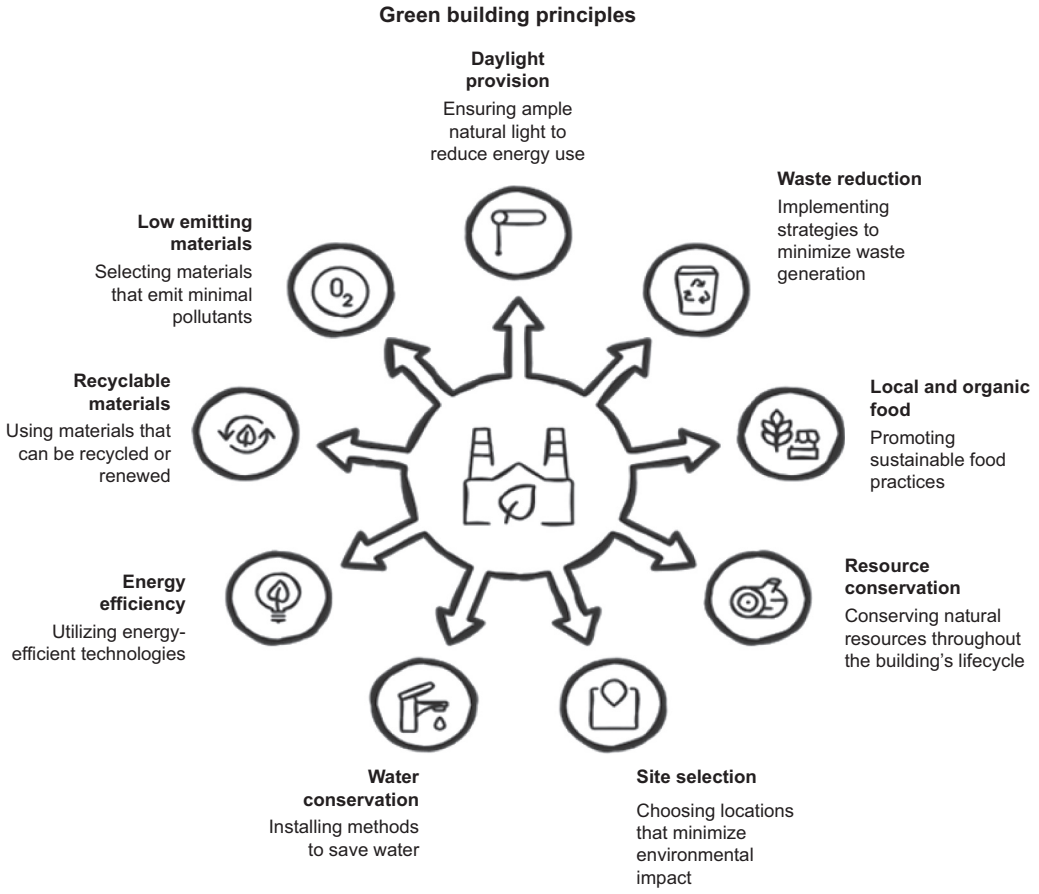

Fig. 1: Principles of green building

40% of districts have healthcare systems exposed to very high to high climate risks, while 20% face a moderate level of risk.[4] However, taking the lead in promoting green and sustainable development, the Indian government, particularly the Ministry of Health and Family Welfare, has increasingly focused on building strong, climate-smart health infrastructure over time. These efforts aim to reduce the country's vulnerability to natural and other disasters, ultimately protecting lives and livelihoods and fostering a more resilient nation. Additionally, as a signatory to the "Male Declaration," India is committed to strengthening its health sector to make it climate-resilient, which calls for increased investment in this area.[5] Increasing investment in this area will improve the health sector's climate resilience and support the attainment of the United Nations Sustainable Development Goals (SDGs), thus ensuring universal access to adequate health services.

Green healthcare vision is a multifaceted approach that encompasses all the aspects of construction as well as operations. Figure 1 depicts the principles of green building. The vision mainly aims to have green buildings to decrease the ecological footprint protecting the natural resources.[6]

The adoption of green hospitals, climate-resilient infrastructure, and ecosystem-based approaches can transform the healthcare sector into a model of sustainability. These approaches can reduce resource use, strengthen service continuity, and improve facility preparedness.

This paper uses facility-level Indian Public Health Standards (IPHS) self-assessment data to examine how prepared India's public facilities are concerning selected infrastructure proxies of climate-smartness across facility types.

The objectives of this study were as follows:

- Assessment: To evaluate the extent of climate-resilient infrastructure available at each facility type across different states.
- To identify the attributes of healthcare facilities that contribute to their vulnerability and affect climate resilience.

This paper explores the intersection of climate change and healthcare, emphasizing the critical need for systemic reforms. It advocates for investments in climate-resilient infrastructure, sustainable healthcare practices, and workforce capacity-building to address climate-induced health challenges. By fostering a resilient, inclusive, and sustainable healthcare system, India can better mitigate the impacts of climate change, safeguard public health, and contribute to global climate goals.

Methodology

Indian Public Health Standards is a detailed guideline that provides benchmarks for public health facilities, including infrastructure, human resources, equipment, etc. The IPHS standards were used to create a checklist on which data was collected from each facility on all the parameters, starting from the general upkeep and appearance, outpatient department, non-communicable diseases (NCD) clinical services, physiotherapy services, inpatient wards, and other services. Data was collected for each facility type and then

Table 1: Facility types terminologies

Facility type terminologies	
SHC	A sub-health centers is the first point of contact between the primary health care system and the community and has at most 2–4 basic beds
PHC	A PHC is the first port of call to a qualified doctor of the public sector in rural areas for curative, preventive, and promotive healthcare. It has 4–6 beds
CHC	A CHC is a 30-bed hospital providing specialist care in medicine, obstetrics and gynecology, surgery, pediatrics, dental, etc
SDH	An SDH is a 31–100 bed hospital at the secondary referral level responsible for the sub-district/sub-division of a defined geographical area containing a defined population
DH	A DH functions as a secondary level of health care which provides curative, preventive, and promotive healthcare services to the people living in urban (district headquarters, town and adjoining areas) and the rural people in the district. The bed strength of a DH varies from 75 to 500 beds depending on the size, terrain, and population of the district

CHC, community health center; DH, district hospital; PHC, primary health center; SHC, sub-health centers; SDH, sub-district/divisional hospital

Table 2: Domain-wise scoring criteria

Domains	*Total of domains*
Garden and landscaping	10
Environment-friendly	60
Drainage and sanitation	30

Table 3: Domains and line items of index

Domains	*Line item*
Garden and landscaping	Open space as per NBC norms** (60% of total area)
	Presence of garden and landscaping
Environment-friendly	Use of rainwater harvesting
	Use of solar energy
	Use of low-energy LED lighting/ energy-efficient measures
	Computerized registrations
Drainage and sanitation	Availability of color-coded BMW bins
	Availability of ETP
	Availability of a well-managed drainage and sanitation system

ETP, effluent treatment plant

analyzed on the identified and chosen specific line items pertinent to climate-resilient infrastructure. These items were categorized into three domains: Garden and landscaping, environment-friendly, and drainage and sanitation. Further line items were selected in these three domains. We applied this selection uniformly across all five types of healthcare facilities: District hospitals (DH), sub-district hospitals (SDH), community health centers (CHC), primary health centers (PHC), and sub-health centers (SHC). Table 1 provides the facility type terminologies.

Index Construction

We scored each line item within a domain using a five-level scoring rubric based on percentage availability. Table 2 depicts the domain-wise scoring criteria, and Table 3 depicts the domains and their corresponding line items. We then summed item scores within each domain. The maximum possible scores were 10 for garden and landscaping (2 items × 5) depicted in Table 4, 60 for environment-friendly (4 items × 15) depicted in Table 5, and 30 for drainage and sanitation (3 items × 10) depicted in Table 6, yielding a composite maximum of 100.

Table 4: Scoring criteria of the garden and landscaping domain

	% available	*Score*
Garden and landscaping	More than 80%	5
	50–80%	4
	25–50%	3
	0–25%	1
	0%	0

Table 5: Scoring criteria of environment-friendly domain

	% available	*Score*
Environment-friendly	More than 80%	15
	50–80%	13
	25–50%	11
	0–25%	9
	0%	0

Table 6: Scoring criteria of drainage and sanitation domain

	% available	*Score*
Drainage and sanitation	More than 80%	10
	50–80%	8
	25–50%	6
	0–25%	4
	0%	0

The data provided critical information on whether each item was required as per the established standards, its current availability within the facilities, and the precise percentage of its availability in accordance with the standard. Based on this data, we proceeded to assign scores to each line item within its respective domain. We utilized the data to rigorously evaluate the climate resilience of public health facilities across India. Our composite climate resilient index (out of 100) aggregated scores across three critical domains: Garden and landscaping, environment-friendly measures (including solar and rainwater harvesting), and drainage and sanitation. The assessment revealed a clear gradient of readiness, with higher-tier facilities demonstrating better, though still incomplete, resilience.

The final score was calculated by adding all the scores of the three domains to obtain the value of the index. The extracted value represented climate resiliency of different facility types, namely DH,

Table 7: Facility type-wise result table with climate resilient index score

Facility type	*Facilities assessed*	*Climate resilient index score (out of 100)*	*Detailed findings and key vulnerabilities*
DH	768	87	These apex institutions demonstrate the highest level of systemic readiness. To build upon this lead, there is a strategic opportunity to enhance energy autonomy; currently, 48% of facilities utilize solar panels. Expanding this will further secure energy reliability and advance our commitment to mitigating Scope 2 emissions at the highest care level
SDH	1,239	76	Maintaining a robust resilience profile, these intermediate facilities serve as a vital secondary layer. Efforts are being directed toward strengthening the adoption of environment-friendly energy sources, which are currently integrated into approximately half of the assessed facilities, to ensure seamless operational continuity during climate events
CHC	6,352	74	These centers maintain a consistent baseline of resilience across a wide geographic footprint. To further modernize this tier, focus is being placed on a tripartite integration of rainwater harvesting, solar energy adoption, and computerized registration, as current implementation levels in these areas remain below 50%
PHC	30,471	74	As the foundational pillars of our health system, PHCs demonstrate steady resilience metrics. There is a significant pathway for growth in digital and ecological infrastructure; enhancing the current 34% computerized registration rate and 30% green-energy adoption will be pivotal for managing climate-induced health surges at the grassroots level
SHC	1,69,499	60	Representing our most extensive reach into rural communities, these facilities show high compliance in essential services such as BMW management (exceeding 50%). To bolster this frontline defense, the next phase of development will focus on scaling rainwater harvesting, solar energy, and digital data management, which are currently in the early stages of implementation (under 20%)

BMW, biomedical waste; CHC, community health center; DH, district hospital; PHC, primary health center; SHC, sub-health centers; SDH, sub-district/divisional hospital; SHC, sub-health centers

SDH, CHC, PHC, and SHC, which were further analyzed to identify the common gap areas in the public health facilities.

The score calculated for each facility was further triangulated with GHG emissions from each facility. Using the Klimeg calculator and utilizing the emission factor for scope 2 emissions from electricity generation, the GHG emissions were calculated.[7] As per the National Programme on Climate Change and Human Health (NPCCHH) report, in a public healthcare facility, one bed requires 3 kW of energy; further calculations were done based on this assumption to provide a value in CO_2e/kWh, which is the carbon dioxide emitted per kWh of electricity use.[8]

Data Source and Unit of Analysis

We used facility-level IPHS self-assessment data captured against defined checklist items. For each line item, we used the reported availability and derived the percentage availability against the standard. We analyzed results by facility type (DH, SDH, CHC, PHC, SHC) and used aggregated percentages to describe common gaps.

Missing Data

Where a line item was not reported, we treated it as "not available" for conservative estimation (or specify your actual rule if different).

Results

We established the global context of the healthcare sector's environmental impact, noting that the health system globally contributes a substantial 4–8% of the total commercial GHG emissions.[9] This figure is equivalent to the environmental output of a major industrialized nation and underscores the sector's crucial role in climate mitigation. Faced with this global challenge and the escalating public health threats posed by climate change, the Indian context, as emphasized by the National Health Action Plan, demands that our health system be rapidly fortified to become truly climate-resilient.[10]

To quantify the healthcare sector's contribution, we aligned our assessment with the GHG protocol's framework. We used the GHG protocol categories to frame the mitigation discussion, but we did not quantify Scope 1, Scope 2, or Scope 3 emissions because facility-level energy and procurement consumption data were not available in this dataset. Instead, we used selected infrastructure indicators (for example, solar power availability and energy-efficiency measures) as proxy markers of mitigation readiness. Table 7 depicts the facility type-wise result with the climate resilient index score.

Systemic Gaps: The Triad of Missing Infrastructure

The assessment of over 200,000 public health facilities across India reveals a consistent and critical pattern of underinvestment at the grassroots level. The most common challenges and systemic gaps, irrespective of state or facility type, coalesce around a triad of missing elements:

- Lack of solar panels (energy resilience): The low uptake prevents facilities from mitigating Scope 2 emissions and ensures their

Table 8: Calculation of GHG emissions from a DH (assuming one DH has two hundred beds)

Category	*Calculation/value*
Electricity utilized/bed	3 kW/bed
Total energy utilized=	4,60,800 kW
Emission factor=	0.064 kg CO_2e/kWh
GHG emission/DH	200 × 3 kW × 0.064
	38.4 kg CO_2e/h
Total GHG emission by DH	200 × 3 × 768 × 0.064
	29,491.2 kg CO_2e/h

DH, district hospitals; GHG, greenhouse gas

Table 9: Calculation of GHG emissions from a PHC (assuming one PHC has six beds)

Category	*Calculation/value*
Electricity utilized/bed	3 kW/bed
Total energy utilized=	6 × 3 × 30,471
	5,48,478 kW
Emission factor=	0.064 kg CO_2e/kWh
GHG emission/PHC	6 × 3 kW × 0.064
	1.152 kg CO_2e/h
Total GHG emission by PHC	6 × 3 × 30,471 × 0.064
	35,102.592 kg CO_2e/h

GHG, greenhouse gas; PHC, primary health centers

continued dependency on an often-unreliable grid or high-carbon backup power (Scope 1/DG sets), directly undermining resilience during extreme weather events.

- Absence of rainwater harvesting technology (water security): The lack of this crucial infrastructure exacerbates water scarcity during droughts and hinders facility self-sufficiency, placing additional strain on already stressed regional water tables, a key climate vulnerability.
- Deficit in computerized registration (digital preparedness): This gap reveals an underlying weakness in data infrastructure, hindering the efficient tracking of climate-sensitive diseases and the rapid mobilization of resources—a necessity for any modern, climate-smart health response.

Discussion

The results present a clear resilience paradox within the Indian public health system. While DH achieved the highest composite climate resilient index score of 87, reflecting stronger structural defenses against immediate climate shocks, these facilities simultaneously represent the sector's most significant vulnerability in terms of GHG emissions. While DH scored higher on the proxy resilience index, they are also typically the most energy-intensive facilities, thus offering the highest leverage for mitigation actions. Table 8 depicts the calculation of GHG emissions from the DH, based on the assumption that one DH has 200 beds. Table 9 depicts the calculation of GHG emissions from PHC, based on the assumption that one PHC has 6 beds, it shows contrast between the two facility types.

As the largest and most intensive consumers of energy across the spectrum of care, DHs possess the highest absolute demand for electricity- the source of our measured Scope 2 emissions. Even a highly rated, structurally resilient DH relies on a massive influx of grid power. Given that, in many Indian states, grid electricity remains carbon-intensive (often sourced from coal), the physical size and operational intensity of DHs mean their carbon footprint, especially Scope 2, is disproportionately large compared to smaller facilities like CHCs and PHCs. This suggests that achieving a high score on the resilience index, based largely on passive and basic infrastructure, is not synonymous with achieving a low-carbon or net-zero operational status.

Smaller facilities may consume less energy per facility, but their very large numbers mean that system-wide improvements at PHC and SHC levels can deliver major cumulative gains in resilience. In parallel, targeted mitigation actions at DHs can yield large absolute reductions because these facilities have higher energy demand and more complex services. India therefore needs a two-track approach: Scale low-cost resilience gaps across SHCs/PHCs and implement deeper mitigation upgrades in DHs.

Throughout the analysis, the systemic gaps identified are the pervasive absence of solar panels, rainwater harvesting, and computerized registration, particularly at the SHC level (scoring only 60)—demanding immediate, low-cost interventions. However, the high-GHG footprint of DHs and tertiary centers requires a strategic pivot toward innovative, large-scale decarbonization solutions utilized globally. Basic resilience must be augmented by a radical commitment to carbon mitigation.

Over the years, the Government of India has taken multiple steps to mitigate the impact of climate change on human health and to make our infrastructure climate-resilient. Initiatives like the Ayushman Bharat Digital Mission (ABDM) are one such example that has laid a strong foundation for computerized registration, electronic storage, retrieval, a data-driven, and patient-centric healthcare ecosystem, and the utilization of telemedicine applications, indirectly strengthening India's climate resilience infrastructure. The flagship program launched by the government in this domain is the NPCCHH, which focuses on strengthening health systems, capacity building, and creating state-level action plans (SAPCCHHs) to address heat, pollution, and vector-borne diseases while promoting climate-resilient infrastructure. The measures taken under this program include the installation of light-emitting diode; (LED) lights, solar panels (decentralized renewable energy) and water conservation measures. Decentralized renewable energy solutions, along with energy-efficient LED lights, have great potential to provide cost-effective and reliable electricity in many low-income settings where the grid is unreliable or non-existent. Apart from national initiatives, there are many state-level initiatives like the "Saura Swasthya" initiative in Karnataka and "Energy for Health," Chhattisgarh Solarization, etc., which are leading this renewable energy front.

India can also learn from various innovative solutions from international best practices that can transform India's health infrastructure from high-carbon vulnerability to climate leadership:

Decarbonizing the Energy Matrix (Targeting Scope 2): The Smart Hospital Model

- Global precedent (The Caribbean and United States of America): The Pan-American Health Organization's (PAHO) "Smart Hospital" program in the Caribbean retrofits facilities to be structurally resistant to disasters and environmentally efficient. Similarly, systems like Kaiser Permanente in the United

States of America have prioritized shifting energy use to 100% renewable sources via power purchase agreements (PPAs) or on-site generation.
- Proposed Indian solution: Beyond simple solar panel adoption, DHs and tertiary centers must be mandated to implement smart energy grids and deep geothermal solutions (as seen in use by Johnson & Johnson in Belgium). These solutions offer continuous, low-carbon power, reducing reliance on both the carbon-intensive grid and polluting diesel generators (addressing Scope 1 emissions simultaneously).

Supply Chain Engagement (Targeting the Undermeasured Scope 3): Green Procurement

- The problem: Globally, the supply chain (Scope 3) accounts for 60–80% of the health sector's total carbon footprint – a category we could not accurately measure. This includes pharmaceuticals, medical devices, and consumables.
- Global precedent (UK's NHS): The United Kingdom's National Health Service (NHS) has set a clear policy: By 2030, it will no longer purchase from suppliers not aligned with its net-zero ambitions. They use the science-based targets initiative (SBTi) criteria to set clear, externally verified emissions reduction expectations for vendors.
- Proposed Indian solution: India must leverage its massive procurement power to drive market change. The Ministry of Health should establish a "Green Procurement Standard" that favors suppliers demonstrating verified reductions in manufacturing emissions, reducing the carbon embedded in every bandage and syringe purchased by DHs.

Transforming Clinical Care and Operations (Digital Decarbonization)

- Global precedent (telemedicine): Studies from institutions like Johns Hopkins University confirm that virtual care models significantly cut carbon emissions, primarily by avoiding patient and staff travel (a major component of Scope 3). A single in-person visit can emit several kilograms of CO_2, whereas a virtual visit emits only a fraction of that.
- Proposed Indian solution: The national mandate for computerized registration (a glaring gap in 66% of PHCs) must evolve into a comprehensive digital health infrastructure. This shift, supported by the internet of medical things (IoMT) and remote monitoring devices, not only improves patient outcomes but also reduces physical travel and infrastructure demand, delivering climate co-benefits directly.

While DH offer a foundation of resilience, true climate stewardship requires viewing them not as isolated buildings, but as complex, carbon-intensive ecosystems. The pathway to a climate-smart health system in India must integrate grassroots measures at the SHC level with top-down, innovative, and market-shaping decarbonization strategies targeting the high-emitting infrastructure of the DHs.

Conclusion

Our analysis of IPHS self-assessment data shows a clear preparedness gradient across facility types. District hospitals scored higher on the index, while SHC scored lowest, indicating that frontline infrastructure remains highly vulnerable to climate shocks. Across facility types, recurring gaps cluster around three practical priorities-solar power availability, rainwater harvesting, and computerized registration. India should therefore prioritize rapid, low-cost upgrades at SHC/PHC levels to improve service continuity, while also undertaking higher-leverage mitigation upgrades in energy-intensive hospitals. Future work should add structural resilience and operational continuity indicators and integrate facility energy and procurement data to enable direct emissions estimation.

Strengths and Limitations

The study is evaluating more than 2,00,000 public healthcare facilities, one of the largest digital self-assessments conducted across the country. It is crucial to acknowledge a systemic limitation: Due to constraints in current facility-level data and reporting mechanisms, we were unable to calculate Scope 1 (direct emissions from owned sources like diesel generator sets for power backup) and, most critically, Scope 3 (indirect emissions from the massive value chain, including the procurement of pharmaceuticals, medical devices, and other supplies). This limitation suggests that the sector's overall carbon footprint is likely a significant underestimation.

Artificial Intelligence (AI) Declaration

During the preparation of this manuscript, the authors used Google Gemini for language editing and text paraphrasing to improve clarity. The authors reviewed and edited all output and take full responsibility for the final content of the published article.

Authors' Contributions

Dr Arpita Aggarwal: Conceptualization of the manuscript and preparation of the first draft.
Dr Priyanka Shenoy: Review of the draft manuscript and preparation of tables.
Dr Prachi Thakral: Review of literature and contribution to manuscript writing.
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REVIEW ARTICLE

Laboratory Network Strengthening under Pradhan Mantri Ayushman Bharat Health Infrastructure Mission: A Policy Review

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Abstract

Aim and background: The coronavirus disease (COVID)-19 pandemic revealed significant gaps in India's diagnostic and disease surveillance systems, emphasizing the importance of strengthening public health preparedness and infrastructure. In response, the Government of India (GoI) introduced the Pradhan Mantri Ayushman Bharat Health Infrastructure Mission (PM-ABHIM) in 2021, with laboratory network expansion as a key component. This study compares the proposed targets and current implementation status of laboratory strengthening initiatives under PM-ABHIM, identifies key implementation gaps, and provides recommendations.

Materials and methods: This study is a secondary data-based policy review of the progress made under PM-ABHIM, focusing on District Integrated Public Health Laboratories (IPHLs), Block Public Health Units (BPHUs), Biosafety level laboratories (BSL-3/4), and Metropolitan Surveillance Units (MSUs). Data were obtained from reports of the Ministry of Health and Family Welfare (MoHFW), National Centre for Disease Control (NCDC) updates, government publications, and relevant literature published between 2021 and 2025.

Results: The review found that substantial progress has been made in establishing laboratory infrastructure under PM-ABHIM, but implementation remains uneven across states and program components. Delays in operationalization, shortages of trained human resources, gaps in digital integration, and disparities in rural–urban access continue to affect the effective functioning of laboratory services. Progress in the establishment of BSL laboratories and MSUs was also slower than anticipated due to administrative and infrastructural challenges.

Conclusion: Pradhan Mantri Ayushman Bharat Health Infrastructure Mission has laid an important foundation for reinforcing India's laboratory and disease surveillance network. However, efforts toward operational readiness, workforce strengthening, and improved coordination mechanisms are essential to achieve the objectives of the mission and preparedness for future public health emergencies.

Keywords: Biosafety level laboratories, Diagnostic services, Disease surveillance, Health infrastructure, Metropolitan Surveillance Units, Pradhan Mantri Ayushman Bharat Health Infrastructure Mission, Policy review, Public health laboratories.

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Introduction

Coronavirus disease (COVID)-19 pandemic revealed the importance of health as a public good and highlighted the need to strengthen the health system of India across all levels of care. To reinforce public health infrastructure and ensure better management of future disease outbreaks and pandemics, the Pradhan Mantri Ayushman Bharat Health Infrastructure Mission (PM-ABHIM) was announced in the Union Budget 2021–2022 on February 1, 2021. Pradhan Mantri Ayushman Bharat Health Infrastructure Mission was launched as a Centrally Sponsored Scheme with some Central Sector Components, implementing the Atmanirbhar Bharat Package.[1]

Under this scheme, the total financial outlay for the period (2021–2022 to 2025–2026) was Rs. 63,544.56 crore, out of which Rs. 54,204.78 crore was allocated for Centrally Sponsored Scheme Components and Rs. 9,339.78 crore for implementation of Central Sector Components.[2]

The PM-ABHIM has significantly increased the allocation for healthcare infrastructure development demonstrating the government's commitment to strengthening healthcare infrastructure.[3]

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Background

Need for Strengthening Diagnostic Infrastructure in India

The COVID-19 pandemic exposed major gaps in India's public health infrastructure, particularly in diagnostics and disease surveillance.[4] Before the introduction of PM-ABHIM, public health laboratories in India faced significant gaps that hindered effective

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disease surveillance and diagnosis. There was an absence of a comprehensive national policy and strategic plan for developing public health laboratories, resulting in fragmented and poorly coordinated efforts across states and programs. Quality assurance and accreditation were limited mostly to vertical programs [e.g., National Tuberculosis Elimination Program (NTEP) Integrated Disease Surveillance Program (IDSP), and NACP], like the National Tuberculosis (TB) Elimination Program, which provided services for TB patients, etc. While this strategy has contributed to disease control, it has also led to systemic weaknesses across three major areas:

- First, under such a system, if the same patient has TB and diabetes, he or she is required to have samples drawn at different clinics (often located far from each other) and to be managed by healthcare professionals who are unable to view and correlate the diagnostic results from different laboratories. As a result, care providers are unable to treat the patient as a whole.
- Second, it results in duplication of infrastructure, equipment, and personnel, leading to underutilization and wastage of resources.
- Third, most importantly, this leads to gaps in outbreak management. A disease-focused healthcare system has poor capacity for comprehensive surveillance, outbreak preparedness, and timely human and infrastructural response during public health emergencies.[5]

There were no systems for coordination among health-related and other departments, such as food, water, climate, and veterinary sciences.[6]

India has a diverse diagnostic laboratory network comprising public and private facilities, including hospital-attached and stand-alone laboratories, functioning across various levels of health care. In the public sector, laboratories operate through sub-centers (SCs), Primary Health Centers (PHCs), Community Health Centers (CHCs), District hospitals (DHs), and medical colleges, while private laboratories function through independent diagnostic centers and hospitals. Despite the widespread presence of these facilities, the laboratory system remained fragmented, with variations in infrastructure, coordination, accessibility, and quality of diagnostic services across levels of care.[7]

Several concerns have been observed regarding healthcare delivery and diagnostic facilities across India. National health programs have faced challenges in achieving major health outcomes, including disease control, malnutrition reduction, and Millennium Development Goals, due to inadequate healthcare delivery, weak preventive practices, and limited resources. Secondary and tertiary facilities are often overburdened with fulfilling primary healthcare needs in urban areas because of insufficient primary healthcare facilities, lack of awareness among patients, and poor referral mechanisms.[7]

The Integrated Disease Surveillance Programme (IDSP) aimed to integrate laboratories across programs, but the absence of a clear integration roadmap led to duplication and waste of funds. Coordination between national, state, and district-level laboratories was inadequate, further aggravated by insufficient inter-sectoral collaboration with medical colleges, research institutions, and the private sector. In addition, the lack of a national laboratory database and specimen transportation system outside vertical programs adversely affected timely and reliable diagnosis.[5,8]

Under the IDSP, District Public Health Laboratories (DPHLs) were established in a phased manner for the diagnosis of epidemic-prone diseases. Since 2019, 77 DPHLs were sanctioned, and 368 laboratories received approval, of which 232 were performing tests as per IDSP standards. Despite these initiatives, significant gaps remained in laboratory coordination and integration.[9]

To address these gaps holistically, the Government of India (GoI) launched PM-ABHIM. It complements the National Health Mission and seeks to address critical gaps in public health infrastructure, including critical care and primary healthcare facilities in urban and rural areas.[10] Pradhan Mantri Ayushman Bharat Health Infrastructure Mission focuses on establishing digital disease surveillance laboratory networks at block, district, regional, metropolitan, and national levels, along with strengthening health units at Points of Entry to enable effective detection, investigation, prevention, and response to disease outbreaks and health emergencies.[11]

Given the ambitious scope of PM-ABHIM, particularly regarding laboratory infrastructure strengthening, a critical review is essential to understand the alignment between the policy design and its field-level implementation. This review compares the proposed targets and current implementation status of laboratory network strengthening under PM-ABHIM, with specific focus on District Integrated Public Health Laboratories (IPHLs), Block Public Health Units (BPHUs), Biosafety Level (BSL) laboratories, and Metropolitan Surveillance Units (MSUs). It also aims to identify implementation gaps and provide recommendations for improving laboratory infrastructure and disease surveillance systems under PM-ABHIM.

Materials and Methods

This study employed a qualitative descriptive policy review approach to assess the implementation status of laboratory network strengthening under PM-ABHIM in India. The review focused specifically on components related to District IPHLs, BPHUs, BSL laboratories, and MSUs. The study was based on secondary data collected from 2021 to 2025. Data were obtained from official reports, operational guidelines, annual reports, and policy documents published by the Ministry of Health and Family Welfare (MoHFW), National Centre for Disease Control (NCDC), Press Information Bureau (PIB), and other government sources. Relevant peer-reviewed literature, public health reports, and technical documents related to laboratory strengthening, disease surveillance systems, and diagnostic infrastructure in India were also reviewed.

Inclusion Criteria

Documents specifically addressing PM-ABHIM, public health laboratory systems, disease surveillance infrastructure, biosafety level laboratories, or implementation progress related to diagnostic strengthening in India were included.

Exclusion Criteria

Documents not relevant to public health laboratory systems or PM-ABHIM, duplicate records, opinion-based articles, news reports, and sources lacking a credible institutional basis were excluded from the review.

Results

Framework for Laboratory Network Strengthening under PM-ABHIM

One of the key interventions under PM-ABHIM is the development of cost-effective laboratory systems capable of delivering rapid,

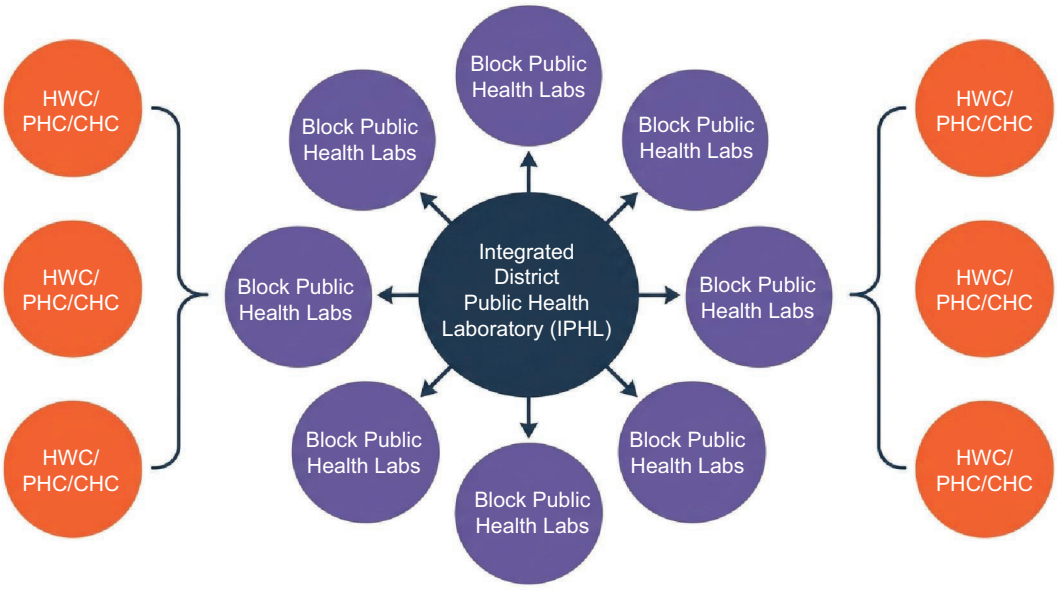

Fig. 1: Downward linkages of IPHL (Hub and Spoke model)

reliable, and accurate diagnostic services to improve patient care and public health outcomes. This includes the establishment of an integrated network of public health laboratories functioning across various levels of the healthcare system, with the district serving as the central hub through well-defined upward and downward referral linkages.[12]

District IPHLs

The District IPHL functions as the nodal point within the broad laboratory network, including veterinary laboratories, to facilitate multi-sectoral coordination for clinical management and public health surveillance. Under PM-ABHIM, IPHLs are proposed to be established across 730 districts of the country during the period financial year (FY) 2021–2022 to FY 2025–2026, with an allocated budget of Rs. 1,482.40 crore.[1]

Implementation Mechanism of IPHL

Under PM-ABHIM, a policy decision was taken to integrate the multiple laboratories functioning within DHs into a unified IPHL system. This is also adopted as a principle in the Indian Public Health Standards 2022. The development of IPHLs involves leveraging the existing resources of clinical and program-based laboratories within hospitals. Hence, it will reduce the duplication of resources. The implementation process may differ across states; however, certain broad operational measures have been suggested for establishing IPHLs, including the constitution of State- and District-level committees with representation from programs such as NTEP, IDSP, and NACP to conduct gap assessments as per the GoI pre-assessment checklist. Site selection is carried out through physical verification for the integration of existing laboratories through extension, restructuring, new construction, or upgradation to provide district-wide diagnostic services.[12]

BPHUs

Block Public Health Units are being established to reduce disparities in healthcare access between urban and rural areas. Under PM-ABHIM, the vision is to establish a CHC, Block PHC, or Sub-DH as the Block Headquarters (HQ), which would function as a referral hub for Sub-Health Centers and PHCs within the block. Block Public Health Units comprise a Block Public Health facility (PHC/CHC/SDH), a Block Public Health Laboratory (BPHL), and a Block Health Management Information System (HMIS) Cell.[13] Under this scheme, 3,382 BPHUs are proposed to be established across blocks in 11 empowered action group (EAG) States/Union Territories (UTs) (Bihar, Madhya Pradesh, Assam, Rajasthan, Uttar Pradesh, Chhattisgarh, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Odisha, and Uttarakhand) by 2025–2026, with a budget of Rs. 3,829.52 crore.[2]

The IPHL at the DH level will serve as the central hub for BPHLs and support diagnostic testing that might not be available at the block level. In turn, BPHLs are expected to serve as referral hubs for health and wellness centers (HWCs) and other lower-level healthcare facilities, as shown in Figure 1.[12]

The IPHL network is further proposed to be connected with zonal, state, and regional laboratories, which would function as referral laboratories for various national health programs, including NTEP, IDSP, National Vector Borne Disease Control Programme (NVBDCP), NACP, and National Viral Hepatitis Control Program (NVHCP). Existing regional-level laboratories are also expected to be integrated with IPHLs. In addition, IPHLs are proposed to establish linkages with medical colleges, research institutions, and universities for diagnostic services, research, and development activities, as illustrated in Figure 2.[12]

BSL

Biosafety level laboratories are specialized facilities designed for the safe handling of hazardous biological agents under controlled containment conditions.[14,15] They support IPHLs when highly infectious pathogens are suspected and are linked through national referral pathways defined by MoHFW and NCDC. Under PM-ABHIM, two BSL-4 facilities, nine BSL-3 facilities, and four Mobile BSL-3 units have been established. In addition, 10 BSL-3 laboratories and one BSL-4 laboratory have been approved under the NCDC.[16]

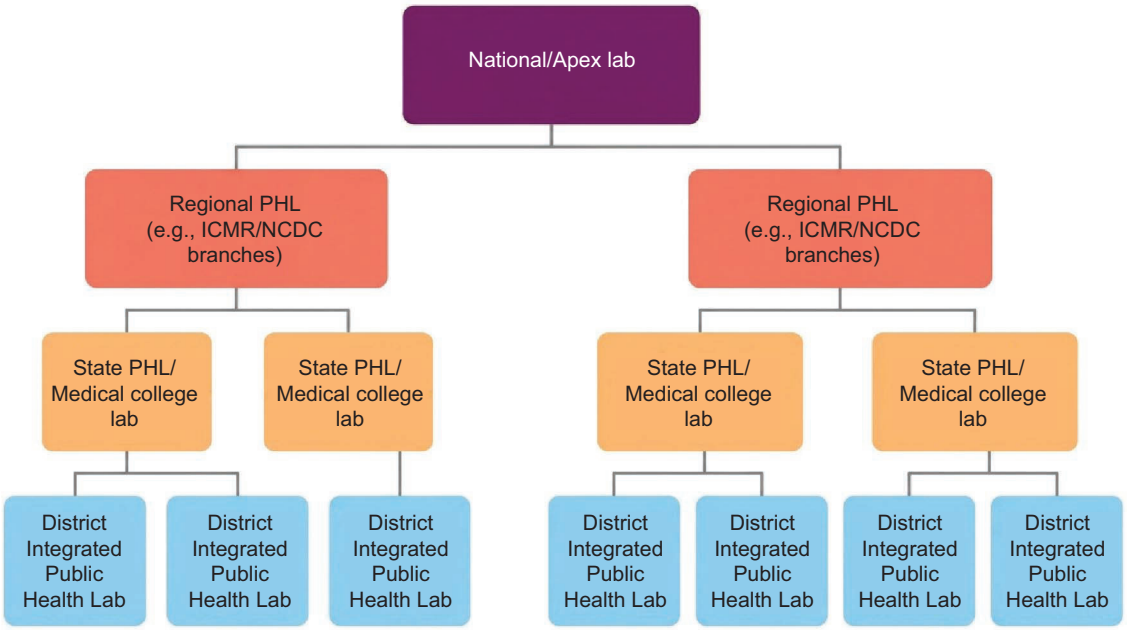

Fig. 2: Upward linkages of IPHL

MSUs

Pradhan Mantri Ayushman Bharat Health Infrastructure Mission intends to strengthen urban disease surveillance in India through the establishment of MSUs in 10 Tier-I and 10 Tier-II cities. Implementation of MSUs under PM-ABHIM is being carried out through tripartite memoranda of understanding (MoUs) between the NCDC, State Health Departments, and Municipal Corporations. Metropolitan Surveillance Units serve as urban surveillance nodes intended to enhance epidemiological tracking in metropolitan areas. Although they are not directly integrated with BPHUs or IPHLs, they form part of the broader national surveillance ecosystem and are intended to provide data inputs to the IDSP and Integrated Health Information Platform (IHIP), which also obtain information from IPHLs. Twenty MSUs have been proposed under PM-ABHIM.[10]

Implementation Status

While PM-ABHIM provides an extensive framework for strengthening India's public health laboratory network, the implementation status across different components shows variations in progress related to infrastructure development and operationalization.

Against the target of establishing IPHLs in all 730 districts by 2025–2026 under PM-ABHIM, the implementation status as of September 2025 indicates partial progress across districts. Out of 766 districts, 439 DPHLs have been sanctioned, of which 386 are reported to be functional, while 53 are sanctioned but not yet operational. In total, 327 districts still lack a sanctioned DPHL.[17] Table 1 shows the state-wise status of sanctioned and functional DPHLs under PM-ABHIM.

Under PM-ABHIM, 3,382 BPHUs have been proposed in 11 EAG States/UTs. Of the 2033 approved BPHUs, work has started in 1,210 units, while 408 units have become operational.[3,18]

The implementation status of BSL laboratories under NCDC shows varying levels of progress across sites. Out of the 10 proposed sites, six have identified locations, signed MoUs, and received revised project estimates. However, several sites are still awaiting approvals and revalidation processes. The remaining four sites continue to face challenges related to pending MoUs, land allocation, and relocation due to feasibility issues. Proposed relocation of certain sites has also been reported in Raipur, Ahmedabad, and Hyderabad. In addition, the Indian Council of Medical Research (ICMR) is undertaking efforts to expand its network of BSL-3 and BSL-4 laboratories to strengthen diagnostic infrastructure and improve access to laboratory services across the country.[19]

Under PM-ABHIM, 20 MSUs have received approval for strengthening urban disease surveillance. Of these, tripartite MoUs have been signed for 17 MSUs. Metropolitan Surveillance Units in Ahmedabad, Mumbai, and Bhubaneswar are operational as of January 2025.[20]

Implementation Gaps and Challenges

Despite the progress achieved under PM-ABHIM, several implementation gaps and operational challenges continue to affect the strengthening of India's laboratory network. Delays in operationalization of sanctioned IPHLs, BPHUs, BSL laboratories, and MSUs indicate persisting administrative and infrastructural problems. In several locations, laboratories remain non-functional despite approval or completion of construction due to delays in equipment installation, procurement processes, and operational clearances.[18,19]

Infrastructure gaps continue to affect laboratory services, particularly in rural, remote, and tribal regions where many healthcare facilities still do not have functional laboratories. Existing disparities in healthcare infrastructure and accessibility have also contributed to uneven implementation across states and districts.[21,22]

Human resource constraints remain another major challenge in improving laboratory systems. Shortages of trained laboratory technicians, microbiologists, pathologists, and technical personnel limit the effective functioning of laboratories and affect service delivery capacity. Vacancy rates in laboratory positions at primary and secondary healthcare levels further hinder operational readiness.[21]

Table 1: State-wise status of DPHLs under PM-ABHIM as of September 2025[17]

State/UT	Districts (N)	DPHLs sanctioned (N = 439)	DPHLs functional (N = 386)
Andaman and Nicobar	3	3	3
Andhra Pradesh	26	17	17
Arunachal Pradesh	26	8	4
Assam	35	31	31
Bihar	38	6	6
Chandigarh	1	1	1
Chhattisgarh	33	12	12
Dadra and Nagar Haveli	1	1	1
Daman and Diu	2	2	2
Delhi	11	1	1
Gujarat	33	24	24
Goa	2	2	2
Haryana	22	22	22
Himachal Pradesh	12	6	2
Jammu and Kashmir	20	19	17
Jharkhand	24	24	19
Karnataka	31	20	20
Kerala	14	9	8
Ladakh	2	2	2
Lakshadweep	1	1	0
Madhya Pradesh	52	10	6
Maharashtra	36	22	6
Manipur	16	7	7
Meghalaya	12	4	4
Mizoram	11	6	2
Nagaland	16	12	7
Odisha*	30	32	32
Punjab	23	23	23
Puducherry	4	3	3
Rajasthan	33	27	27
Sikkim	6	4	3
Telangana	33	6	6
Tamil Nadu	38	38	38
Tripura	8	4	4
Uttarakhand	13	13	13
Uttar Pradesh	75	7	2
West Bengal	23	10	9

DPHLs, District Public Health Laboratories. *Districts Khorda and Sundergarh have two DPHLs sanctioned each

Challenges related to digital integration and laboratory information management systems (LIMS) have also been observed. Limited digital infrastructure, poor internet connectivity in rural settings, high implementation costs, and inadequately trained personnel restrict effective adoption of integrated laboratory information systems and real-time surveillance mechanisms.[23]

In addition, gaps in coordination between different levels of laboratories and across vertical health programs continue to affect integrated surveillance and referral systems. Delays in approvals, land allocation, inter-sectoral coordination, and administrative processes have also affected the establishment of BSL laboratories and MSUs in several states.[19]

The review also identified concerns related to underutilization of diagnostic technologies due to inadequate maintenance systems, irregular power and water supply, procurement-related issues, and limited technical support.[24] Urban–rural disparities in diagnostic infrastructure and laboratory distribution further affect equitable access to laboratory services and timely disease detection.[22]

Discussion

The findings of this review suggest that PM-ABHIM represents an important step toward enhancing India's public health laboratory and disease surveillance systems following the COVID-19 pandemic. The scheme proposes expansion of IPHLs, BPHUs, BSL laboratories, and MSUs to improve diagnostic preparedness and outbreak response capacity. However, the implementation remains incomplete across several components.

A major finding of the review is the gap between approval and operationalization of laboratories and public health units. Although several facilities have been approved under the scheme, many are still under construction or not fully functional. For instance, out of 766 districts, only 439 DPHLs had been sanctioned, while 327 districts still lacked a sanctioned DPHL. Similarly, despite approval of 2,033 BPHUs, only a limited proportion had become operational. Delays in construction, equipment installation, approvals, and operational clearances continue to affect implementation. Shortages of trained laboratory personnel, gaps in digital integration, and limited infrastructure in rural and remote areas further affect the functioning of laboratory services.

The review also highlights variations in implementation across states and continued urban–rural disparities in access to diagnostic services. In addition, delays in the establishment of BSL laboratories and MSUs indicate challenges related to coordination, land allocation, and administrative processes. These findings suggest that improving laboratory infrastructure alone may not be sufficient without parallel improvements in workforce capacity, digital surveillance systems, and operational readiness.

Overall, PM-ABHIM has laid a strong foundation for reinforcing India's laboratory network, but sustained efforts in implementation, coordination, and resource utilization will be essential to achieve its intended public health goals.

Limitations

This review is based entirely on secondary data obtained from government reports, policy documents, annual reports, and published literature. Although these sources provide important insights into the implementation status of PM-ABHIM, they may not completely reflect the operational challenges and ground-level realities across different states and districts. The absence of primary data collection and stakeholder interaction limited

detailed understanding of administrative, infrastructural, and workforce-related barriers affecting implementation. In addition, variations in reporting timelines and availability of updated data across sources may have influenced the assessment of the current implementation status.

Future Research Directions

Future research should focus on field-based assessment of laboratory strengthening initiatives under PM-ABHIM to gain a better understanding of operational readiness, service quality, and utilization of laboratory services at district and block levels. In addition, assessing the integration of surveillance systems through platforms such as IHIP and LIMS may provide insights about the role of digital public health infrastructure in strengthening real-time disease reporting and response mechanisms.

Recommendations

- Sanctioned laboratories and public health units should be operated through timely construction, equipment installation, recruitment of staff, and administrative approvals. Monitoring of laboratories should also be improved.
- Digital integration of laboratory information systems with platforms such as IHIP should be strengthened to improve disease surveillance and outbreak management. It will help in efficient reporting and real-time public health response. Laboratory information management systems used in IPHLs should support accurate and timely information flow among laboratory personnel, clinicians, program managers, and patients.[12]
- There is a need for stronger human resource planning and long-term retention strategies due to high workload, burnout, and frequent turnover among laboratory personnel. Sustainable staffing models should be developed.[25]
- Developing a more integrated and coordinated laboratory network is important for improving timely and equitable public health response. Standardized systems for specimen collection, referral, and transportation should be strengthened to ensure that populations in remote and rural areas also have timely access to diagnostic and laboratory services.[25]

Conclusion

Pradhan Mantri Ayushman Bharat Health Infrastructure Mission represents a major initiative to build India's diagnostic and disease surveillance infrastructure in the post-COVID-19 period. Although progress has been made in the expansion of IPHLs, BPHUs, BSL laboratories, and MSUs, implementation gaps continue to persist. Strengthening coordination, operational readiness, and surveillance integration will be essential to achieve the intended objectives of the scheme. If effectively implemented, the mission has the potential to significantly improve India's preparedness for future outbreaks and public health emergencies.

Ethical Approval

Ethical approval was not required as this study was entirely based on secondary data, which is publicly accessible and anonymized, and no direct interaction with human participants was involved.

Clinical Trial Registration

Not applicable, as this study was a secondary data-based policy review and did not involve a clinical trial.

Artificial Intelligence (AI) Disclosure

No AI tool or version was used in the drafting of the article. The authors take full responsibility for all content presented in this paper.

Data Availability

The data supporting the findings of this study are available from the publicly accessible sources cited in the reference list. No new datasets were generated or analyzed.

Patient Consent

Patient consent for publication was not required for this review article as the study did not involve human participants, patient data, or primary data collection.

Acknowledgment

The authors have no acknowledgments to declare.

Authors' Contributions

Mehak Singla: Conceptualization of the study, literature search, manuscript writing, editing, and drafting the final manuscript.
Vishnupriyan Jayasankar: Literature search, editing, and drafting the final manuscript.
Vinay K Challa: Data presentation and drafting the final manuscript.

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