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Cancer Prevention Across the Life Course: A Global Public Health and Preventive Oncology Perspective with Focus on LMIC Implementation

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Abstract

Background: *Cancer is a leading cause of global morbidity and mortality, with a rapidly increasing burden in low- and middle-income countries (LMICs). Although advances in treatment have improved outcomes in many high-income settings, prevention remains inadequately integrated into routine health systems in several regions. A life-course approach—addressing exposures and opportunities for intervention from childhood to older age—offers a coherent framework to reduce incidence, promote earlier detection, and improve equity.*

Objective: *To synthesize a life-course model for cancer prevention that integrates global public health principles with preventive oncology strategies and highlights practical implementation options for LMICs, including India.*

Methods: *Narrative review of contemporary evidence and policy guidance on primary prevention (vaccination, risk-factor control), secondary prevention (screening and early diagnosis), and precision prevention (risk stratification and genetic counseling), with emphasis on feasibility and systems design.*

Results: *Prevention opportunities exist across all life stages, including HPV and hepatitis B vaccination, tobacco and alcohol control, obesity prevention, infection control, occupational and environmental risk reduction, and early detection strategies tailored to local capacity. Genetic testing and counseling can strengthen risk-based prevention but require ethically sound, affordable pathways and trained workforce. LMIC barriers include low awareness, stigma, limited workforce, fragmented referral pathways, weak pathology capacity, and loss to follow-up; practical solutions include integration with primary health care, task-shifting, opportunistic screening platforms, patient navigation, digital tracking tools, and quality-assured partnerships.*

Conclusion: *A life-course preventive oncology framework grounded in public health principles is scalable and equity-oriented. LMICs can achieve meaningful impact by prioritizing high-value interventions, strengthening referral systems, assuring quality, and incrementally introducing risk-based and genomic approaches.*

1. Introduction

Cancer has become a defining public health challenge of the modern era. The global cancer burden is rising due to population aging, growth, and shifts in exposure patterns. LMICs now account for a growing share of incident cases and deaths, driven by rapid urbanization, changing diets, decreased physical activity, increasing obesity, and persistent infection-associated cancers. Many LMICs face a dual burden in which preventable infection-related cancers coexist with rapidly increasing lifestyle-related malignancies. From a health systems perspective, cancer prevention is uniquely valuable because it reduces incidence, shifts diagnosis toward earlier stages, decreases the need for expensive treatment, and preserves household and national productivity. Yet prevention frequently receives less attention

than treatment in policy and practice. Screening programs may be limited, opportunistic, or poorly linked to confirmatory diagnosis and treatment. Vaccination coverage for preventable cancers may be incomplete. Risk factor control (tobacco, harmful alcohol use, obesity, occupational exposures, indoor and outdoor air pollution) often competes with other priorities.

Prevention is inseparable from equity. Disadvantaged communities typically have higher exposure to risk factors and lower access to early detection and timely treatment. Women may face additional barriers including stigma, limited autonomy for healthcare decisions, and constraints on travel to facilities. Therefore, an effective prevention strategy must be designed to reduce, not amplify, inequities.

The life-course approach—widely used in public health—recognizes that risk accumulates and interventions can be delivered at multiple points over time. In preventive oncology, this means structured, age-appropriate prevention packages: immunization and tobacco prevention in adolescence; screening and reproductive health platforms during adulthood; metabolic risk control and risk-based surveillance in midlife; and survivorship-focused prevention in later life. This review presents a life-course framework that integrates global evidence with practical implementation pathways for LMICs, with particular relevance to India.

2. Life-Course Framework in Preventive Oncology

The life-course framework organizes cancer prevention into complementary layers: primary prevention (preventing carcinogenic exposure and infection), secondary prevention (detecting pre-cancer or early cancer), and precision prevention (tailoring prevention intensity based on individual or familial risk). Prevention is not a single event but a sustained process supported by education, accessible services, quality assurance, and follow-up.

2.1 Childhood and Adolescence

Early-life interventions establish long-term protection. HPV vaccination prevents cervical and other anogenital/oropharyngeal cancers; hepatitis B vaccination reduces future hepatocellular carcinoma. LMIC programs must address delivery logistics, consent processes for adolescents, and community concerns about myths and misinformation. School-based delivery and community outreach can achieve high coverage when linked with reliable cold-chain systems. Behavioral prevention is also crucial. Tobacco initiation often occurs in adolescence; enforcing age restrictions, reducing advertising, and implementing taxation and smoke-free policies complement school-based education. Obesity prevention through physical activity, healthier diets, and reduced ultra-processed food intake is increasingly relevant given links with multiple cancers. Additional prevention includes reduction of second-hand smoke exposure and promotion of healthy indoor air (clean cooking fuels) where biomass smoke is prevalent.

2.2 Reproductive Age

During the reproductive years, women often interact with health services for contraception, pregnancy, childbirth, and gynecologic care. These contacts create high-yield opportunities for opportunistic prevention: cervical screening (VIA, Pap cytology, or HPV testing, depending on resources), breast health education and clinical breast examination (CBE), tobacco and alcohol cessation counseling, and promotion of healthy body weight. Preconception and antenatal visits can incorporate brief risk assessment (family history, tobacco exposure, prior abnormal screening) and counseling on modifiable risks.

2.3 Midlife

Midlife is associated with rising incidence of breast, colorectal, and endometrial cancers. Prevention packages should emphasize sustained risk-factor modification, control of metabolic conditions, and screening appropriate to local epidemiology and resources. In settings where mammography is limited, structured risk assessment and CBE can be implemented while building imaging pathways for high-risk individuals. For colorectal cancer, stool-based testing (e.g., FIT) can be considered where feasible, with clear referral routes for colonoscopy when positive.

2.4 Older Adults and Survivors

Older adults benefit from individualized screening decisions based on comorbidities, functional status, and life expectancy. Prevention includes symptom awareness, timely evaluation, and survivorship care to reduce recurrence risks and late effects of therapy. Survivorship programs can incorporate lifestyle counseling, psychosocial support, and monitoring for second primary cancers.

2.5 Genetic Testing and Counseling Across the Life Course

Genetic risk assessment supports precision prevention by identifying individuals and families with hereditary cancer syndromes such as BRCA-associated breast/ovarian cancer and Lynch syndrome. Genetic services enable earlier screening initiation, intensified surveillance, risk-reducing interventions, and cascade testing for relatives. LMIC implementation faces constraints including cost, limited laboratory access, shortage of trained counselors, and variable legal protections. A pragmatic LMIC pathway is a tiered model: structured family history documentation and risk tools in primary care; referral to specialized centers for counseling and testing; and tele-genetic counseling to extend reach. Partnerships with accredited laboratories and negotiated pricing improve affordability. Programs must prioritize informed consent, confidentiality, and culturally appropriate communication.

3. Global Perspective and Policy Context

High-income countries have shown that organized screening programs, vaccination, and strong tobacco control can reduce incidence and mortality for several cancers. WHO strategies for cervical cancer elimination illustrate the need for coverage, quality testing, and timely treatment. These frameworks reinforce that prevention requires both technology and systems: financing,

workforce, supply chains, quality assurance, and data tracking. Global inequities persist. Many LMICs have limited capacity to implement organized screening, resulting in late-stage presentation and poor survival. Even when screening is offered, weak referral pathways, delays in pathology and imaging, and loss to follow-up can undermine effectiveness. Global lessons must be adapted to local realities through prioritization of high-value interventions, simplified pathways, and strengthening of primary care and community engagement.

4. LMIC and Indian Scenario: Gaps and Opportunities

India illustrates the LMIC challenge of a mixed cancer profile. Infection-related cancers remain significant in many regions, while breast cancer incidence has risen and is now a leading malignancy among women in several states. Tobacco-related cancers remain major contributors to mortality. Screening coverage remains below desired levels due to awareness gaps, stigma, financial barriers, time constraints, shortages of trained staff, inconsistent supplies, and fragmented referral pathways. Loss to follow-up between screening and diagnosis is a major determinant of low program effectiveness. Limited pathology and imaging capacity in peripheral areas further delays diagnosis. Despite challenges, India has multiple entry points for scalable prevention: primary health care facilities, maternal and child health platforms, immunization services, and community health workers. Increasing mobile phone penetration allows digital reminders and registries to strengthen continuity of care. LMIC strategies should be phased: start with high-impact interventions (tobacco control, HPV vaccination, VIA screening), build quality assurance and referral systems, and gradually introduce higher-sensitivity tests and genetic counseling for high-risk groups.

5. Practical Implementation Strategies for LMICs

Effective implementation requires programs that fit real-world constraints. A life-course preventive oncology strategy can be operationalized through integration, workforce development, standardized pathways, and continuous quality improvement.

5.1 Integration with Primary Health Care and Routine Platforms

Embedding prevention within existing services increases reach and sustainability. Cervical screening can be offered through reproductive health and family planning clinics; breast health education and CBE can be integrated into gynecology and antenatal clinics; and tobacco cessation counseling can be incorporated into chronic disease visits.

5.2 Task-Shifting and Workforce Development

Task-shifting expands coverage when supported by protocols and supervision. Training should include communication skills, VIA and CBE techniques, infection prevention, documentation, referral criteria, and counseling. Competency-based certification and periodic audits maintain standards.

5.3 Opportunistic Screening and One-Stop Prevention Visits

Opportunistic screening during healthcare encounters can rapidly improve coverage. Standardization requires clear eligibility criteria, privacy measures, and a defined pathway for positive results. Where feasible, screen-and-treat approaches for cervical precancer reduce loss to follow-up.

5.4 Strengthening Referral Pathways and Continuity of Care

Systems should define referral networks, expected turnaround times, and communication loops. Patient navigation improves attendance for diagnostic appointments. Tracking tools identify patients who miss follow-up.

5.5 Digital Health, Registries, and Data Use

SMS reminders, electronic registries, and teleconsultation for counseling reduce loss to follow-up. Indicators (coverage, positivity, referral completion, treatment completion, time-to-diagnosis) support quality improvement.

5.6 Public–Private Partnerships and Financing

Collaboration can expand access to diagnostics and genetics. Partnerships require quality standards, transparent pricing, and equity safeguards. Financing options include subsidies and insurance inclusion.

5.7 Monitoring, Evaluation, and Quality Improvement

Monitoring should include coverage, positivity rates, referral completion, confirmatory diagnosis rates, treatment completion for precancer, and stage distribution of detected cancers. Facility-level quality improvement cycles address bottlenecks.

5.8 Practical Implementation Blueprint for India and Similar LMIC Settings

A pragmatic blueprint can be implemented as a hub-and-spoke model. At the spoke level (primary care and community outreach), services include risk communication, vaccination linkage, and screening. Community health workers mobilize eligible populations, counsel patients, and support appointment adherence. Primary care teams deliver VIA and CBE after standardized training and maintain registries capturing eligibility, screening dates, results, referrals, and outcomes. At the hub level (district or tertiary center), confirmatory diagnosis, pathology, imaging, and treatment services are provided with defined turnaround times. Standard referral forms and appointment scheduling reduce delays. Navigation support (calls, messaging, community follow-up) reduces loss to follow-up. Operationally, a prevention visit can include: brief risk assessment (tobacco, alcohol, obesity, family history), counseling and referral for cessation and weight management programs, cervical screening for eligible women, and breast symptom evaluation with referral for imaging when indicated. Communication materials in local languages should clarify results and next steps.

Quality assurance can be built through checklists, periodic

observation, review of positivity rates, and refresher training. A small set of KPIs can guide implementation: vaccination coverage, screening coverage, proportion of positives completing diagnostic confirmation, time from positive screen to diagnosis, treatment completion for precancer, and stage distribution among cancers detected through the pathway. Integration with broader NCD services improves efficiency. Tobacco cessation services can be shared across cardiovascular, respiratory, and cancer programs, while obesity and physical activity interventions link naturally with diabetes and hypertension clinics. Such integration reduces duplication and improves sustainability under constrained budgets.

6. Cost-Effectiveness and Health Economics

Prevention is consistently more cost-effective than treatment of advanced cancer. Benefits include reduced healthcare expenditure, reduced catastrophic spending, and preservation of productivity. High-value interventions include tobacco control, HPV and hepatitis B vaccination, and simplified screening suited to primary care. VIA offers immediate, low-cost cervical screening results; CBE with structured referral can improve earlier detection where mammography is limited; and stool-based colorectal screening can be considered where diagnostic follow-up exists. Cost-effectiveness depends on coverage, quality, and follow-up completion, highlighting the importance of investing in training, navigation, and data systems. Local evaluation should consider patient costs (transport, wage loss), staff time, and downstream savings. Even moderate stage-shift toward earlier disease reduces treatment costs and improves survival.

7. Discussion and Practical Recommendations

This life-course framework highlights that preventive oncology is not a single intervention but a system of linked actions. Several practical themes emerge. First, prevention should be aligned with the dominant cancer risks of the local population. In many LMIC settings, cervical and tobacco-related cancers contribute substantially to mortality. Therefore, HPV vaccination, cervical screening using feasible methods, and strong tobacco control can generate high returns. In parallel, rising breast cancer burden requires early diagnosis pathways, breast health awareness, and structured referral for imaging and biopsy when clinically indicated. Colorectal cancer prevention and screening can be introduced selectively where health systems can ensure colonoscopy follow-up and safe treatment, avoiding ineffective programs that generate positives without timely confirmation. Second, the effectiveness of screening is primarily determined by the pathway that follows a positive test. A screening test without a reliable referral mechanism, pathology, and treatment access can cause anxiety, reduce trust, and waste resources. LMIC program design should therefore prioritize end-to-end pathways: communication of results, referral completion, diagnostic confirmation, and treatment completion. Patient navigation is not a luxury; it is often the difference between detection and benefit. Navigation can be implemented through counselors, trained nurses, or community workers supported by simple scripts and referral checklists.

Third, task-shifting and simplification are essential. Many effective prevention actions do not require specialist-level delivery. VIA, CBE, counseling for tobacco cessation, and structured risk assessment can be delivered in primary care when providers are trained and supervised. Specialists are then focused on confirmatory diagnosis and treatment and on complex decision-making such as management of high-risk genetic syndromes. In this model, a tertiary cancer center functions as a training and quality hub, supporting peripheral facilities through standard protocols, periodic mentoring visits, and tele-mentoring. Fourth, prevention must be integrated with broader noncommunicable disease control. Tobacco, alcohol, obesity, and metabolic conditions are shared risks for cancer, cardiovascular disease, and diabetes. Integrated NCD clinics can deliver consistent counseling, monitor risk factors, and support behavior change over time. Integration improves efficiency and reduces duplication of counseling and follow-up systems.

Fifth, digital tools can strengthen continuity but should be designed for LMIC realities. High-value uses include patient registries, appointment reminders, referral tracking, and dashboards for monitoring key indicators. Digital systems should be low-bandwidth, multilingual, and compliant with privacy expectations. Importantly, digital tools must augment human systems rather than replace them; for example, a missed appointment should trigger a human follow-up by a community worker. Sixth, equity should be deliberately engineered. Program coverage should be monitored by geography, socioeconomic status, and gender to detect gaps. Outreach strategies should be tailored for populations with low access, including rural areas and informal settlements. Practical equity measures include outreach screening camps linked to fixed referral facilities, transport support for diagnostic visits, and flexible clinic hours. Community engagement with local leaders and women's groups can reduce stigma and improve participation.

Finally, genetic testing and counseling should be introduced in a risk-stratified manner. LMICs should begin with systematic family history capture and clear referral criteria. Genetic services should be offered where results will change management (earlier screening, intensified surveillance, or risk-reducing interventions). Ethical safeguards are crucial: informed consent, counseling quality, confidentiality, and clear documentation practices. Tele-genetic counseling can reduce specialist shortages and improve access. Limitations of this review include its narrative nature and the heterogeneity of LMIC contexts. Implementation choices should be guided by local epidemiology, health system capacity, and community preferences. Nevertheless, the life-course framework provides a coherent structure for prioritization and phased expansion, allowing countries and institutions to move from fragmented activities to an integrated preventive oncology program.

Additional practical considerations include prevention of environmental and occupational exposures. In several LMIC

settings, exposures to biomass smoke, ambient air pollution, asbestos in older buildings, unsafe pesticide use, and informal industrial hazards remain relevant. Prevention programs should therefore interface with environmental health and occupational safety policies, including safer cooking fuels, workplace protections, and enforcement of exposure limits. Infection control beyond HPV and hepatitis B is also important: addressing Helicobacter pylori where locally appropriate, and strengthening general infection prevention can reduce long-term cancer risk. Emerging approaches such as HPV self-sampling may help reach women who avoid pelvic examinations due to stigma or lack of privacy, but successful rollout still depends on reliable laboratory services and timely treatment for positives. Similarly, opportunistic oral cancer screening in high-risk tobacco users, combined with cessation services, may be valuable in India where smokeless tobacco is common. Finally, a mature prevention program should include clear links to palliative and supportive care services. While palliative care is not prevention, it strengthens trust in the health system and reduces fear of diagnosis—indirectly improving participation in screening and early diagnosis pathways.

8. Ethical, Equity, and Implementation Considerations

Equity must remain central to preventive oncology. Without deliberate design, programs may preferentially benefit urban or higher-income populations. Equity-promoting strategies include outreach through community health workers, culturally tailored communication, flexible clinic hours, and services closer to home. Genetic testing introduces ethical issues: informed consent, confidentiality, psychosocial impacts, and potential discrimination. Counseling must be accessible and safeguards should protect privacy. Implementation quality is also an ethical issue. Screening programs must avoid harm from false positives and poor-quality procedures. Quality assurance—standardized training, periodic audits, and clear clinical pathways—is essential.

9. Future Directions

The future of preventive oncology is increasingly data-driven and personalized. AI-assisted risk stratification, digital decision-support tools, and genomic integration may improve targeting of prevention resources, but these should complement foundational public health measures. A phased roadmap is practical: strengthen primary prevention and basic screening; establish robust referral and tracking systems; introduce higher-sensitivity tests where feasible; and expand genetic services for high-risk groups. Implementation science research is needed to optimize task-shifting models, test digital tools for follow-up, and identify strategies that reduce inequities.

10. Conclusion

Cancer prevention is a continuous process across the life course. A public health–grounded preventive oncology framework integrates vaccination, risk-factor reduction, screening, early diagnosis, and precision prevention in a structured and scalable manner. For LMICs—including India—implementation is achievable by prioritizing high-value interventions, integrating services into primary care and reproductive health platforms, enabling task-shifting, strengthening referral pathways, and leveraging digital tools for follow-up. Embedding monitoring and quality improvement ensures that screening translates to timely diagnosis and treatment. With sustained policy commitment and equity-focused design, life-course prevention can reduce incidence, improve early detection, and deliver long-term economic and societal benefits [1-20].

Life Stage	Primary Prevention	Secondary Prevention	Risk-Based/Precision Strategies
Childhood & Adolescence	HPV & hepatitis B vaccination; tobacco prevention; healthy diet & activity	—	Family history screening; risk education
Reproductive Age	Lifestyle counseling; infection prevention	Cervical screening (VIA/Pap/HPV); breast education & CBE	Risk tools; referral for genetic counseling if indicated
Midlife	Risk-factor modification; metabolic risk control	Mammography where feasible; FIT where feasible	Enhanced surveillance for high-risk groups
Older Adults/Survivors	Healthy aging; smoking cessation; physical activity	Individualized screening; symptom-based early diagnosis	Survivorship monitoring; second primary prevention

Table 1: Cancer Prevention Interventions Across the Life Course

Barrier	Level	Practical Solutions
Low awareness, stigma, fear	Community	IEC campaigns; culturally tailored counseling; school/workplace programs
Workforce shortage	Health system	Task-shifting; protocol training; tele-mentoring; hub-and-spoke models
Weak referrals and follow-up loss	Process	Defined pathways; navigation; registers/digital tracking; screen-and-treat where feasible
Financial barriers	Household/system	Subsidized screening; insurance inclusion; negotiated pricing; targeted support
Limited genetics/diagnostics	Specialized services	Tiered risk assessment; tele-genetic counseling; partnerships with accredited labs

Table 2: Common Barriers in LMIC Cancer Prevention and Practical Solutions

Tool/Intervention	Cost Level	Delivery Setting	Notes
HPV vaccination	Moderate	Schools/community clinics	High impact; needs coverage and community acceptance
Hepatitis B vaccination	Low–Moderate	Routine immunization	Strengthen birth dose and completion
VIA cervical screening	Low	Primary care/gyne clinics	Immediate results; supports screen-and-treat models
Pap cytology	Moderate	Secondary care	Needs lab quality and repeat-visit follow-up
HPV testing	Moderate–High	Secondary/tertiary	Higher sensitivity; phased rollout for priority groups
Clinical breast exam	Low	Primary care/OPD	Requires training and imaging referral pathways
FIT for colorectal cancer	Moderate	Community/primary care	Requires colonoscopy access for positives
Family history risk tool	Low	Any OPD	Enables targeted genetics referral and surveillance

Table 3: Cost-Effective Prevention and Early Detection Tools for Resource-Limited Settings

Conflict of Interest

The author declares no conflict of interest.

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