

MINI REVIEW



Comparative analysis of Indian and foreign population for cervical cancer

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ABSTRACT

Cervical cancer remains a significant global health challenge, with a particularly high prevalence in low- and middle-income countries, such as India. This report investigates disparities in cervical cancer incidence, risk factors, screening methodologies, and treatment outcomes between India and developed nations, aiming to identify key differences and suggest strategies for enhancing cervical cancer control in resource-limited settings. A multi-faceted methodology was employed, including an extensive literature review, data extraction from major health databases, surveys, and an analysis of reports from governmental and non-governmental organizations. The study applied descriptive and comparative statistical methods, trend analysis, and thematic analysis to comprehensively evaluate the data. Results indicate that India experiences markedly higher cervical cancer incidence and mortality compared to developed countries. Contributing factors include suboptimal HPV vaccination coverage, insufficient Pap smear screening, and regional variability in treatment options. In contrast, developed nations benefit from widespread HPV vaccination and robust screening programs, leading to lower cervical cancer rates and improved patient outcomes. The report underscores the need for strengthening prevention strategies in India by increasing HPV vaccination rates and expanding access to screening and treatment. Addressing these deficiencies is essential for reducing the burden of cervical cancer and enhancing patient outcomes in India.

KEYWORDS

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Global health;
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Introduction

Cervical cancer represents a significant public health issue globally, with a particularly high prevalence in and middle-income countries. This project report aims to examine and compare the incidence, risk factors, screening methods, and treatment outcomes of cervical cancer in the Indian population versus those in developed countries [1]. Cervical cancer ranks as the fourth most common cancer among women worldwide. However, its impact is disproportionately severe in developing countries such as India. In these regions, the burden of the disease is notably high, highlighting a critical need for effective public health interventions and improved healthcare access [2].

In India, cervical cancer remains a major concern due to a combination of factors, including limited access to preventive care, lower rates of screening, and various socio-economic barriers. The incidence of cervical cancer in India is significantly higher compared to that in developed nations, where robust screening programs and advanced treatment options are more readily available [3]. Developed countries benefit from comprehensive screening programs, such as regular Pap smears and HPV testing, which have been effective in early detection and prevention of cervical cancer. These countries also have greater access to advanced treatment modalities, contributing to better outcomes and survival rates. In contrast, the lack of widespread screening and preventive measures in India results in higher rates of advanced-stage cervical cancer and poorer treatment outcomes [4].

By comparing these aspects between India and developed countries, this report aims to highlight the disparities and propose strategies to enhance cervical cancer control and prevention, particularly in resource-limited settings

Objectives

This report aims to provide a comprehensive analysis of cervical cancer, focusing on the differences in incidence rates between Indian and foreign populations. Cervical cancer is a significant health issue worldwide, and understanding the variations between different regions can inform more effective prevention and treatment strategies [5]. Firstly, the incidence of cervical cancer in India is notably higher compared to that in developed countries. This discrepancy can be attributed to various factors, including differences in healthcare infrastructure, access to preventive services, and socioeconomic conditions. In India, the higher incidence rate highlights the urgent need for targeted public health interventions and improved healthcare access [6].

Key risk factors influencing cervical cancer rates include human papillomavirus (HPV) infection, sexual behavior, and socioeconomic status. In both Indian and foreign populations, HPV is a primary risk factor for cervical cancer. However, variations in sexual practices, healthcare access, and public awareness contribute to differences in cervical cancer rates. For example, in developed countries, widespread HPV

vaccination programs and regular screenings have significantly reduced the incidence of cervical cancer. In contrast, such measures are less prevalent in India, leading to higher cancer rates [7]. Screening methods for cervical cancer differ significantly between India and developed countries. Developed nations typically employ comprehensive screening programs, including Pap smears and HPV testing, which enable early detection and intervention. These screenings are often coupled with follow-up care and treatment, resulting in better outcomes. In India, screening practices are less widespread, and many women lack access to these crucial services. This gap in screening contributes to the higher incidence of advanced-stage cervical cancer and poorer treatment outcomes [8].

The treatment outcomes and survival rates for cervical cancer also vary between the two populations. In developed countries, advanced treatment options, including surgery, radiation, and chemotherapy, are more readily available, leading to improved survival rates. Conversely, in India, access to these treatments can be limited, resulting in lower survival rates and poorer overall outcomes [9]. To address these disparities, it is essential to suggest strategies for improving cervical cancer prevention and treatment in India. Enhancing public awareness, increasing access to screening and vaccination programs, and strengthening healthcare infrastructure are critical steps toward reducing the burden of cervical cancer.

Additionally, this report will explore the role of epigenetic changes in cervical carcinogenesis. Epigenetic mechanisms, such as DNA methylation, histone modifications, and non-coding RNAs, play a crucial role in the dysregulation of tumor suppressor genes. Understanding these mechanisms can provide insights into the molecular basis of cervical cancer and aid in identifying novel biomarkers and therapeutic targets. This knowledge can potentially improve cervical cancer prevention, early detection, and treatment by targeting the underlying genetic and epigenetic changes associated with the disease [10].

In summary, this report seeks to analyze the differences in cervical cancer incidence between Indian and foreign populations, identify key risk factors, compare screening methods, evaluate treatment outcomes, and suggest strategies for improvement. By elucidating the role of epigenetic changes in cervical carcinogenesis, the report aims to contribute to the development of more effective prevention and treatment strategies for cervical cancer.

Global Overview

Cervical cancer is the fourth most prevalent cancer among women worldwide. The primary cause of cervical cancer is Human Papillomavirus (HPV) infection. Effective screening and vaccination programs have played a crucial role in significantly lowering the incidence of cervical cancer in developed countries.

This type of cancer originates in the cervix, the lower segment of the uterus that connects to the vagina. It remains one of the most common cancers affecting women globally. In 2020, there were approximately 604,000 new cases of cervical cancer and 342,000 deaths worldwide. These statistics underscore the continuing challenge posed by cervical cancer, particularly in regions where access to preventive measures such as HPV vaccination and regular screening is limited. The global efforts to combat cervical cancer are pivotal in reducing these numbers

and improving outcomes for women around the world [11].

Causes of CC

The primary cause of cervical cancer is infection with the human papillomavirus (HPV), a virus transmitted through sexual contact. Among the various strains of HPV, certain high-risk types, particularly HPV-16 and HPV-18, are known to cause precancerous changes in cervical cells. If these changes are not detected and treated, they can progress to cervical cancer over time [12].

In addition to HPV infection, several other risk factors contribute to the development of cervical cancer:

Early onset of sexual activity

Engaging in sexual activity at a young age increases the risk of HPV infection, as the cervix is more susceptible to the virus in adolescents and young adults.

Multiple sexual partners

Having multiple sexual partners raises the likelihood of exposure to HPV and other sexually transmitted infections, which can contribute to the development of cervical cancer.

Smoking

Tobacco use has been linked to an increased risk of cervical cancer. Chemicals in cigarettes can cause changes in cervical cells and weaken the immune system's ability to combat HPV infections.

Weakened immune system

A compromised immune system, whether due to conditions such as HIV/AIDS or immunosuppressive treatments, can reduce the body's ability to clear HPV infections, leading to a higher risk of developing cervical cancer.

Long-term use of oral contraceptives

Extended use of oral contraceptives has been associated with an increased risk of cervical cancer. The exact mechanism is not fully understood, but hormonal changes may influence the susceptibility of cervical cells to HPV-related damage [13].

Understanding these risk factors is crucial for the prevention and early detection of cervical cancer. Addressing them through targeted public health strategies and personal health measures can help reduce the incidence of this disease and improve outcomes for women globally.

Prevention and treatment of cervical cancer

Cervical cancer prevention primarily hinges on regular screening and vaccination against Human Papillomavirus (HPV). The most effective preventive measures include routine screening tests and HPV vaccination. Screening tests, such as the Pap test and HPV test, are crucial as they can identify precancerous changes in the cervix, facilitating early intervention and treatment [14].

Primary screening modalities

HPV DNA Testing

HPV DNA testing has emerged as a recommended primary screening method for cervical cancer in average-risk individuals. This test identifies the presence of HPV DNA in cervical cells, allowing for early detection of the virus and associated precancerous changes.

Cytology (Pap Test)

The Pap test, or cytology-based screening, has traditionally been the primary method for detecting cervical cancer. It involves examining cervical cells under a microscope to identify abnormal changes. While effective, it is now frequently used in combination with HPV testing to enhance screening accuracy.

Co-testing

Co-testing, which includes both cytology and HPV testing, is recommended as a screening strategy, particularly for high-risk populations. This dual approach improves the detection of cervical abnormalities and is useful in providing comprehensive screening results [15].

Advantages of primary HPV screening

HPV testing offers several benefits over traditional cytology-based methods. It can detect precancerous changes earlier, allowing for timely intervention. Additionally, primary HPV screening generally reduces the total number of screening tests required and addresses inequities in screening and follow-up care. It provides equally accurate disease detection with fewer tests compared to cytology alone, streamlining the screening process [16].

Considerations

Current primary HPV screening involves a speculum examination, but future advancements may include FDA approval for vaginal self-sampling, which could enhance accessibility. However, there are concerns that HPV-negative neoplasms might be missed with primary HPV screening, necessitating continued research to address these potential gaps. The evolving impact of HPV vaccination on cervical cancer incidence must also be monitored as vaccination rates increase [17].

Treatment of cervical cancer

The treatment approach for cervical cancer depends on the disease's stage and the patient's overall health. Common treatment options include:

Surgery

Surgical procedures such as cone biopsy, hysterectomy, or radical hysterectomy are performed to remove cancerous tissue. In early-stage cases, surgery may aim to preserve fertility, whereas in more advanced stages, it focuses on controlling the disease.

Radiation Therapy

Radiation therapy can be administered as external beam radiation or internal radiation (brachytherapy) to target and destroy cancer cells. This treatment is often used in conjunction with other therapies to enhance its effectiveness.

Chemotherapy

Chemotherapy involves the use of drugs to kill rapidly dividing cancer cells. It is frequently employed in more advanced stages of cervical cancer to manage the disease and improve patient outcomes.

Targeted Therapy

Targeted therapy includes newer medications that focus on specific molecular pathways in cancer cells. This approach is

sometimes used in cases where traditional treatments are less effective [18].

In early-stage cervical cancer, the treatment strategy often emphasizes preserving fertility, while in more advanced stages, the primary goal shifts to controlling the disease and enhancing the patient's quality of life.

In summary, preventing cervical cancer through effective screening and vaccination is crucial. HPV DNA testing, cytology (Pap test), and co-testing are primary screening modalities, each with distinct advantages. HPV testing provides early detection and reduces the number of required screenings. Treatment options, including surgery, radiation, chemotherapy, and targeted therapy, are tailored to the disease stage and patient health, aiming to manage the disease and improve overall outcomes [19]. Cervical Cancer in India: India accounts for nearly one-third of global cervical cancer deaths. Socioeconomic factors, limited access to healthcare, and lack of awareness contribute to the high incidence and mortality rates.

Cervical Cancer in Developed Countries Developed countries have seen a decline in cervical cancer incidence and mortality due to organized screening programs and widespread HPV vaccination. Early detection and advanced treatment options have improved survival rates (Figure 1).

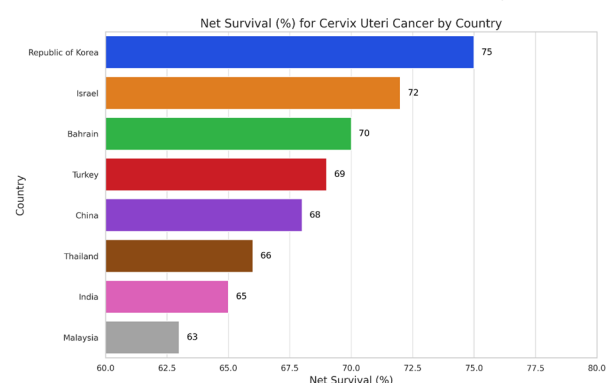


Figure 1. Net Survival% for cervical cancer by country (Data collected from WHO- SURVCAN).

Methodology

The methodology for this study on cervical cancer involves a multi-step approach to data collection, analysis, and presentation. The first step, Data Collection, includes a comprehensive Literature Review to gather information from scientific journals, healthcare reports, and government publications. This is complemented by Database Extraction, where data is sourced from major databases like GLOBOCAN, NCRP, and CDC [20].

To gain insights into public awareness, screening, and treatment practices, the study utilizes Surveys and Questionnaires. Additionally, Government and NGO Reports from organizations such as WHO, UNICEF, and local NGOs are analyzed to understand broader trends and policies affecting cervical cancer rates.

Data Analysis is conducted through several methods. Descriptive Statistics are used to summarize the incidence and mortality rates of cervical cancer. Comparative Analysis

involves statistical tests to compare data between India and high-income countries, highlighting disparities and similarities. Trend Analysis examines the changes in cervical cancer rates over time, providing insights into the effectiveness of interventions. Furthermore, Thematic Analysis is employed to identify recurring themes from qualitative data, offering a deeper understanding of the contextual factors influencing cervical cancer prevalence and treatment [21].

Finally, the Presentation of results is done using Graphs and Charts to visually represent data comparisons, and Tables to succinctly summarize key data points, making the findings accessible and comprehensible.

Epigenetic modifications and biomarkers in cervical cancer

Epigenetic modifications are crucial in the development and progression of cervical cancer. Aberrant DNA methylation is a common epigenetic change in cervical cancer, leading to the silencing of tumor suppressor genes. Key genes such as MRV1 and NTRK3 are often inactivated by DNA methylation in this context. Additionally, histone modifications, including acetylation and methylation, contribute to the dysregulation of gene expression patterns and cervical carcinogenesis. For example, histone acetylation is vital for the development of cervical cancer. Noncoding RNAs, such as miRNAs, lnc RNAs, and circ RNAs, are also epigenetically dysregulated in cervical cancer, impacting the expression of tumor suppressor genes and oncogenes. These epigenetic changes occur in both the cellular genome and the viral HPV genome, leading to the activation of viral oncogenes and the inactivation of cellular tumor suppressor genes [22].

Biomarkers for cervical cancer

Biomarkers are essential tools for detecting, monitoring or predicting disease development. In India, several promising biomarkers for cervical cancer have been identified. HPV DNA testing is widely used, with studies showing a high prevalence of HPV16 in Chennai and a lower prevalence in Jammu and Kashmir. Another promising biomarker is HPV E6/E7 mRNA testing, which indicates the persistence of oncogenic HPV by upregulating the expression of HPV E6/E7 genes. This method is particularly useful for screening and triaging HPV DNA-positive women. Epigenetic biomarkers, including aberrant DNA methylation patterns of genes such as MRV1 and NTRK3, have also shown potential for detecting cervical cancer and precancerous lesions in Indian women. Additionally, alterations in tumor suppressor genes like TP53, PTEN, and PML are common features of cervical cancer pathogenesis in India [23].

In foreign populations, similar biomarkers are employed, with HPV DNA testing being a standard practice worldwide. HPV E6/E7 mRNA testing and epigenetic biomarkers, such as methylation patterns in genes like CADM, EPB41L3, DAPK, and APC, are also used to detect cervical cancer. Dysregulation of tumor suppressor genes like RB1, EP300, and FBXW7 through genetic and epigenetic mechanisms is frequently observed in these populations. These biomarkers provide valuable insights into the molecular mechanisms underlying cervical cancer, aiding in early detection and treatment strategies across different regions [24].

Results

Cervical cancer rates in India are considerably higher than in many other countries, with the condition affecting a larger portion of the female population. India also faces a much higher mortality rate from cervical cancer, resulting in a significant number of deaths each year. The low coverage of HPV vaccination and limited use of Pap smear screenings contribute to these outcomes in India. In contrast, other countries have implemented more widespread HPV vaccination programs, which are often given to young girls and, in some places, boys. These countries also have established routine cervical screening practices, which help in early detection and prevention [25].

Treatment options in India vary greatly depending on the region and the specific healthcare facility, which can limit the quality of care received. On the other hand, many foreign countries offer more comprehensive and advanced treatment options, contributing to better outcomes for patients. The disparity in survival rates highlights the need for India to enhance its prevention strategies, increase vaccination coverage, and improve access to consistent and effective screening and treatment protocols. Addressing these issues could significantly reduce the impact of cervical cancer on the population [26].

Discussions

Cervical cancer presents significant public health challenges in India, with higher incidence and mortality rates compared to other regions. The burden of the disease remains substantial due to lower coverage of HPV vaccination, approximately 22%, and the limited implementation of Pap smear screenings. These factors contribute to the continued high mortality, with approximately 60,000 deaths annually in India. In contrast, countries with effective HPV vaccination programs and widespread cervical screening practices have seen a decline in cervical cancer rates [27].

The discussion on epigenetic modifications highlights their critical role in the progression of cervical cancer. Aberrant DNA methylation, histone modifications, and the involvement of noncoding RNAs are significant in silencing tumor suppressor genes and activating oncogenes, driving cancer development. The importance of biomarkers like HPV DNA testing and HPV E6/E7 mRNA testing is emphasized for early detection and treatment. These tools are crucial in identifying both cervical cancer and precancerous lesions, though their implementation in India is limited, particularly in rural areas [28].

A comparative analysis with high-income countries reveals stark differences in the adoption and accessibility of preventive measures. While HPV DNA testing is a standard practice in many countries, its application in India is inconsistent. The variability in access to these crucial diagnostic tools highlights the need for a more robust and systematic approach to cervical cancer prevention and early detection in India.

Conclusions

Cervical cancer remains a critical public health concern in India, with incidence and mortality rates significantly higher than in many other countries. The limited coverage of HPV

vaccination, at around 22%, and inadequate implementation of Pap smear screenings are key factors contributing to the high burden of this disease. These gaps in preventive measures have led to approximately 60,000 cervical cancer-related deaths annually, highlighting the urgent need for improved healthcare strategies.

In contrast, countries with comprehensive HPV vaccination programs and routine cervical screening have achieved substantial reductions in cervical cancer incidence and mortality. The effective deployment of these preventive measures has not only decreased the disease burden but has also improved overall survival rates. This comparison underscores the importance of strengthening India's healthcare infrastructure to provide more consistent and widespread access to vaccinations and screenings.

Moreover, the role of epigenetic modifications, such as DNA methylation and histone changes, in the progression of cervical cancer points to the need for advanced diagnostic tools like HPV DNA and HPV E6/E7 mRNA testing. Despite their proven effectiveness in early detection, these technologies are underutilized in India, especially in rural areas. Addressing these disparities by integrating advanced diagnostic methods into routine practice and enhancing public health campaigns for vaccination and screening could significantly reduce the impact of cervical cancer in India, ultimately leading to better outcomes and decreased mortality.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Vu M, Yu J, Awolude OA, Chuang L. Cervical cancer worldwide. *CPC*. 2018;42(5):457-465. <https://doi.org/10.1016/j.currprobcancer.2018.06.003>
2. Cecilia NC, Rosliza AM, Suriani I. Global burden of cervical cancer: a literature review. *Int J Public Health Clin Sci*. 2017;4(2):10-18.
3. Kaur S, Sharma LM, Mishra V, Goyal MG, Swasti S, Talele A, et al. Challenges in cervical cancer prevention: real-world scenario in India. *South Asian J. Cancer*. 2023;12(01):009-16. <https://doi.org/10.1055/s-0043-1764222>
4. Senapathy JG, Umadevi P, Kannika PS. The present scenario of cervical cancer control and HPV epidemiology in India: an outline. *Asian Pac J Cancer Prev*. 2011;12(5):1107-1115.
5. Buskwofie A, David-West G, Clare CA. A review of cervical cancer: incidence and disparities. *J Natl Med Assoc*. 2020;112(2):229-232. <https://doi.org/10.1016/j.jnma.2020.03.002>
6. Krishnan S, Madsen E, Porterfield D, Varghese B. Advancing cervical cancer prevention in India: implementation science priorities. *Oncologist*. 2013;18(S2):13-25. <https://doi.org/10.1634/theoncologist.18-S2-13>
7. Sreedevi A, Javed R, Dinesh A. Epidemiology of cervical cancer with special focus on India. *Int J Womens Health*. 2015:405-414. <https://doi.org/10.2147/ijwh.s50001>
8. Saxena U, Sauvaget C, Sankaranarayanan R. Evidence-based screening, early diagnosis and treatment strategy of cervical cancer for national policy in low-resource countries: example of India. *Asian Pac J Cancer Prev*. 2012;13(4):1699-1703. <http://dx.doi.org/10.7314/APJCP.2012.13.4.1699>
9. Alimena S, Pachigolla SL, Feldman S, Yang D, Orio PF, Lee L, et al. Race-and age-related disparities in cervical cancer mortality. *J Natl Compr Canc Netw*. 2021;19(7):789-795. <https://doi.org/10.6004/jnccn.2020.7665>
10. Fang J, Zhang H, Jin S. Epigenetics and cervical cancer: from pathogenesis to therapy. *Tumour Biol*. 2014;35(6):5083-5093. <https://doi.org/10.1007/s13277-014-1737-z>
11. Rauf L, Eid A, Hamed E. A global perspective on cervical cancer screening: a literature review. *Int J Community Med Public Health*. 2023;10(5):1. <https://dx.doi.org/10.18203/2394-6040.ijcmph20231044>
12. Barukčić I. Human Papillomavirus—The Cause of Human Cervical Cancer. *J Biosci Med*. 2018;6(4):106-125. <https://doi.org/10.4236/jbm.2018.64009>
13. Chelimo C, Woules TA, Cameron LD, Elwood JM. Risk factors for and prevention of human papillomaviruses (HPV), genital warts and cervical cancer. *J Infect*. 2013;66(3):207-217. <https://doi.org/10.1016/j.jinf.2012.10.024>
14. Aggarwal P. Cervical cancer: can it be prevented? *World J Clin Oncol*. 2014;5(4):775. <https://doi.org/10.5306%2Fwjco.v5.i4.77>
15. Bedell SL, Goldstein LS, Goldstein AR, Goldstein AT. Cervical cancer screening: past, present, and future. *Sex Med Rev*. 2020;8(1):28-37. <https://doi.org/10.1016/j.sxmr.2019.09.005>
16. Kiguradze E, Gogoladze T, Alibegashvili T. Primary HPV testing as an alternative strategy for cervical cancer screening. *Experimental and Clinical Medicine Georgia*. 2023;(3). <https://doi.org/10.52340/jecm.2023.03.05>
17. Sekar PK, Thomas SM, Veerabathiran R. The future of cervical cancer prevention: advances in research and technology. *Explor Med*. 2024;5(3):384-400. <https://doi.org/10.37349/emed.2024.00226>
18. PC Yee G, de Souza P, M Khachigian L. Current and potential treatments for cervical cancer. *Curr. Cancer Drug Targets*. 2013; 13(2):205-220. <https://doi.org/10.2174/1568009611313020009>
19. Elfström KM, Herweijer E, Sundström K, Arnheim-Dahlström L. Current cervical cancer prevention strategies including cervical screening and prophylactic human papillomavirus vaccination: a review. *Curr Opin Oncol*. 2014;26(1):120-129. <https://doi.org/10.1097/CCO.0000000000000034>
20. Momenimovahed Z, Salehiniya H. Incidence, mortality and risk factors of cervical cancer in the world. *Biomed Res Ther*. 2017;4(12):1795-1811. <https://doi.org/10.15419/bmrat.v4i12.386>
21. Vaccarella S, Lortet-Tieulent J, Plummer M, Franceschi S, Bray F. Worldwide trends in cervical cancer incidence: impact of screening against changes in disease risk factors. *Eur J Cancer*. 2013;49(15):3262-3273. <https://doi.org/10.1016/j.ejca.2013.04.024>
22. Liu H, Ma H, Li Y, Zhao H. Advances in epigenetic modifications and cervical cancer research. *BBA Reviews on Cancer*. 2023; 1878(3):188894. <https://doi.org/10.1016/j.bbcan.2023.188894>
23. Litjens RJ, Hopman AH, van de Vijver KK, Ramaekers FC, Kruitwagen RF, Kruse AJ. Molecular biomarkers in cervical cancer diagnosis: a critical appraisal. *Expert Opin Med Diagn*. 2013;7(4):365-377. <https://doi.org/10.1517/17530059.2013.808621>
24. Iida M, Banno K, Yanokura M, Nakamura K, Adachi M, Nogami Y, et al. Candidate biomarkers for cervical cancer treatment: Potential for clinical practice. *Mol Clin Oncol*. 2014;2(5):647-655. <https://doi.org/10.3892/mco.2014.324>
25. Mehrotra R, Hariprasad R, Rajaraman P, Mahajan V, Grover R, Kaur P, et al. Stemming the wave of cervical cancer: human papillomavirus vaccine introduction in India. *J Glob Oncol*. 2018;4. <https://doi.org/10.1200%2FJGO.17.00030>
26. Mishra GA, Pimple SA, Shastri SS. Prevention of cervix cancer in India. *Oncology*. 2016;91(1):1-7. <https://doi.org/10.1159/000447575>
27. Krishnan S, Madsen E, Porterfield D, Varghese B. Advancing cervical cancer prevention in India: insights from research and programs. *The World Bank*; 2013.
28. Ojha PS, Maste MM, Tubachi S, Patil VS. Human papillomavirus and cervical cancer: An insight highlighting pathogenesis and targeting strategies. *Virus disease*. 2022;33(2):132-154. <https://doi.org/10.1007/s13337-022-00768-w>