Assessment of the cost-effectiveness of the cervical cancer screening program

Avaliação da custo-efetividade do programa de rastreamento do câncer de colo do útero

Evaluación de la rentabilidad del programa de detección del cáncer de cuello uterino

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ABSTRACT

Objective: To evaluate the cost-effectiveness of cervical cancer screening in Brazil, based on aggregated data from the Cancer Information System between 2014 and 2023. **Methodology:** Economic, descriptive and analytical study, using Markov modeling. Direct costs by health status and quality-adjusted life years (QALYs) were estimated, considering the real distribution of cytopathological results recorded in the period. **Results:** 9,466,798 cytopathological tests were analyzed, of which 94.82% presented normal results. The total accumulated cost was BRL 254,979,093.58, generating 9,328,017 QALYs. The average cost per QALY was BRL 27.33, indicating high economic efficiency of screening, even if carried out opportunistically. **Conclusion:** The results show that cervical cancer screening in Brazil is a highly cost-effective strategy. Despite operational limitations and regional inequalities, the current program has great potential to generate health benefits at low cost, reinforcing the importance of strengthening preventive public policies.

DESCRIPTORS:
Economic Assessment in Health; Cost-Effectiveness Analysis; Mass Screening; Women's Health Services; Uterine Cervical Neoplasms.

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RESUMO

Objetivo: Avaliar a custo-efetividade do rastreamento do câncer de colo do útero no Brasil, com base em dados agregados do Sistema de Informação do Câncer entre 2014 e 2023. **Metodologia**: Estudo econômico, descritivo e analítico, com uso de modelagem de Markov. Foram estimados os custos diretos por estado de saúde e os anos de vida ajustados por qualidade (*quality-adjusted life years,* QALYs), considerando a distribuição real dos resultados citopatológicos registrados no período. **Resultados**: Foram analisados 9.466.798 exames citopatológicos, dos quais 94,82% apresentaram resultados normais. O custo total acumulado foi de BRL 254.979.093,58, com geração de 9.328.017 QALYs. O custo médio por QALY foi de BRL 27,33, indicando elevada eficiência econômica do rastreamento, mesmo realizado de forma oportunística. **Conclusão**: Os resultados evidenciam que o rastreamento do câncer de colo do útero no Brasil é uma estratégia altamente custo-efetiva. Apesar de limitações operacionais e desigualdades regionais, o programa atual apresenta grande potencial para gerar benefícios em saúde a baixo custo, reforçando a importância do fortalecimento das políticas públicas preventivas.

DESCRITORES:
Avaliação Econômica em Saúde; Avaliação de Custo-Efetividade; Programas de Rastreamento; Serviços de Saúde da Mulher; Neoplasias do Colo do Útero.

RESUMEN

Objetivo: Evaluar la rentabilidad del tamizaje del cáncer de cuello uterino en Brasil, a partir de datos agregados del Sistema de Información sobre el Cáncer entre 2014 y 2023. **Metodología:** Estudio económico, descriptivo y analítico, utilizando modelos de Markov. Se estimaron los costos directos por estado de salud y años de vida ajustados por calidad (AVAC), considerando la distribución real de los resultados citopatológicos registrados en el período. **Resultados:** Se analizaron 9.466.798 pruebas citopatológicas, de las cuales el 94,82% presentó resultados normales. El costo total acumulado fue de BRL 254.979.093,58, generando 9.328.017 AVAC. El costo promedio por AVAC fue de BRL 27,33, lo que indica una alta eficiencia económica del tamizaje, incluso si se realiza de manera oportunista. **Conclusión:** Los resultados muestran que el tamizaje del cáncer de cuello uterino en Brasil es una estrategia altamente costo-efectiva. A pesar de las limitaciones operativas y las desigualdades regionales, el programa actual tiene un gran potencial para generar beneficios de salud a bajo costo, lo que refuerza la importancia de fortalecer las políticas públicas preventivas.

DESCRIPTORES:
Evaluación Económica en Salud; Análisis de Costo-Efectividad; Tamizaje Masivo; Servicios de Salud para Mujeres; Neoplasias del Cuello Uterino.

INTRODUCTION

Cervical cancer is considered a preventable and treatable condition, especially when identified in early stages through organized screening strategies. However, it remains one of the main causes of cancer death among women of reproductive age in several Latin American countries, including Brazil[1]. It is estimated that persistent infection by high-risk oncogenic human papillomavirus (HPV) is responsible for more than 95% of diagnosed cases[2].

Regular cytopathological Papanicolaou examination constitutes the main measure adopted in Brazil for detecting precursor lesions of cervical neoplasia. However, the current screening model presents significant operational challenges: low adherence of the target population, concentration of examinations outside the recommended age range, and failures in the follow-up of altered cases[3]. These

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problems compromise the effectiveness and efficiency of the program, especially among women in situations of greater socioeconomic vulnerability.

Health economic analysis has been increasingly used as a tool to support public policy formulation, allowing evaluation of whether an intervention represents rational use of available resources[4]. Among the most widely used methods, cost-effectiveness analysis stands out, which calculates the ratio between the direct costs of a strategy and its effectiveness, usually expressed in Quality Adjusted Life Years (QALYs) or life years gained[5].

In Brazil, few studies apply cost-effectiveness analyses based on real data from the Unified Health System (SUS), especially in the field of cancer prevention. Previous studies suggest that preventive programs are generally more cost-effective than curative approaches, although they present implementation challenges[6].

Therefore, this study aims to estimate the cost-effectiveness of cervical cancer screening in Brazil, based on real aggregated data from women examined between 2014 and 2023. Using a Markov model, total costs by health state and quality-adjusted life years (QALYs) were estimated.

OBJECTIVE

To evaluate the cost-effectiveness of cervical cancer screening in Brazil, based on real aggregated data from women examined between 2014 and 2023. Using a Markov model, total costs by health state and quality-adjusted life years were estimated, allowing calculation of the average cost per QALY generated in the current screening scenario.

METHODOLOGY

This is an economic, descriptive and analytical study, focusing on cost-effectiveness evaluation. Cost-effectiveness analysis (CEA) is an economic evaluation that compares the costs and outcomes of health programs, constituting an instrument to measure consequences in relation to employed resources[7].

The formulation of the guiding question was based on the PCC mnemonic, used to structure descriptive research, according to the Joanna Briggs Institute (2010)[8]. P- Women aged 25 to 64 years served by the SUS in Brazil (screening target audience); C- Cost-effectiveness evaluation based on QALYs (health economic analysis); C- Cervical cancer screening in the real Brazilian scenario, between 2014 and 2023. From this, the following guiding question was obtained: "What is the effectiveness, measured in QALYs, and the accumulated cost of cervical cancer screening practiced in Brazil, according to national secondary data between 2014 and 2023?".

The model considered exclusively the real screening scenario, characterized by low coverage, opportunistic performance and diagnosis at various stages[9]. The costs involved in performing the

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cytopathological examination include expenses with materials such as glass slides and working time for clinical laboratory diagnosticians[10].

The adopted time horizon was ten years (2014 to 2023) to ensure the robustness of results, from the perspective of the unified health system. Considering direct costs, the Management System of the SUS Procedures, Medications and OPM Table (SIGTAP) was used, and to analyze mortality and altered examination results for low-grade intraepithelial lesion, high-grade intraepithelial lesion, and carcinoma and adenocarcinoma, the Mortality Information System and the Cancer Information System were used, respectively.

It is worth noting that these are the number of examinations performed, and it is not possible to identify unique women, given the aggregated nature of the database. However, inclusion criteria include examinations from women in the screening age range - 25 to 64 years - residing throughout Brazilian national territory who underwent cytopathological examinations through the Unified Health System. Alternatively, those already transferred to Oncological Reference Units for palliative care or in treatment were excluded.

The direct cost analysis considered average values by health state, based on procedures recommended by the Ministry of Health and records from the SUS Table (SIGTAP). Included were the costs of performing cytopathological examination, colposcopy, biopsy, surgical procedures (such as conization) and cancer treatment (surgery, radiotherapy and chemotherapy). The total accumulated cost was obtained by multiplying the number of women in each state by the corresponding annual average cost.

Although classical economic evaluation involves comparing scenarios with calculation of the incremental cost-effectiveness ratio (ICER), in this study the analysis was based solely on the current screening scenario in Brazil, with the objective of estimating the cost-effective performance per QALY generated - a metric that expresses the efficiency of the current program in terms of benefit per invested resource.

This study followed the guidelines of the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) methodological framework to ensure standardization and transparency in presenting health economic evaluation[11].

Modeling was performed using Microsoft Excel® software, with a simplified structure based on Markov states: "Healthy", "Low-grade lesion", "High-grade lesion", "Cancer" and "Death". Markov modeling is an analytical tool that uses a mathematical system to calculate transition probabilities between states. It is used in various areas, including health[12]. The progression between states, although theoretical, was represented according to the actual distribution observed in national data.

Effectiveness was estimated in terms of QALYs, based on the actual distribution of

cytopathological results recorded in the period. Each health state was associated with a utility weight (QALY), according to international literature[13], being: 1.0 for healthy women, 0.8 for low-grade lesion, 0.6 for high-grade lesion and 0.4 for cancer. Multiplying the number of women in each clinical state by the respective weight allowed calculation of the total accumulated QALYs generated by screening. The total accumulated cost was obtained by multiplying the number of women in each state by the corresponding annual average cost.

Finally, the cost per QALY was calculated, resulting from the ratio between the total estimated cost and the total number of QALYs generated in the period from 2014 to 2023. The analysis was performed using electronic spreadsheets in Microsoft Excel®, allowing data consolidation and generation of descriptive tables.

This study used exclusively aggregated secondary data, in the public domain, available in official information systems of the Ministry of Health, such as the Cancer Information System (SISCAN), the Mortality Information System (SIM) and the Management System of the SUS Procedures, Medications and OPM Table (SIGTAP). No identifiable individual information was accessed or analyzed. Therefore, in accordance with Resolution No. 510, of April 7, 2016, of the National Health Council[14], which provides for the standards applicable to research in Human and Social Sciences that use publicly accessible data and do not involve direct risk to participants, this study is exempt from submission to the Research Ethics Committee.

RESULTS

From the data collection performed in the Cancer Information System, a data matrix was obtained containing aggregated values of examinations within normality, examinations with results for low-grade lesion, high-grade lesion, and carcinoma and adenocarcinoma. 9,466,798 examinations were obtained, of which 94.82% were within normality, 3.13% represented low-grade lesion, 1.94% represented high-grade lesion, and 0.10% of examinations represented carcinoma/adenocarcinoma.

For the cost-effectiveness analysis, a transition matrix was created, representing the annual probabilities of change between health states according to the Markov economic model: Healthy, Low-grade intraepithelial lesion, High-grade lesion, Cervical cancer and death.

Chart 1. Health state transition matrix per year, between 2014 and 2023. Belém, Pará, Brazil, 2025.

Variables	Healthy	Low-grade intraepithelial lesion	High-grade lesion	Cervical cancer	Death
Healthy	0.936	0.035	0.022	0.001	0.005
Low-grade intraepithelial lesion	0.000	0.551	0.346	0.019	0.084
High-grade lesion	0.000	0.000	0.699	0.037	0.250
Cancer	0.000	0.000	0.000	0.186	0.814
Death	0.000	0.000	0.000	0.000	-

Source: Ministry of Health. Department of Informatics - SUS - DATASUS. Cancer Information System (SISCAN)[15]; Mortality Information System (SIM), 2025[16].

It was observed that most women remained in a healthy state (93.6%) throughout the following year. The progression predicted in the transition matrix from healthy state to low-grade intraepithelial lesion was 3.5%, and to high-grade lesion, 2.2%. Direct transition to cancer was rare (0.1%). Among women with low-grade lesion, progression to high-grade intraepithelial lesion was observed at 34.6% and to cancer at 1.9%. The persistence rate of low-grade lesion was 55.1%. Among those with high-grade lesion, 69.9% remained in the same state, 3.7% progressed to cancer and 25% died. Patients with cancer presented a progression rate to death of 81.4% and cancer persistence of 18.6%. No reverse transition (e.g., from cancer to previous states) was considered in the model, assuming unidirectional disease evolution.

Based on the percentage distribution of cytopathological examinations performed between 2014 and 2023 and the estimated average costs by health state, it was possible to calculate the total accumulated cost of cervical cancer screening in Brazil over the analyzed period.

The frequency of procedures considered in the model was based on national guidelines and usual clinical practices. The cytopathological examination (Papanicolaou) was assumed to be annual, in accordance with the National Cancer Institute's recommendation[17] for the first two examinations and considering the predominant opportunistic performance in areas of high vulnerability. In cases of low-grade intraepithelial lesion, an annual frequency of colposcopy and biopsy was adopted, according to follow-up protocols. For high-grade lesions, conization and anatomopathological examination were considered to be performed in the same year as diagnosis. For the clinical state of cancer, average annual costs were aggregated based on usual treatments offered by SUS, including surgery, chemotherapy and

radiotherapy[18-19]. Thus, the model contemplates the relevant direct costs of each health state over an annual cycle.

Chart 2. Estimate of total costs based on the number of women and average annual cost by health state. Belém, Pará, Brazil, 2025.

Health Status	Number of women	Average annual costs	Estimated total cost
Healthy	8,976,503	BRL 13,72	BRL 123.157.621,16
Low-grade intraepithelial lesion	296,581	BRL 17,10	BRL 5.071.535,10
High-grade intraepithelial lesion	183,815	BRL 83,31	BRL 15.313.627,65
Cancer	9,899	BRL 11.257,33	BRL 111.436.309,67
Total	-	-	BRL 254,979,093.58

Source: Ministry of Health. *DATASUS – Sistema de Gerenciamento da Tabela de Procedimentos, Medicamentos e OPM do SUS* (SIGTAP), 2025[20].

It is observed that, although the number of cancer cases represents only 0.10% of total examinations, oncological treatment represents a significant portion of total costs, estimated at about 43.7% of the predicted value of BRL 255 million. On the other hand, most of the accumulated costs (about 48.3%) refer to women with normal examination results, reflecting the costs of screening and routine monitoring, even in the absence of lesions.

The high-grade lesion condition also represented an important impact (BRL 15 million), since it involves procedures such as conization, colposcopy, frequent biopsies and specialized follow-up.

The effectiveness of screening was estimated through the calculation of QALYs, based on real data from cytopathological examinations performed between 2014 and 2023 (n = 9,466,798). The results were categorized according to possible clinical states, and each state was associated with a QALY. From the attribution of utility weights to each health state, it was possible to calculate the effective impact of screening on the health of the female population served, and by multiplying the number of women in each category by the respective weight, an estimated total of 9,328,017 QALYs was obtained, reflecting the effectiveness of screening performed in Brazil over the evaluated period.

The projected distribution of the cohort by health state and the respective Quality-Adjusted Life Years over ten annual follow-up cycles is highlighted. There was a progressive reduction in the proportion

of healthy individuals, accompanied by a gradual increase in states of low and high-grade intraepithelial lesion, as well as in cases of cervical cancer and death.

It is observed that the number of women in a healthy state progressively reduces over the cycles, while there is a gradual increase in states of low-grade intraepithelial lesion, high-grade lesion and cervical cancer, reflecting the natural progression of the disease in the absence of effective intervention. In parallel, the number of deaths grows steadily, indicating the accumulation of losses over time. These results illustrate the dynamics of transition between health states and the progressive impact of the disease on the cohort's total QALYs.

Based on previous estimates of total cost and effectiveness, it was possible to calculate the average cost per QALY generated by the cervical cancer screening program in Brazil, between 2014 and 2023. This indicator allows evaluation of the program's efficiency in transforming invested financial resources into health gains adjusted for quality of life.

Chart 3. Cost of quality-adjusted life years generated in Brazil between 2014 and 2023. Belém, Pará, Brazil, 2025.

Indicator	Estimated value
Total accumulated cost (BRL)	BRL 254.979.093,58
Accumulated QALYs	9,328,017
Cost per QALY (BRL/QALY)	BRL 27,33

Source: Own elaboration based on data from the Cancer Information System (SISCAN)[15] and the Management System of the SUS Procedures, Medications and OPM Table (SIGTAP) – DATASUS, 2025[20].

The total accumulated cost of screening, considering all health states and the respective average annual costs per woman, was BRL 254,979,093.58. At the same time, the program generated a total of 9,328,017 QALYs, as demonstrated in the previous subsection. The ratio between these two variables resulted in an average cost of BRL 27.33 per QALY.

DISCUSSION

The results found in this study demonstrate that cervical cancer screening, even when performed opportunistically and with partial coverage in Brazil, presents highly cost-effective performance. The average cost per QALY generated was BRL 27.33, a value significantly lower than the acceptability threshold recommended by the World Health Organization (WHO), which defines as cost-effective

interventions whose cost per QALY does not exceed three times the country's per capita Gross Domestic Product (GDP)[21]. Considering that the Brazilian per capita GDP in 2023 was approximately BRL 50,000.00, the value found in this study represents only 0.05 times this limit, which reinforces its economic viability.

The observed effectiveness, expressed in more than 9.3 million accumulated QALYs, is directly related to the high proportion of examinations with normal results (94.82%), demonstrating the potential of screening to preserve quality of life on a large scale, even when performed with operational limitations. However, even the states of low and high-grade intraepithelial lesion, which together represented about 5% of cases, contributed more than 347,000 QALYs, demonstrating the positive impact of early detection before progression to invasive cancer[17].

The cost analysis reinforces the following scenario: although cancer treatment represents the smallest proportion of women, it corresponds to one of the largest portions of total costs, given the complexity and high values associated with chemotherapy, radiotherapy and surgeries. Furthermore, it reinforces the thesis that early diagnosis of precursor lesions is much cheaper and more effective, both in clinical and financial terms[22]. It is also noteworthy that the absence of organized screening in Brazil has resulted in inefficiency in the use of SUS resources, with unnecessary repetition of examinations in women already assisted - often annually - without proven gain in clinical outcomes. This practice, known as over-screening, increases program costs, exposes patients to avoidable risks and compromises equity, while more vulnerable populations remain without access to early disease detection[23].

The comparison between average costs by health state corroborates this argument: while a healthy woman costs about BRL 20.00/year to the system, the cost of oncological treatment can exceed BRL 12,000.00 per patient, as demonstrated in previous budget impact analyses[24].

The Brazilian reality, however, is marked by a fragmented, opportunistic and unequal screening model, with large regional and socioeconomic disparities. According to researchers[25], the effective screening coverage in the North and Northeast regions is significantly lower than in the Southeast, a fact that contributes to the high incidence and mortality from cervical cancer in vulnerable populations, especially among Black, Indigenous, riverside women and those with low education. Furthermore, regional inequality in the supply of examinations and installed capacity for colposcopy and biopsy limits the program's potential impact on more vulnerable populations, such as those in the North Region[26].

Even with these limitations, the data analyzed here demonstrate that the Brazilian health system is capable of generating significant health gains for modest values when it maintains systematic screening actions. This finding is consistent with previous studies of economic evaluation in cervical cancer, which showed that screening programs have excellent cost-benefit even with partial coverage[27].

Another relevant point refers to potential under-reporting and follow-up losses, which may have

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limited the sensitivity of the data used in this study. Although the analysis used a solid database (SISCAN and SIM), the absence of individual clinical data and the Markov model based on aggregated data made it impossible to directly follow the progression of each case. Finally, it is emphasized that the cost-effectiveness observed in this study should be interpreted as a technical argument in favor of consolidating continuous, equitable and territorialized preventive public policies. In a scenario of budget restriction, investing in cervical cancer screening regularly can not only save lives but also avoid future expenses with costly treatments, expanding the social and economic return of SUS.

Study limitations

This study presents some limitations that should be considered in interpreting the results. First, the use of aggregated secondary data made individual longitudinal follow-up of women impossible, which limits the analysis of clinical transitions over time. Additionally, the Markov modeling employed adopted a simplified and unidirectional structure, without considering reverse transitions, such as lesion regression. Another point concerns the absence of differentiation between clinical stages of cancer and histological types, as well as the national standardization of costs, which may not reflect regional variations in expenses with procedures and treatments. The analysis also did not consider indirect costs (such as loss of productivity), which may underestimate the total economic impact of the disease and intervention.

It is recommended that future studies use clinical databases with individual and temporal data, allowing the development of more robust and personalized models. Furthermore, comparative evaluations between different screening models - opportunistic, organized or hybrid - can offer relevant support for public policy decisions. The incorporation of sensitivity analysis and scenarios is also desirable to expand the external validity of findings and adapt them to different regional and population contexts.

Contributions to nursing, health or public policy

The study contributes to consolidating evidence that supports the prioritization of preventive actions and reiterates the need to strengthen public policies aimed at expanding coverage, regularity and equity of screening, especially in vulnerable regions and populations.

CONCLUSION

This study demonstrated that cervical cancer screening in Brazil, as practiced in the real scenario between 2014 and 2023, presents a highly cost-effective relationship between invested resources and health gains for the female population. Based on the analysis of aggregated secondary data and Markov modeling, a total of 9,328,017 QALYs generated was estimated with a total accumulated cost of BRL 254.979.093,58, resulting in an average cost per QALY of only BRL 27,33.

These results reinforce the importance of screening as an effective and financially viable strategy for preventing and controlling cervical cancer, even when performed opportunistically. The high

effectiveness combined with low cost per unit of health generated demonstrates that investment in screening is a rational and sustainable alternative for SUS, especially in contexts of budget limitation.

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Editor-in-Chief: André Luiz Silva Alvim 🆔

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