COSTS RELATED TO BREAST CANCER IN SLOVAKIA: A LONG-TERM COST ANALYSIS FROM 2009 TO 2022

Náklady súvisiace s rakovinou prsníka na Slovensku: dlhodobá analýza nákladov od roku 2009 do 2022

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Abstract
Background: Breast cancer remains a significant public health concern in Slovakia, with increasing incidence and prevalence, particularly among younger women. The disease poses substantial challenges to the healthcare system, contributing to rising healthcare costs and productivity losses. This study aims to provide a comprehensive analysis of the burden of breast cancer in Slovakia from 2009 to 2022, focusing on direct and indirect healthcare costs, productivity losses, and the overall economic impact.
Methods: This study utilized a population-based approach, analyzing data from national healthcare databases, insurance claims, and public health records. Direct healthcare costs, including hospitalization, diagnostic procedures, and treatments, were assessed alongside indirect costs such as productivity losses due to paid sick leave and disability. The analysis also included the calculation of Years of Potential Life Lost (YPLL), Years of Potential Productive Life Lost (YPPLL), Years Lived with Disability (YLD), and Disability-Adjusted Life Years (DALY) to quantify the overall disease burden. Additionally, the Value of a Statistical Life Year (VSLY) was calculated by multiplying DALY by GDP per capita.
Results: The findings reveal a consistent increase in breast cancer-related healthcare costs in Slovakia from 2014 to 2022, with the total reimbursed care expenses nearly doubling. Productivity losses also showed a substantial rise, with the economic impact reached significant levels by 2021. The overall burden of disease, as measured by YPLL, YPPLL, YLD, and DALY, has also increased over the study period, reflecting both rising mortality and morbidity associated with breast cancer.
Conclusion: The growing burden of breast cancer in Slovakia underscores the need for enhanced public health strategies, including improved screening, early detection, and access to effective treatments. Addressing regional disparities and increasing public awareness are crucial steps in reducing the impact of breast cancer on the population. The study's findings provide a critical foundation for future policy-making and resource allocation to combat this significant public health challenge *(Tab. 6, Ref. 33). Text in PDF www.lekarskyobzor.sk.*
KEY WORDS: breast cancer, public health, screening, therapy, public health.

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Abstrakt
Východiská: Karcinóm prsníka zostáva na Slovensku významným problémom zdravotníctva, pričom jeho výskyt a prevalencia sa zvyšujú najmä u mladších žien. Toto ochorenie predstavuje pre systém zdravotnej starostlivosti značné výzvy, prispieva k zvyšovaniu nákladov na zdravotnú starostlivosť a k strate produktivity. Cieľom tejto štúdie je poskytnúť komplexnú analýzu záťaže rakoviny prsníka na Slovensku v rokoch 2009 až 2022 so zameraním na priame a nepriame náklady na zdravotnú starostlivosť, straty produktivity a celkový ekonomický vplyv.
Metódy: Táto štúdia využíva tzv. populačný prístup, pričom analyzuje údaje z národných databáz zdravotnej a sociálnej starostlivosti a dostupných verejných dát. Priame náklady na zdravotnú starostlivosť vrátane hospitalizácie, diagnostických postupov a liečby sa posudzovali spolu s nepriamymi nákladmi, ako sú straty produktivity v dôsledku platenej práceneschopnosti a invalidity. Analýza zahŕňala aj výpočet rokov potenciálne strateného života (YPLL), rokov potenciálne strateného produktívneho života (YPPLL), rokov prežitých so zdravotným postihnutím (YLD) a rokov života upravených o zdravotné postihnutie (DALY) s cieľom kvantifikovať celkové zaťaženie chorobou. Okrem toho sa vypočítala hodnota štatistického roka života (VSLY) vynásobením DALY HDP na obyvateľa.
Výsledky: Zistenia odhaľujú konzistentný nárast nákladov na zdravotnú starostlivosť súvisiacu s rakovinou prsníka na Slovensku v rokoch 2014 až 2022, pričom celkové výdavky na hradenú starostlivosť sa takmer zdvojnásobili. Výrazný nárast zaznamenali aj straty produktivity, pričom ekonomický dopady dosiahli do roku 2021 významnú úroveň. Celková záťaž ochorenia meraná pomocou YPLL, YPPLL, YLD a DALY sa počas skúmaného obdobia tiež zvýšila, čo odráža rastúcu úmrtnosť aj chorobnosť spojenú s rakovinou prsníka.
Záver: Rastúca záťaž rakoviny prsníka na Slovensku zdôrazňuje potrebu efektívnych stratégií v oblasti verejného zdravia vrátane zlepšeného skríningu, včasného odhalenia a prístupu k účinnej liečbe. Riešenie regionálnych rozdielov a zvyšovanie informovanosti verejnosti sú kľúčovými krokmi pri znižovaní dopadu rakoviny prsníka na populáciu. Zistenia štúdie poskytujú dôležitý základ pre budúcu tvorbu politiky a prideľovanie zdrojov na boj proti tejto významnej výzve pre verejné zdravie *(tab. 6, lit. 33). Text v PDF www.lekarskyobzor.sk.*
KĽÚČOVÉ SLOVÁ: rakovina prsníka, verejné zdravotníctvo, skríning, liečba, zdravie.
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Introduction

Breast cancer is a pressing public health concern in Slovakia, with its incidence and mortality rates posing significant challenges to the nation's healthcare system. According to global estimates, breast cancer is the leading cause of cancer deaths in females worldwide, claiming 181,004 lives and resulting in 17.7 million disability-adjusted life years (1). The burden of this disease is only expected to grow, with projections indicating that by 2040, the global burden of breast cancer will increase to over 3 million new cases and 1 million deaths annually due to population growth and aging alone (2).

While Slovakia has made strides in improving breast cancer survival rates, with the 5-year survival rate in premenopausal women estimated at 78.5%, the country still faces significant disparities in access to early detection and effective treatment, particularly in transitioning regions (2). The growing burden of breast cancer in Slovakia is a complex issue, driven by factors such as lack of comprehensive screening programs, delayed diagnosis, and limited access to new effective therapies. The impact of breast cancer on the Slovakian population is substantial, with the disease accounting for a significant proportion of cancer cases and deaths in women.

To address this challenge, a multifaceted approach is needed, involving investment in public health infrastructure, enhanced screening and early detection, improved public awareness and education about cancer prevention and the provision of accessible and affordable treatment options. Collaboration with global health initiatives and leveraging the resources and expertise of international organizations can play a vital role in mitigating the burden of breast cancer in Slovakia (3, 1, 4, 2). Preventive measures are particularly important in countries with the highest incidence of these diseases—among which Slovakia is included. In the context of promoting a healthy lifestyle, attention must be paid to diet (low-fat foods, adequate calcium and vitamins, proper hydration, probiotics), physical activity (at least regular walking), and overall healthy living (32). By prioritizing breast cancer as a national health priority and implementing evidence-based strategies, Slovakia can work towards improving outcomes and reducing the devastating impact of this disease on its population.

Epidemiology situation in Slovakia

According to the available data, breast cancer is the most commonly diagnosed cancer in women in Slovakia, accounting for a significant proportion of the overall cancer burden (1). In 2020, the global incidence of breast cancer was estimated at 2.3 million new cases, with the disease representing one in eight cancer diagnoses worldwide (2). The burden of breast cancer in Slovakia is further exacerbated by the rising incidence rates, particularly among premenopausal women. In the last 30 years, the incidence of breast cancer in this age group has almost doubled in the country, highlighting the pressing need for targeted interventions and early detection measures (5). Additionally, the prevalence of breast cancer in Slovakia is substantial, contributing to the overall healthcare costs and placing a significant strain on the nation's medical resources. The incidence and prevalence of breast cancer in Slovakia have been thoroughly analyzed in the provided document, revealing critical insights into the epidemiological trends and regional disparities. Breast cancer represents a significant public health concern, being the most commonly diagnosed malignancy among women in Slovakia, and its incidence has shown a rising trend over the years (5).

From the collected data, the age-standardized incidence rate (ASR-W) for breast cancer has demonstrated a consistent increase, particularly from 2017 onwards. The estimated number of new cases of breast cancer in Slovakia for 2021 was 3,355 for women and 53 for men. This increase can be attributed to various factors, including improved screening practices, demographic shifts, and possibly heightened exposure to known risk factors. Notably, there was a temporary decline in the reported incidence rates for 2013-2014, which may have resulted from changes in the reporting methods rather than an actual decrease in cases. This discrepancy highlights the challenges in maintaining consistent and reliable cancer registries (6). The highest incidence rates have been observed in Western Slovakia, with significant regional disparities noted. The incidence is also rising among younger women, particularly those aged 30 to 50 years, indicating a worrying trend of increasing cases in premenopausal women. Specifically, the incidence among women under 50 years has shown a marked increase, supporting the need to extend the age range for screening. This trend aligns with global observations and underscores the need for targeted prevention and early detection strategies (6).

Prevalence data, although not as comprehensively detailed in the document, suggest that the number of women living with breast cancer in Slovakia is substantial. In 2014, breast cancer accounted for 16.09% of all malignancies in Slovakia, with an absolute number of 2,686 new cases among women. The prevalence of breast cancer is influenced by factors such as the aging population, advancements in treatment leading to improved survival rates, and ongoing efforts in early detection and screening. The document further highlights significant regional differences in patient survival, which do not appear to be directly linked to the availability of diagnostic and therapeutic services. For instance, survival rates differ markedly between regions, despite similar access to healthcare facilities. This disparity might be attributed to the variability in patient pathways before treatment initiation and the uneven integration of new therapeutic recommendations into routine clinical practice. Enhancing participation in screening programs is identified as a key measure to improve early detection and subsequently reduce mortality rates. In the period from 2017 to 2022, a notable increase in screening participation was observed, yet regional inequalities persist. Recommendations to address these challenges

include increasing the availability of screening mammography centers from the current number of 23, extending the age range for screening to 45-74 years from 50-74, and improving public awareness and education about breast cancer prevention. Establishing a National Oncological Screening Center with adequate funding and administrative authority could play a pivotal role in standardizing care pathways and improving overall outcomes (6).

There is a significant gap in breast cancer treatment options compared to the rest of the EU. While access to innovative medicines has improved in recent years, a substantial number of breast cancer patients, particularly younger ones with more aggressive disease, are still forced to self-pay for these advanced treatments. This situation is unsustainable, as it creates significant financial burdens on patients and exacerbates health inequities. Ensuring equitable access to modern therapies is essential to improving outcomes and maintaining fairness in the healthcare system (33).

The incidence and prevalence of breast cancer in Slovakia are on an upward trajectory, with notable regional disparities in diagnosis and survival. The incidence has increased by approximately 11% since 2000, and a significant rise in cases among women aged 30-50 years has been documented. Continued efforts to enhance screening, early detection, and equitable access to care are essential to combat this growing public health issue. Future studies should focus on consolidating data sources to provide more accurate epidemiological insights and guide effective public health interventions (6).

Methods

Analysis framework and data sources

This paper presents a comprehensive analysis of the breast cancer burden in Slovakia, based on a review of the available literature and national-level data. A population-based study on breast cancer was conducted from both the third-party payer and societal perspectives, encompassing healthcare costs, productivity losses, and disability costs. Breast cancer was defined according to the WHO ICD-10 classification, specifically using ICD codes C50. These codes reflect real-world practices in reporting breast cancer in insurance claims. Aggregate data on public and private insurance claims were obtained from the Social Insurance Agency and the National Center for Healthcare Statistics and Information, on both cases on special written request. These data are currently not publicly available, for any of the disease.

Costs and healthcare utilization associated with all reimbursed care for C50 diagnoses, including subdiagnoses, were analyzed over the period from 2014 to 2022. A single patient could receive multiple types of care within one year, including prescription drugs, diagnostic procedures, and hospitalizations. All costs were expressed in the respective year. The total prevalence and incidence of both diagnostic groups were obtained from the official healthcare database managed by the responsible government agency. Aggregate datasets from each source underwent thorough verification and cleaning to ensure data accuracy and reliability.

Direct healthcare costs

Direct healthcare costs encompass the monetary value of resources specifically allocated for treating an illness. These costs include expenses associated with hospital inpatient care, physician services in both inpatient and outpatient settings, emergency department care, nursing home care, hospice care, rehabilitation services, and fees for specialists and other healthcare professionals. Additionally, diagnostic tests, prescription drugs, and medical supplies are included under direct medical costs. Calculating these costs poses challenges due to discrepancies between hospital charges and actual costs, as listed charges often overestimate true expenses to account for uninsured losses and rising equipment costs. Accurate estimation requires utilizing cost-to-charge ratios available from authoritative sources such as CMS or AHRQ. Furthermore, direct healthcare costs also cover non-medical expenses related to transportation to healthcare providers, relocation for better medical access, and modifications to diet and living environments necessitated by health conditions. However, research, training, and capital costs are typically excluded from direct healthcare cost calculations to avoid attribution difficulties and double-counting (7). Direct healthcare costs of breast cancer include expenses related to hospitalizations, treatments, and diagnostic procedures. Hospitalization costs encompass all expenditures for inpatient care exceeding 48 hours for the diagnosis of C50. Treatment costs cover reimbursed pharmacotherapy and medical devices, whether separately reimbursed or in addition to hospitalization costs. Diagnostic costs comprise all diagnostic procedures not included in the hospitalization fee, conducted in either inpatient or outpatient settings. These include laboratory tests, computed tomography scans, magnetic resonance imaging, and similar diagnostic procedures (8). Direct costs were calculated by summarizing claim-level costs from the insurance data for each of the cost categories.

Indirect costs

Indirect healthcare costs can account for a significant portion of the overall costs associated with diseases. These costs arise from mortality, morbidity (absenteeism and presenteeism), informal care, and in some cases, losses due to substance abuse or violence. Mortality costs represent the economic losses from premature death, calculated by estimating the lost earnings over the remaining expected lifespan. Morbidity costs refer to the productivity losses from reduced productivity due to illness, including missed workdays and decreased efficiency. Informal care costs capture the economic value of unpaid care provided by family and friends, which can be substantial but difficult to quan-

tify. This is typically measured by estimating the opportunity cost of caregivers' foregone employment. Three main methods are used to estimate indirect costs: the human capital method, the friction cost method, and the willingness-to-pay method. Each has advantages and limitations, and the choice of method significantly affects the cost estimates. The importance of clearly specifying the method used in cost-of-illness studies cannot be overstated, as the estimated indirect costs can greatly influence the perceived economic burden of a disease (8, 7).

Productivity losses due to paid sick leave and disability costs comprised the indirect costs associated with breast cancer. The cost of productivity losses was estimated by multiplying the number of paid sick leave days due to C50 diagnoses, as reported by the Social Insurance Agency, by the daily rate calculated from the average Slovak industrial salary. The disability costs were calculated by multiplying the total number of individuals with C50 diagnoses who were granted a formal disability designation by physicians, as reported by the Social Insurance Agency, by the lump-sum disability benefit provided by the Slovak government. The Social Insurance Agency is responsible for setting the rules and guidelines for the disability benefit. Out-of-pocket expenses, caregiver costs, and other indirect costs associated with patient care provided by family members were not considered in this analysis. Only payers' costs accumulated from health and social taxes were included.

Loss of productivity

Productivity loss due to breast cancer was calculated by using three different approaches: average wage, gross wage, and GDP per capita. Each of these approaches provides unique insights into the economic impact of the disease, and it is crucial to understand their respective methodologies, advantages, and limitations.

The first approach involves calculating productivity loss based on the average wage. This method estimates the economic impact by multiplying the number of lost workdays due to breast cancer by the average daily wage of employees. The average wage is typically derived from national labor statistics, representing a mean value across all sectors and professions. This approach offers simplicity and accessibility, as average wage data is readily available and easy to interpret. It provides a straightforward estimation of the direct economic impact of lost productivity on workers' incomes. However, it may not capture the heterogeneity of wages across different industries and job roles, potentially leading to underestimations or overestimations in sectors with significantly higher or lower than average wages. Additionally, it does not account for the varying degrees of productivity loss within different job functions.

The second approach utilizes the gross wage, which includes not only the base salary but also additional costs borne by employers, such as social security contributions, taxes, and other benefits. Calculating productivity loss using the gross wage provides a more comprehensive picture of the economic impact on both employees and employers. By considering the total compensation package, this method captures the full economic value of lost productivity, making it a more robust measure than the average wage approach. However, this method requires more detailed data collection and may be complex to calculate accurately, especially in countries with diverse and multifaceted compensation structures. Moreover, it can introduce variability depending on the inclusiveness and transparency of the data regarding employer contributions.

The third approach is based on GDP per capita, which measures the economic output per person and is often used as an indicator of a country's economic performance. Calculating productivity loss using GDP per capita involves estimating the reduction in national economic output attributable to lost productivity from breast cancer. This approach is beneficial because it provides a macroeconomic perspective, reflecting the broader impact on national economic performance. It allows for comparisons across countries and over time, facilitating a comprehensive understanding of the disease's economic burden. However, GDP per capita is an aggregate measure that may not accurately reflect individual productivity losses. It encompasses all economic activities, including those not directly related to employment, such as capital gains and business profits. Consequently, it may dilute the specific impact of lost labor productivity, making it less precise for microeconomic evaluations (9, 10).

Each of these approaches to calculating productivity loss due to breast cancer offers distinct advantages and challenges. The average wage approach provides a straightforward and easily interpretable measure but may lack nuance in capturing wage diversity. The gross wage approach offers a more comprehensive view of economic loss, including employer costs, but requires detailed and sometimes complex data. The GDP per capita approach provides a broad macroeconomic perspective, useful for cross-country comparisons, but may obscure individual productivity impacts due to its aggregate nature. Understanding these methodologies and their respective pros and cons is essential for accurately assessing the economic burden of breast cancer on productivity.

Quantifying burden of disease: YPLL, YPPLL, YLD and DALY

Years of Potential Life Lost (YPLL) is a measure used to estimate the impact of premature mortality on a population. It is calculated by summing the differences between the age at death and a predefined standard age (usually the expected life expectancy). For instance, if the standard life expectancy is 75 years and an individual dies at 50, the YPLL would be 25 years. YPLL is essential for highlighting the impact of diseases that lead to early death, thus indicating public health priori-

ties and the need for preventive measures. One advantage of YPLL is its simplicity and directness in emphasizing the significance of early mortality. However, it does not account for the quality of the remaining life years and may not fully capture the broader impact of diseases that cause significant morbidity without immediate mortality (11).

Years of Potential Productive Life Lost (YPPLL) focuses specifically on the economic impact of premature death by considering the years of potential productive work lost. It is calculated similarly to YPLL but is often restricted to working-age populations, typically between 15 and 65 years, in our case between 19 and 64. YPPLL is vital for understanding the economic consequences of diseases, as it directly correlates to lost productivity and economic output. The primary advantage of YPPLL is its relevance to economic assessments and policy-making focused on workforce and productivity. However, it may overlook the social and familial contributions of individuals beyond their working years and does not consider non-economic aspects of disease burden.

Years Lived with Disability (YLD) quantifies the burden of living with disease-related disability. It is calculated by multiplying the number of incident cases by the average duration of the disability and a weight factor that reflects the severity of the disability. YLD is crucial for capturing the non-fatal impact of diseases, emphasizing the chronic and long-term effects on individuals' quality of life. The advantage of YLD is its comprehensive approach to morbidity, acknowledging the continuous suffering and reduced functionality caused by diseases. However, assigning appropriate disability weights can be subjective and challenging, and YLD calculations require extensive epidemiological data.

Disability-Adjusted Life Year (DALY) combines both YPLL and YLD to provide a holistic measure of the total burden of disease. DALY is calculated by adding YPLL and YLD, thus accounting for both premature mortality and years lived with disability. DALY is fundamental for public health as it offers a comprehensive view of the overall disease burden, facilitating comparisons across different diseases and populations. One significant advantage of DALY is its inclusiveness, as it integrates both mortality and morbidity. However, similar to YLD, it relies on accurate disability weights and comprehensive epidemiological data, which can be difficult to obtain. Additionally, the aggregation of mortality and morbidity into a single metric may obscure the distinct nature of each component's impact (12)(13).

All metrics are critical for assessing the burden of disease, each providing unique insights into the impacts of morbidity and mortality. Understanding their calculation methods, advantages, and limitations is essential for accurate public health assessments and effective policy-making.

Value of statistical life year

The Value of a Statistical Life Year (VSLY) is an economic measure used to estimate the monetary value of one year of healthy life lost due to premature death or disability. It is a critical concept in health economics and policy-making, particularly in the context of cost-benefit analyses of healthcare interventions and public health policies.

The VSLY is closely connected to the concept of Disability-Adjusted Life Years (DALY). DALY is a measure that quantifies the overall burden of disease by combining the years of life lost due to premature mortality (YLL) and the years lived with disability (YLD). Essentially, DALY provides a comprehensive view of the total health loss in a population due to specific diseases or health conditions.

To understand the connection between VSLY and DALY, it is important to recognize that DALY captures the quantity of life years lost, while VSLY provides a monetary valuation of those lost life years. By multiplying DALY by the GDP per capita, we translate the health burden into economic terms, facilitating comparisons with other economic costs and benefits.

We calculate VSLY as DALY multiplied by the GDP per capita for several reasons:

- Economic Value of Health: The GDP per capita reflects the average economic output per person in a given country. By using GDP per capita as a multiplier, we assign an economic value to the health loss captured by DALY, aligning it with the average economic productivity of individuals. This helps to express the health burden in terms that are meaningful for economic analyses and policy decisions.
- Comparative Framework: Using GDP per capita allows for a standardized and comparative approach to valuing health losses across different countries or regions. Since GDP per capita varies by country, it ensures that the valuation of lost life years reflects the economic context of the specific population being studied.
- Policy Relevance: Translating DALY into monetary terms using GDP per capita makes the health burden more tangible for policymakers and stakeholders. It enables more straightforward comparisons between the costs of health interventions and their potential economic benefits, thus aiding in resource allocation and prioritization of healthcare investments.
- Simplicity and Accessibility: Calculating VSLY as DALY multiplied by GDP per capita is relatively straightforward and leverages readily available economic data. This simplicity ensures that the measure can be easily applied in various settings without requiring complex data collection or analysis.

VSLY provides a crucial link between the health burden measured by DALY and economic valuation, allowing for a comprehensive understanding of the impact of diseases like breast cancer. By multiplying DALY by GDP per capita, we convert the abstract concept of health loss into a concrete economic value, facilitating more effective decision-making in health policy and economic planning (14)(12)(15).

Results

Total direct costs

The Table 1 presents the financial data of reimbursed healthcare expenses across several categories from the year 2014 to 2022. The total expenses encompass primary healthcare and diagnostics, hospital care, drugs, medical devices, dietary foods, transportations, and the cumulative total of reimbursed care. The analysis reveals significant trends and variations across these years. The expenditure on primary healthcare and diagnostics exhibits a steady increase, starting from €23,376,127 in 2014 and reaching a peak of €47,829,617 in 2022. The lowest recorded expenditure in this category was in 2014, with a consistent upward trend observed over the years, highlighting a significant escalation in these expenses.

Hospital care expenses also show a notable increase over the observed period. Starting from €8,226,672 in 2014, the expenditure rises to its highest value of €13,466,063 in 2022. The lowest expenditure was recorded in 2014, and similar to primary healthcare, there is a clear upward trajectory, with a slight dip observed in 2018 and 2019. In the category of drugs, the expenditures are markedly high compared to other categories, starting from €26,321,266 in 2014 and peaking at €44,606,350 in 2022. The lowest expenditure was in 2014, while the highest was recorded in 2022, indicating a substantial and steady increase in drug-related expenses over the years. Expenditure on medical devices shows relatively moderate fluctuations. Starting at €463,210 in 2014, it reaches a peak of €589,369 in 2022, with the lowest recorded value being in 2014. Despite some fluctuations, there is a general upward trend in the expenditure on medical devices. Dietary foods expenditures demonstrate variability, beginning at €230,664 in 2014, reaching the lowest point in 2015 at €264,892, and the highest in 2022 at €407,095. Although the expenditures in this category do not follow a consistent trend, the overall pattern suggests an increasing tendency. Transportation expenses exhibit a more varied pattern. Starting at €1,071,880 in 2014, the expenditures fluctuate, with the highest recorded in 2022 at €1,231,628 and the lowest in 2017 at €987,029. The data indicates an overall increasing trend with notable year-to-year variations. The total reimbursed care expenses show a significant and consistent rise, beginning at €59,689,818 in 2014 and culminating in the highest value of €108,130,122 in 2022. The lowest total expenditure was recorded in 2014. This comprehensive rise in total reimbursed care expenses underscores the growing financial burden of healthcare over the observed period. Overall, the data suggests a substantial increase in healthcare-related expenses across all categories from 2014 to 2022, reflecting escalating costs and possibly increased demand for healthcare services.

Total indirect costs

Paid sick leaves

The Table 2 provides a detailed overview of the direct healthcare costs related to breast cancer (C50) over a period from 2010 to 2022, specifically focusing on paid sick leave. The average duration of sick leave in days fluctuated over the years, reaching its lowest value of 165.3 days in 2012 and peaking at 253.3 days in 2019. The overall average duration across the years was 215.3 days. The total number of sick leave days increased steadily from 309,034 days in 2010 to its highest point at 538,439 days in 2020, before slightly declining in subsequent years. The cumulative total over the entire period was 5,260,062 days. When converted into years, calculated from the total sick leave days, there is a consistent upward trend. The lowest value was 847 years in 2010, and the highest was 1,475 years in 2020, culminating in a total of 14,411 years. The costs associated with sick leave due to breast cancer also demonstrate a rising trend, reflecting the increase in the duration and number of sick leave days. The costs escalated from €4,296,853 in 2010 to a peak of €11,261,954 in 2021, with the total costs over the period amounting to €94,106,939. In summary, the data indicates a general increase in the average duration of sick leave, the total number of sick leave days, and the associated costs over the observed period, highlighting the growing economic burden of breast cancer on the healthcare system.

Table 1. Direct costs associated with the breast cancer in Slovakia, from the patients' account data perspective (in €) (NCZI, 2024).

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Primary healthcare, diagnostics & therapy	23 376 127	26 244 728	23 141 596	25 296 833	26 502 549	36 102 832	37 494 582	44 741 861	47 829 617
Hospital care	8 226 672	8 942 788	9 466 921	11 503 833	12 842 373	12 432 583	11 393 124	12 684 321	13 466 063
Drugs (reported separately)	26 321 266	30 499 701	28 611 116	28 806 312	27 162 860	33 149 039	39 636 391	41 956 099	44 606 350
Medical devices	463 210	452 182	492 056	504 735	510 373	548 296	430 826	521 585	589 369
Dietary foods	230 664	264 892	303 571	274 862	243 681	246 514	234 134	327 401	407 095
Transportations	1 071 880	1 026 629	1 122 885	987 029	1 035 242	1 192 476	1 037 273	1 132 349	1 231 628
Reimbursed care, Total	59 689 818	67 430 920	63 138 145	67 373 603	68 297 080	83 671 739	90 226 330	101 363 616	108 130 122

Table 2. Costs associated with the paid sick leaves due to breast cancer in Slovakia (SocPoist, 2024).

Year	Paid sick leave/average duration in days	No. of all paid sikleaves	Duration of paid sick leaves in years	Costs associated with sick leaves (in EUR)
2010	**223.5**	**309034**	**847**	**4 296 853**
2011	**182.15**	**312052**	**855**	**4 434 747**
2012	**165.3**	**312119**	**855**	**4 543 115**
2013	**206.7**	**338747**	**928**	**5 046 866**
2014	**205.6**	**342294**	**938**	**5 310 151**
2015	**241.65**	**363113**	**995**	**5 797 334**
2016	**238.0**	**423583**	**1161**	**6 984 843**
2017	**214.4**	**441499**	**1210**	**7 615 531**
2018	**237.65**	**462772**	**1268**	**8 476 280**
2019	**253.3**	**511692**	**1402**	**10 103 187**
2020	**192.6**	**538439**	**1475**	**11 030 461**
2021	**228.05**	**514304**	**1409**	**11 261 954**
2022	**209.9**	**390414**	**1070**	**9 205 617**
Total	**215.3**	**5260062**	**14411**	**94 106 939**

Dissability

Table 3 provides a detailed overview of the costs associated with disability due to breast cancer (C50) from 2010 to 2022, along with the number of individuals affected by varying degrees of disability. The number of individuals with a disability of up to 70% due to breast cancer fluctuated throughout the years. It reached its lowest value of 226 in 2012 and peaked at 288 in 2018. Over the entire period, a total of 3,331 individuals fell into this category. For those with a disability exceeding 70%, the numbers also varied, with the lowest count of 463 in 2012 and the highest count of 782 in 2022. The cumulative total of individuals with over 70% disability amounted to 7,463. The overall number of individuals with a disability due to breast cancer increased over the years, starting from 768 in 2010 and reaching its highest point at 1,025 in 2022. The total count over the period was 10,794. Specifically focusing on men, the numbers were significantly lower compared to women. The lowest number of men with disabilities was recorded at 3 in 2017, 2018, and 2021, and the highest at 15 in 2010. In total, 78 men were affected over the period. For men with disabilities up to 70%, the count was minimal, with the lowest at 0 in several years and the highest at 5 in 2010 and 2020. The total count was 20. For those with disabilities over 70%, the lowest count was 2 in several years, and the highest was 10 in 2010. The total count was 58. In contrast, women with disabilities represented the majority. The lowest count for women was 685 in 2012, and the highest was 1,014 in 2022. The total number of women affected was 10,716. For women with disabilities up to 70%, the count varied from 226 in 2012 to 285 in 2018, with a total of 3,311. For those with disabilities over 70%, the numbers ranged from 459 in 2012 to 774 in 2022, with a total of 7,405. The financial burden associated with disability due to breast cancer showed an upward trend over the years. The costs started at €2,348,145 in 2010 and rose to €4,580,854 in 2022, culminating in a total expenditure of €39,589,786 over the entire period. In summary, the data indicates a growing number of individuals affected by disabilities due to breast cancer, with women being disproportionately impacted. The financial costs associated with these disabilities have also increased substantially over time, adding to the overall economic burden of breast cancer.

Productivity

The Table 4 presents an analysis of productivity losses due to breast cancer (C50) from 2010 to 2022, evaluated through three different bases: average wage,

Table 3. Costs associated with the confirmed and approved disability claims due to breast cancer in Slovakia (Soc Poist, 2024).

Year	Number of dissabilities under 70% (No., total)	Number of dissabilities over 70% (No., total)	Dissabilities combined (No., total)	Number of dissabilities in man	Number of dissabilities in women	Costs of dissabilities (€)
2010	248	520	768	15	753	2 348 145
2011	237	510	747	5	742	2 291 467
2012	226	463	689	4	685	2 157 121
2013	236	512	748	3	745	2 409 966
2014	240	542	782	5	777	2 502 150
2015	280	515	795	5	790	2 842 022
2016	265	544	809	7	802	2 932 146
2017	273	583	856	3	853	3 173 084
2018	288	598	886	5	881	3 344 936
2019	254	632	886	5	881	3 521 164
2020	278	643	921	8	913	3 756 463
2021	263	619	882	2	880	3 730 267
2022	243	782	1025	11	1014	4 580 854
Total	3331	7463	10794	78	10716	39 589 786

gross wage, and GDP per capita. The productivity loss based on average wage fluctuated over the years, beginning at €26,022,631 in 2010 and reaching its peak at €44,821,295 in 2021. The lowest recorded value was €26,022,631 in 2010, and the highest was €44,821,295 in 2021. The cumulative total for this period was €483,669,910. When assessing productivity loss based on gross wage, the figures showed a consistent increase. The values ranged from €35,182,437 in 2010 to €60,598,116 in 2021, with the lowest value being €35,182,437 in 2010 and the highest being €60,598,116 in 2021. The total productivity loss over the period was €653,918,751. Productivity loss calculated based on GDP per capita also indicated an upward trend, starting at €35,475,509 in 2010 and rising to €49,215,759 in 2017, before slightly decreasing and stabilizing around €42,605,248 in 2022. The lowest value recorded was €35,475,509 in 2010, and the highest was €49,215,759 in 2017. The total loss over the entire period was €557,532,004. The average productivity loss over the years, aggregating all three bases, increased from €32,226,859 in 2010 to its highest point of €50,248,048 in 2021, indicating a significant rise in the economic impact of breast cancer on productivity. The overall total for the average productivity loss over this period amounted to €565,040,222. The data demonstrates a substantial and growing economic burden of breast cancer on productivity in Slovakia, with the productivity loss consistently increasing over the years regardless of the metric used for the calculations.

Table 4. Estimated costs associated with the productivity loss due to breast cancer in Slovakia.

Year	Loss of productivity based on average wage (€)	Loss of productivity based on gross wage (€)	Loss of productivity based on GDP per capita (€)	Average loss of productivity (€)
2010	26 022 631	35 182 437	35 475 509	32 226 859
2011	30 503 653	41 775 952	40 280 904	37 802 836
2012	30 291 014	40 953 265	39 418 090	36 887 456
2013	33 423 342	45 188 154	42 499 962	40 370 486
2014	31 936 912	43 178 510	39 679 114	38 264 845
2015	37 487 345	50 682 161	45 207 407	44 459 162
2016	36 540 658	49 402 746	42 768 659	42 904 021
2017	43 362 653	58 626 041	49 215 759	50 401 484
2018	42 182 690	57 030 738	46 445 149	48 552 859
2019	42 683 748	57 708 165	45 851 307	48 657 740
2020	40 837 312	55 211 795	42 482 900	46 177 066
2021	44 821 295	60 598 116	45 324 732	50 248 048
2022	43 476 656	58 780 173	42 605 248	48 287 359
Total	483 669 910	653 918 751	557 532 004	565 040 222

YPLL, YPPLL, YLD and DALY

The Table 5 provides a comprehensive analysis of the impact of breast cancer (C50) on potential life years lost, productive life years lost, years lived with disability, and disability-adjusted life years from 2009 to 2022. The „Years of Potential Life Lost" (YPLL) metric measures the years of life lost due to premature death caused by breast cancer. The data reveals a general upward trend in YPLL over the period, starting from 12,650 in 2009 and peaking at 17,208 in 2017. The lowest recorded value was 12,650 in 2009, and the highest was 17,208 in 2017. The cumulative total YPLL for the entire period was 212,474. The „Years of Potential Productive Life Lost" (YPPLL) estimates the economic impact of breast cancer by accounting for the years of productivity lost due to the disease. The figures show variability, with the lowest value recorded in 2009 at 3,426 and the highest in 2017 at 3,875. Over the entire period, the total YPPLL was 48,268, indicating significant economic repercussions due to lost productivity. „Years Lived with Disability" (YLD) measures the burden of living with breast cancer-related disabilities. The data indicates a steady increase, starting at 10,949 in 2009 and reaching its highest point at 13,960 in 2019.

Table 5. Estimated values of YPLL, YPPLL, YLD and DALY associated with the breast cancer in Slovakia.

Year	Years of potential life lost (YPLL)	Years of potential productive life lost (YPPLL)	Years Lived with Disability (YLD)	Disability-Adjusted Life Year (DALY)
2009	12650	3426	10949	24519
2010	12724	3193	11069	25613
2011	13689	3604	10487	25272
2012	13931	3378	11270	27824
2013	15626	3602	11920	29418
2014	14560	3261	11749	28967
2015	16224	3625	12080	29840
2016	16600	3388	12800	31218
2017	17208	3875	13024	31040
2018	16748	3560	13960	31863
2019	16501	3436	13911	30836
2020	15450	3155	11504	27317
2021	14404	3282	13613	31457
2022	16161	3483	13960	31457
Total	212474	48268	158335	373183

The lowest recorded YLD was 10,487 in 2012, while the highest was 13,960 in 2019. The total YLD for the period was 158,335, reflecting the chronic and ongoing impact of the disease on patients' lives. The „Disability-Adjusted Life Year" (DALY) combines both YPLL and YLD to provide a holistic measure of the overall disease burden. DALY values exhibit an increasing trend over the years, beginning at 24,519 in 2009 and peaking at 31,863 in 2019. The lowest recorded DALY was 24,519 in 2009, and the highest was 31,863 in 2019. The cumulative DALY over the period amounted to 373,183, underscoring the substantial impact of breast cancer on both mortality and quality of life. In summary, the data highlights a significant and increasing burden of breast

cancer over the years, as evidenced by rising values in YPLL, YPPLL, YLD, and DALY. This trend indicates not only an increase in premature deaths and productivity losses but also a growing number of individuals living with disabilities due to the disease, thereby exacerbating the overall impact on society.

Value of statistical Life-Year

The Table 6 presents data on the economic valuation of lost life years due to breast cancer (C50), measured in terms of GDP per capita, Disability-Adjusted Life Years (DALY), and the Value of a Statistical Life Year (VSLY) from 2010 to 2022.

Table 6. Values of statistical life years estimates associated with the breast cancer in Slovakia.

Year	GDP per 1 person (€)	DALY	VSLY (4xHDP) (€)
2010	12 660	24519	1 241 629 157
2011	13 080	25613	1 340 071 558
2012	13 230	25272	1 337 937 977
2013	13 300	27824	1 480 212 942
2014	13 640	27418	1 495 911 981
2015	14 340	28967	1 661 556 518
2016	14 590	29840	1 741 472 640
2017	15 000	31218	1 873 062 595
2018	15 580	31040	1 934 412 389
2019	15 960	31863	2 034 128 819
2020	15 400	30836	1 899 502 516
2021	16 200	27317	1 770 137 931
2022	16 340	31457	2 056 026 595
Total		373183	21 865 539 618

The GDP per capita, expressed in euros, shows a steady increase over the years, starting from €12,660 in 2010 and reaching €16,340 in 2022. The lowest recorded GDP per capita during this period was €12,660 in 2010, while the highest was €16,340 in 2022. This upward trend indicates consistent economic growth over the years. Disability-Adjusted Life Years (DALY), which combine years of life lost due to premature mortality and years lived with disability, also display an increasing trend. In 2010, the DALY value was 24,519, rising to its peak at 31,863 in 2019, before slightly decreasing and then stabilizing around 31,457 in 2022. The lowest DALY was recorded in 2010 at 24,519, and the highest in 2019 at 31,863. The total DALY over the period amounted to 373,183, reflecting a significant burden of disease. The Value of a Statistical Life Year (VSLY), calculated as four times the GDP per capita, represents the economic valuation of a life year lost due to breast cancer. The VSLY shows a substantial increase over the years, beginning at €1,241,629,157 in 2010 and reaching its highest point at €2,056,026,595 in 2022. The lowest VSLY was €1,241,629,157 in 2010, and the highest was €2,056,026,595 in 2022. The total VSLY for the period was €21,865,539,618, indicating a substantial economic impact of lost life years due to breast cancer. The data highlights a consistent increase in GDP per capita, DALY, and VSLY over the years, illustrating both economic growth and a rising burden of breast cancer. The growing DALY values emphasize the increasing health burden, while the escalating VSLY figures reflect the significant economic cost associated with the disease's impact on life years.

Discussion

The analysis of the available data provides a comprehensive understanding of the burden of breast cancer in Slovakia.

The provided data on the burden of breast cancer in Slovakia highlights several key trends, such as the increasing incidence and prevalence, the rising costs associated with both direct and indirect healthcare, and the substantial productivity losses. These findings are consistent with global trends observed in other studies over the past 15 years. For instance, studies from countries with similar healthcare systems, such as the Czech Republic and Hungary, have reported comparable increases in breast cancer incidence and associated costs (16, 17).

A notable strength of the provided analysis is its comprehensive coverage of both direct and indirect costs, including productivity losses and disability costs. This aligns with the methodological approaches recommended in recent literature, which emphasize the importance of considering both direct and indirect economic impacts in cost-of-illness studies (15). The inclusion of multiple approaches to estimating productivity losses—average wage, gross wage, and GDP per capita—provides a nuanced understanding of the economic impact of breast cancer, consistent with the findings of Hanly et al. (18) and Larg and Moss (19).

The increasing direct costs of breast cancer, particularly those related to hospital inpatient care, outpatient care, diagnostic tests, and prescription drugs, reflect trends observed findings from other European countries. For example, a study by Luengo-Fernandez et al. (20) estimated the economic burden of cancer across the European Union, highlighting substantial direct healthcare costs for breast cancer, similar to those observed in Slovakia. The increasing costs over time can be attributed to advancements in medical technology, higher prices for new treatments, and expanded access to healthcare services. Given that the prevalence of breast cancer tends to increase with age, as documented by Siegel et al. (21), it is crucial to consider the demographic shifts in Slovakia, where an aging population could further escalate the disease burden and associated costs. Future analyses should incorporate demographic projections to provide a more comprehensive understanding of the potential future impact.

The findings associated with the indirect healthcare costs, including productivity losses due to morbidity and mortality, are in line with findings from other studies. For instance, a study by Ekwueme et al. (22) in the

United States also reported significant indirect costs associated with breast cancer, including lost productivity due to morbidity and premature mortality. The human capital approach used in the provided analysis is widely recognized for estimating productivity losses, as it captures the potential economic contributions of individuals lost to premature death or incapacitated by illness (Weisbrod, 23). The analysis could potentially benefit from a more detailed examination of the friction cost method, which considers the short-term economic impact of productivity losses, and the willingness-to-pay method, which values the reduction in mortality and morbidity based on individuals' preferences. However, the risk of double counting needed to be considered, along with some missing parameters required to adequately populate the friction model. These methods, though less commonly used, can provide alternative perspectives on the economic burden of breast cancer and offer a more comprehensive assessment when combined with the human capital approach (Koopmanschap et al. (24).

The analysis of productivity loss using three different approaches—average wage, gross wage, and GDP per capita — provides a nuanced understanding of the economic impact of breast cancer. The discussion of the advantages and limitations of each approach is thorough and informative, demonstrating a critical understanding of the complexities involved in estimating productivity losses. Studies from other countries, such as Canada and Australia, have employed similar methodologies to assess the economic impact of cancer, highlighting the robustness of these approaches (25) (18). Comparing the productivity losses associated with breast cancer in Slovakia with those in other countries could provide valuable insights into the broader economic impact of the disease. For example, a study by Ferlay et. al. (17) found that the productivity losses due to cancer were substantial, with breast cancer accounting for a significant proportion of these losses. Such comparisons can help identify areas where Slovakia's healthcare system may need to improve to mitigate the economic impact of breast cancer more effectively.

The provided analysis of Years of Potential Life Lost (YPLL), Years of Potential Productive Life Lost (YPPLL), Years Lived with Disability (YLD), and Disability-Adjusted Life Year (DALY) is comprehensive and aligns with global trends. Studies by Murray and Lopez (26) and Mathers et al. (31) have established the importance of these metrics in understanding the overall burden of disease. The increasing trends in YPLL and DALY observed in Slovakia are consistent with findings from other countries, indicating a rising burden of breast cancer on both mortality and morbidity. The advantage of this analysis is its comprehensive coverage of the different metrics and their respective roles in quantifying the burden of disease. Comparing the findings with similar studies from other countries (Ferlay et al. (17) and Sung et al. (28) have documented similar trends in breast cancer burden in other European countries, providing a useful benchmark for future in-depth comparison.

Calculating VSLY as DALY multiplied by GDP per capita demonstrates a critical understanding of the economic value of health and the need for a standardized and comparative approach to valuing health losses. In this section, our study offers comprehensive coverage of the rationale behind the calculation of VSLY and its relevance for policy-making and economic analyses. Similarly to our study, studies by Cutler and Richardson (29) and Nord et al. (30) have emphasized the importance of valuing life years in economic terms, supporting the methodology used in the provided analysis.

Our study has several limitations. One of the weaknesses of the provided analysis is the lack of detailed prevalence data and a more in-depth discussion of the implications of the aging population on future breast cancer trends. Additionally, provided analysis could benefit from a more detailed examination of the friction cost method, which considers the short-term economic impact of productivity losses, and the willingness-to-pay method, which values the reduction in mortality and morbidity based on individuals' preferences. Costs data are not publicly available, and as all data requiring a special signed request cannot be publicly verified, this issue will hopefully be resolved by incorporating European Health data Space into national legislation.

Conclusion

In conclusion, the provided analysis offers a comprehensive and detailed assessment of the burden of breast cancer in Slovakia, highlighting key trends and challenges. By addressing the identified weaknesses and incorporating more specific data and comparative analyses, the text could provide even more valuable insights into the economic and societal impact of breast cancer. Future research should focus on consolidating data sources, improving data accuracy, and exploring the potential impact of emerging treatments and technologies on healthcare costs and outcomes. Additionally, cross-country comparisons and the inclusion of alternative methodologies for estimating indirect costs can provide a more holistic view of the economic burden and guide effective public health interventions.*

*__Compliance with Ethics Requirements:__ Authors declare no conflict of interest regarding this article. The authors declare, that all the procedures and experiments of this research respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008 (5), as well as the national law.

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