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ORIGINAL PAPER

Economics of public health programs for underserved populations: a review of economic analysis of the National Breast and Cervical Cancer Early Detection Program

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Abstract

Purpose The purpose of this paper is to provide a brief overview of economic analysis methods used in estimating the costs and benefits of public health programs and systematically review the application of these methods to the National Breast and Cervical Cancer Early Detection Program (NBCCEDP).

Methods Published literature on economic analyses of the NBCCEDP was systematically reviewed. The Consensus on Health Economic Criteria checklist was used to assess methodological quality of the included studies.

Results Methods available for economic analysis of public health programs include program cost, cost-effectiveness, cost–utility, cost–benefit analysis, and budget impact analysis. Of these, program cost analysis, cost-effectiveness analysis, and cost–utility analysis have been applied to the NBCCEDP in previously published literature.

Conclusion While there have been multiple program cost analyses, there are relatively fewer cost-effectiveness and cost–utility studies and no cost–benefit and budget impact analysis studies to evaluate the NBCCEDP. Addressing these gaps will inform implementation of effective public health programs with equitable resource allocation to all population subgroups.

Keywords Economic analysis · Cost-effectiveness · Cancer screening · Public health · Underserved

Introduction

Economic analysis is the study of decisions in order to maximize value in an environment of resource constraints. Because public funds for health services are finite, decision makers must allocate available resources among various activities to promote health and prevent diseases. Economic analysis provides a systematic appraisal of the consequences of alternative choices in allocating (i.e., spending) public health budgets. The results of this analysis can guide decisions regarding the most effective and efficient use of public health resources [1].

Economic analyses of publicly funded cancer prevention programs are vital for three reasons. First, cancer is a costly disease. The direct cost of cancer care in the USA was $124.5 billion dollars in 2010 and is projected to increase by nearly 40% by the year 2020 [2]. Cancer costs are even higher when productivity losses incurred by cancer survivors are included [3]. Second, effective cancer prevention offers high value. Routine screening for early detection of colorectal, breast, and cervical cancers is among the 25 most cost-effective preventive services recommended by the United States Preventive Services Task Force [4]. While there are fewer studies that establish the value of primary prevention of cancer, certain primary prevention interventions are known to be cost-effective [5]. Third, underserved populations experience disparities in receipt of these high-value cancer prevention services [6] and are more likely to have adverse cancer outcomes [7].

Disclaimer The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Public health programs can improve access to cancer prevention services for these underserved populations, thereby reducing cancer morbidity and mortality in a cost-efficient manner. Further, to the extent that underserved populations may be at greater risk of poor cancer outcomes than the general population, public health programs targeted to underserved populations may be even more effective than among the general population; however, studies have not yet emerged to demonstrate this. Hence, economic evaluation of public health programs for cancer prevention, especially focused on the underserved, is essential to provide evidence of their value to decision makers to ensure their scalability and replicability.

Economic analysis methods commonly used in research related to public health programs are program cost analysis, cost-effectiveness analysis, cost–utility analysis, cost–benefit analysis, and budget impact analysis [8]. We provide a brief description of key concepts in economic analyses followed by a description of economic analysis methods used for evaluating public health cancer prevention programs for the underserved. Next, we conduct a systematic review of literature to identify economic analyses of the Centers for Disease Control and Prevention's (CDC) National Breast and Cervical Cancer Early Detection Program (NBCCEDP) and identify gaps in the literature. The CDC's NBCCEDP is a national program providing breast and cervical cancer screening to low-income, uninsured, and underinsured women in the USA [9]. Currently, the NBCCEDP funds 70 state, tribal, and territorial health agencies.

Key Concepts in Economic Analyses

Key concepts important to all types of economic analyses include the perspective of the analysis and categories of costs attributable to the disease. The perspective of the analysis is the viewpoint from which the analyses are conducted. Typical perspectives include the patient and family; employer; health insurers or payer, including federal and state programs such as Medicare and Medicaid; or society overall. Three categories of costs attributable to disease are usually identified as follows: (1) direct costs resulting from the use of resources for medical and non-medical care; (2) indirect costs, also known as productivity losses, associated with morbidity and premature mortality from cancer; and (3) psychosocial (intangible) costs, such as pain and suffering [10]. Examples of these cost categories and their measurements are listed in Table 1.

Direct costs are typically measured by health insurance payments and patient out-of-pocket spending. Existing payment or cost data may not be available for new technologies or new community-based interventions. In such cases, micro-costing studies may be needed to collect detailed data on resources utilized and the value of those resources. Indirect costs, or losses caused by illness or premature death, are typically measured as time lost from work, or loss of usual activities, and valued in one of three ways: the human capital (HC), friction cost (FC), or willingness-to-pay (WTP) approach [10]. In the HC approach, gender- and age-specific average wages are combined with time lost from work to calculate the value of the lost time, which is based on the patient's estimated earnings in the labor market. In contrast, the FC approach calculates lost hours only as those not worked until another employee takes over the patient's work [11]. The WTP approach estimates the amount an average individual would be willing to pay for an additional year of life [12]. All three approaches yield different estimates of the value of productivity losses [12]. Estimating productivity costs by using any of these three approaches is controversial for underserved populations, because these populations have lower wages and subsequently lower time costs and lower willingness to pay than those of the general population [13].

Table 1 Medical care cost categories

Cost component	Examples	Measurement
Direct costs		
Medical	Cost of hospitalizations, physician visits, and cancer therapy	Health insurance payments, patient out-of-pocket health care spending
Non-medical	Cost of transportation to and from medical care and housekeeping services	Patient spending
Indirect costs		
Morbidity	Cost of time lost from work/lost productivity, time spent seeking medical care, caregiver time, or changes in caregiver productivity	Days lost from work from employer or patient perspective combined with value of time
Mortality	Cost of productivity lost due to premature death	Years of life lost combined with value of time
Intangible/psychosocial costs	Cost of pain, suffering, grief	Usually measured as reduction in quality of life

Overview of economic analysis methods

Table 2 presents an overview of economic evaluation methods used in public health. The choice of method is largely dependent on the purpose of the analysis, the audience requesting the analysis, and the availability of data. These methods are briefly described next.

Program cost analysis

Program cost analysis refers to a systematic collection of the cost of a program [14] and can be performed as a stand-alone analysis or as an essential step in the complete economic evaluation of a health program. When performed as a stand-alone analysis, the results of program cost analyses are presented as either average cost or incremental cost of program per individual served [15]. Program cost analyses are helpful in making a case for starting or expanding a healthcare program [16]. Program costs include both fixed and variable costs. Fixed costs are costs that do not change with the number of people served, and include costs for facilities and capital equipment (e.g., rent and depreciation or amortization), and overhead expenses for shared resources such as administrative personnel [14]. Variable costs increase with the number of individuals served and usually include clinical personnel time and materials.

Finkelstein and colleagues [17] recommend that economic evaluations of public health programs should include more than only the direct dollar outlays associated with implementation of the program. To evaluate the true societal cost of a program, the opportunity cost (the cost to society of giving up on alternate, competing programs) of participation in the program and program resources such as donated volunteer hours or donated facilities and equipment also should be included [17]. Gorsky presents methods for estimating program costs using a seven-step resource-cost- or ingredient-based approach that includes three types of resource costs—variable costs, fixed costs, and participant costs [18].

Cost-effectiveness analysis (CEA)

CEA incorporates both the costs and consequences of competing health interventions to determine the intervention that offers the highest value. The cost-effectiveness of an intervention is computed by using an incremental cost-effectiveness ratio (ICER) that compares the cost and outcomes of an intervention with either the standard of care or the next least expensive alternate intervention in case of multiple competing interventions. The ICER is compared with some selected threshold value based on literature and/or accepted norms. For instance, the ICER for a program that addresses cancer screening among underserved women would be compared to a threshold computed based on ICERs from evaluation of other similar programs that provide disease prevention services to underserved populations. If the ICER is below this selected threshold, the intervention is considered to be cost-effective [19]. CEA is the most common method of economic analysis in the healthcare literature because the outcome is measured in short-term, natural units such as patients screened or cancers detected, which are easier to measure and easier to interpret as compared to long-term health benefits [20, 21].

CEA is useful when comparing alternative interventions within a healthcare program that address the same health outcome, or when comparing alternate health programs that deliver similar services, such as cancer screening. All direct medical, direct non-medical, and indirect costs can be included in CEA study depending on the perspective of the analysis.

Cost–utility analysis (CUA)

CUA is a special case of CEA wherein the health outcome is a broader measure of health that incorporates both survival and quality of life. The quality-adjusted life-year (QALY) is the most common outcome measure in CUA in developed countries. QALYs are computed as a product of the life-years gained and utility weight. Utility weight is a value assigned to a particular health state based on the desirability of living in the state, typically from the highest desirability of living in "perfect" health (weighted 1) to the lowest desirability of death (weighted 0) [22, 23]. When the effect of an intervention is measured by using QALYs, the analysis is called CUA because the health outcome has been adjusted for quality of life by using utility weights [24]. QALYs serve as the common outcome measure that enables comparison of ICERs across programs that address diverse public health outcomes. Using QALYs ensures that programs that may not improve longevity but improve quality of life are not undervalued [25]. However, QALYs do not appropriately incorporate certain fairness and distributional concerns that are important in allocation of resources. Because certain underserved populations may have a lesser potential for experiencing health gains, interventions that improve their quality of life may result in fewer QALYs saved for them. However, underserved populations may value the treatment just as highly as others. These distributional consequences of QALYs must be considered when using cost–utility analyses for underserved populations [26].

Cost–benefit analysis (CBA)

CBA requires that all costs and consequences are in the same units. In CBA, a monetary value is usually assigned to health outcomes such that costs and effects of all programs are measured in dollars. In the place of ICERs computed in

Table 2 Methods used in economic analyses

Method	Measure of costs and benefits	Features	Perspective	Cost categories			
				Direct medical	Direct non-medical	Indirect	Intangible
Program cost analysis	Total cost per patient served; costs include fixed and variable resources; no measure of benefits	Results straightforward, but not directly actionable. Lack of standardization regarding program costs to be included limits comparability.	Payer	Included only for the specific payer			
Cost-effectiveness analysis	Incremental cost-effectiveness ratio; health benefits in natural units gained	Outcomes straightforward, but no comparability between programs affecting different outcomes	Societal	Included for all payers, including patient	Included	Included	Included
			Payer	Included only for the specific payer			
Cost–utility analysis	Incremental cost-effectiveness ratio; benefits measured in quality-adjusted life-years (QALYs) gained	Results comparable across healthcare programs. No standard definitions on utility measures, especially for underserved populations	Societal	Included for all payers, including patient	Included	Included	Intangible costs included in the utility measure
			Payer	Included only for the specific payer			
Cost–benefit analysis	Net benefit; health benefits valued in dollars	Results comparable across healthcare programs. Assigning monetary values to health outcomes is controversial	Societal	Included for all payers, including patient	Included	Included	Included
			Payer	Included only for the specific payer			
Budget impact analysis	Short-term incremental cost	Provides actionable findings on affordability. Biased against programs with long-term benefits and high short-term costs	Payer	Included only for the specific payer			

CEA and CUA, results of CBA are reported as net monetary benefit, which is derived by subtracting total costs from total benefits. A net monetary benefit greater than zero implies that the program is cost-effective. CBA is typically performed by using the societal perspective to capture all costs and benefits irrespective of who accrues them. This makes CBA useful when comparing programs across various sectors such as health, education, and housing. Although CEA and CUA answer questions about technical efficiency of a health program (i.e., Given that a goal has been decided, what is the least costly way of achieving it?), CBA answers questions about allocative efficiency (i.e., How much of society's limited resources should be allocated to achieving this goal as compared to other societal goals?) [27].

CBA differs from an evaluation of whether a program is cost minimizing. Cost minimization analysis compares only the costs of programs that have equivalent outcomes. Zarnke et al. found that nearly 53% of studies labeled as CBA are cost minimization analyses and do not appraise health outcomes [28]. Monetary value of health benefits may be derived by using the WTP, HC, or FC approach as described earlier. Nearly 70% of the true CBAs examined by Zarnke et al. used the HC approach to value health states [28]. CBA of healthcare interventions is rare in the USA because assigning a monetary value to health and life is controversial. When the focus of the intervention is underserved populations, these populations differ from the general public in terms of work productivity or willingness to pay, the measures used for computing monetary value of health benefits in a CBA [8]. CBA is more popular in European nations [29] and in other US governmental agencies such as the Environmental Protection Agency and the Congressional Budget Office [30].

Budget impact analysis (BIA)

A BIA is an economic assessment that estimates the financial consequences of implementing a health program or whether the intervention is affordable. BIA is an analysis of all the expenditures and savings associated with the implementation of a health care program accrued to the payer, usually a government entity, in the short-term, including diagnostic and treatment costs for cancers detected in the screening program [31]. BIA usually does not take into consideration the costs incurred by the patients and the non-monetary consequences of the program implementation, including health benefits. BIA is a limited tool designed to inform decision makers of the impact of a new program on their budget relative to the status quo in the near future. Although BIA considers the number of people benefitting from a program, it does not consider the sociodemographic characteristics of the population being served. BIA is about financial feasibility rather that efficiency or equity, which must be addressed by decision makers using other methods.

Method

This systematic literature review was conducted and described in accordance with the PRISMA guidelines [23]. A systematic search for published, English-language literature on economic analysis of NBCCEDP was conducted from 1 January 2000 to 31 July 2019. Searches were executed in the following bibliographic databases: Medline, Embase, PsycInfo, Scopus, CINAHL, EconLit, and ProQuest Central. Our search used a combination of keywords and controlled vocabulary for several concepts including cost or economic analysis and the National Breast and Cervical Cancer Early Detection Program, which were adapted for each database search. The search results and study selection process are illustrated in Fig. 1.

All references were uploaded in Covidence systematic review software (https://covidence.org), and duplicates were removed. Articles were excluded if the abstract did not contain some indication of "cost/cost-effectiveness" and the "National Breast and Cervical Cancer Early Detection Program." Studies conducted outside the USA were also excluded. Full-text articles were selected for extraction if they examine costs or cost-effectiveness/utility/benefit of various components of the National Breast and Cervical Cancer Early Detection Program. We also excluded studies that examined costs incurred to other programs such as Medicaid or other institutions.

The following information was extracted using a standardized data collection form: author and publication year, population studied, data source and time period of the study, type of economic analysis, study perspective, type of cost estimates, health outcomes examined, and estimates of program costs or incremental cost-effectiveness ratios. Cost estimates were not adjusted to a single reference year, nor was a quantitative synthesis of cost estimates or ICERs performed due to the heterogeneity in populations, time periods of data collection, cost estimates reported, and other differences in methodology.

The methodological quality of the included articles was assessed using an adapted version of Evers' Consensus on Health Economic Criteria (CHEC) checklist [32] similar to other systematic reviews of economic analyses [33]. This checklist was recommended by the Cochrane Collaboration to perform a quality assessment of both full (cost-effectiveness, cost–utility, and cost–benefit) and partial (cost analyses) economic analyses [34].

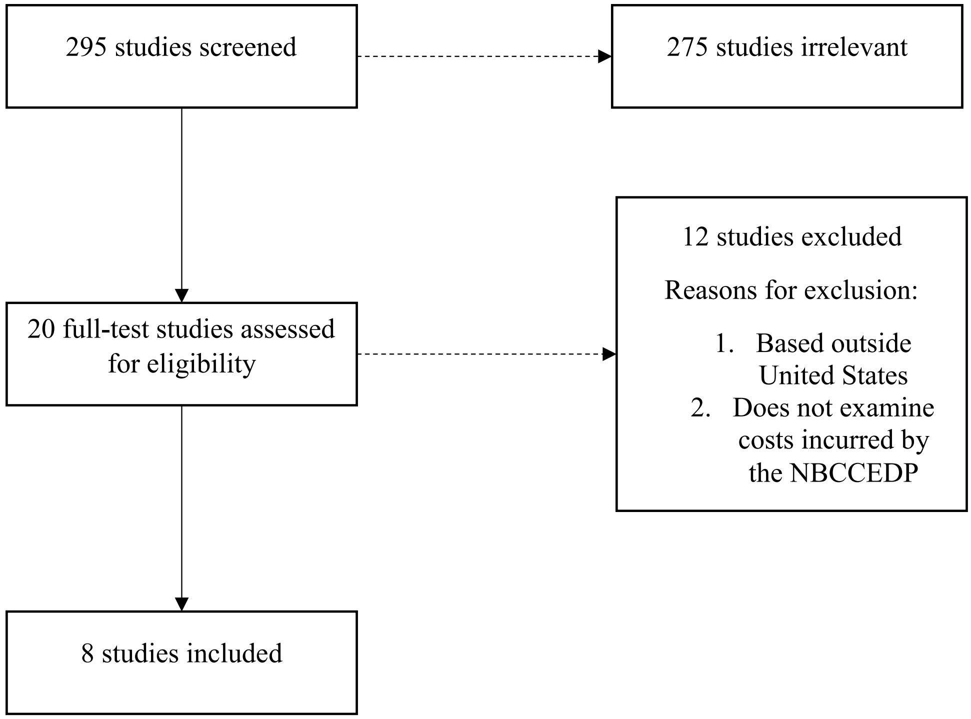

Fig. 1 PRISMA diagram

Results

Study characteristics and findings from the eight full texts reviewed are presented in Table 3. An overview of the quality assessment is provided in Table 4. Out of the eight studies, six studies present only a program cost analysis. Two studies present a cost–utility analysis of breast cancer screening and patient navigation as part of the NBCCEDP and use QALYs to present health outcomes. Five of the eight studies use the payer perspective, two studies use a modified societal perspective, and one study uses the patient perspective. Three papers examine variation in costs among grantees. Seven of the eight papers present direct medical costs, whereas one paper examines direct non-medical costs and indirect costs. Direct medical cost data presented in the studies come from the Web-based cost assessment tool (CAT). Personal costs for women receiving screening as part of NBCCEDP were collected using survey data. Effectiveness measures in the studies were derived from published literature.

Using data from nine NBCCEDP grantees from 2003 to 2004, Ekwueme et al. reported the cost per woman served by the program as $555 including in-kind contributions by providers. The mean cost of screening a woman for breast cancer was $105, and the cost per breast cancer detected was $10,566. For cervical cancer, these costs were $60 and $13,340, respectively [35]. Using data from 63 NBCCEDP grantees from 2006 to 2007, Ekwueme et al. reported cost per woman served by the program as $296 including in-kind contributions. The weighted mean cost of screening for breast cancer was $110, the weighted mean cost of a diagnostic procedure was $401, and the weighted mean cost per breast cancer detected was $35,480. For cervical cancer, the corresponding cost estimates were $61, $415, and $18,995, respectively [15].

Subramanian et al. reported that the average cost of mammograms ranged from $69 to $86 among the nine programs but there was limited variation in the cost of Pap smears. They also reported that there was considerable variation (39–62%) in the service mix offered by programs (proportion of breast screens compared to cervical screens) [36]. Subramanian using data from 51 NBCCEDP grantees from 2010 to 2012 reported mean cost per woman served as $337, with a cost of $205 at the 10th percentile and $499 at the 90th percentile. They also reported that the proportion of breast cancer screens compared to cervical screens ranged from 18 to 72% and this likely impacts the cost per woman as the clinical cost of breast cancer screening is generally higher than cervical cancer screening. The mean cost was $140 for breast cancer screening and $69 for cervical cancer screening. Breast cancer screening cost at the 10th percentile was $89, while the 90th percentile was $205 a difference of $116. For cervical cancer screening, these same percentile costs were $45 and $97, respectively, a difference of $52 [37]. Trogdon et al. reported that some of the cost difference among programs may be explained by their structure (centralized, decentralized, or mixed). Average clinical costs per woman served were lowest for mixed program structures compared to decentralized and centralized program structures. Compared with centralized programs, for each

Table 3 Economic analyses of the National Breast and Cervical Cancer Early Detection Program (NBCCEDP)

Author, year and title	Population and years of data	Type of study/perspective/cost categories included	Outcome measure	Key findings
Ekwueme, 2007 Cost analysis of the National Breast and Cervical Cancer Early Detection Program	Cost assessment tool for nine grantees of the NBCCEDP from July 2003 to June 2004	Cost analysis/payer/direct medical costs including in-kind donations		With in-kind contributions, the cost of screening services to women in nine programs was estimated at $555 per woman served. Without in-kind contributions, this cost was $519. The mean cost of screening a woman for breast cancer was $105, and the cost per breast cancer detected was $10,566. For cervical cancer, these costs were $60 and $13,340, respectively
Ekwueme, 2008 Estimating Personal Costs Incurred by a Woman participating in mammography screening in the National Breast and Cervical Cancer Early Detection Program	Data were collected between 1999 and 2000 from 1870 women who had a mammogram in 1997 through NBCCEDP in Maryland, New York, Ohio, or Texas using the Survey of Mammography Rescreening	Cost analysis/patient/direct non-medical costs and indirect costs		Women with an annual income less than $10,000 incurred a personal cost of $17 per screening and a lifetime discounted cost of $262, whereas women with annual income ranging from $10,000-$20,000 incurred a personal cost of $31 per screening and a lifetime discounted cost of $475. Non-Hispanic white women had the highest personal costs, whereas non-Hispanic women of other races incurred the lowest personal costs
Subramanian, 2008 Identifying and controlling for program-level differences in comparative cost analysis: lessons from the economic evaluation of the National Breast and Cervical Cancer Early Detection Program	Cost assessment tool for nine grantees (3 decentralized, 3 mixed, 3 centralized) and the Minimum Data Set for the 12-month period from July 2003 to June 2004. In addition, qualitative interviews and surveys were conducted with the 9 programs	Cost analysis/payer/direct medical costs		The average cost of a mammogram was $80.95 and $14.83 for a Pap test. The average cost of mammograms ranged from $69.00 to $85.49 among the nine programs. There was limited variation in the average cost of Pap smears among the nine programs. Proportion of breast screens compared to cervical screens (%) ranges from 39.2 to 61.5 among the programs

Table 3 (continued)

Author, year and title	Population and years of data	Type of study/perspective/cost categories included	Outcome measure	Key findings
Ekwueme, 2014 Cost of services provided by the National Breast and Cervical Cancer Early Detection Program	Cost assessment tool for 63 grantees of the NBCCEDP during 2006/2007	Cost analysis/payer/direct medical costs including in-kind donations		Total cost of all NBCCEDP services was $296 (per woman served. The estimated mean cost of screening and diagnostic services for breast cancer was $110 with an office visit and $88 without, the weighted mean cost of a diagnostic procedure was $401, and the weighted mean cost per breast cancer detected was $35,480. For cervical cancer, the corresponding cost estimates were $61, $21, $415, and $18,995, respectively
Subramanian, 2019 Awardee-specific economic costs of providing cancer screening and health promotional services to medically underserved women eligible in the National Breast and Cervical Cancer Early Detection Program	Cost assessment tool for 51 grantees of NBCCEDP during 2010–2012	Cost analysis/payer/direct medical costs including in-kind donations		The mean cost per woman served was $337.01, with a cost of $204.83 at the 10th percentile and $498.98 at the 90th percentile. The mean clinical cost per woman served was $175.02. Awardees at the 10th percentile had a clinical cost per woman served of $112.75, while those at the 90th percentile had a cost of $221.53. The proportion of breast cancer screens ranged from 18 to 72% and this likely impacts the cost per woman as the clinical cost of breast cancer screening is generally higher than cervical cancer screening. The mean cost was $139.98 for breast cancer screening and $69.36 for cervical cancer screening. Breast cancer screening cost at the 10th percentile was $88.5, while the 90th percentile was $204.81, a difference of $116.29. For cervical cancer screening, these same percentile costs were $44.97 and $97.12, respectively, a difference of $52.15

Table 3 (continued)

Author, year and title	Population and years of data	Type of study/perspective/cost categories included	Outcome measure	Key findings
Trogdon, 2019 The effect of delivery structure on costs, screening, and health promotional services in state National Breast and Cervical Cancer Early Detection Program	Cost assessment tool for 51 grantees of NBCCEDP during 2010–2012	Cost analysis/payer/direct medical costs including in-kind donations		Across the 51 state programs, ten were centralized, 17 were decentralized and 24 were mixed. Average clinical costs per woman served were lowest for mixed program structures (breast = $225, cervical = $216) compared to decentralized (breast = cervical = $276) and centralized program structures (breast = $259, cervical = $251). Compared with centralized programs, for each additional woman served, decentralized programs saved costs of $281 (breast) and $284 (cervical). Compared with decentralized programs, for each additional woman served, mixed programs added an additional $109 cost for breast but saved $1,777 for cervical cancer
Rim, 2019 Cost-effectiveness of breast cancer screening in the National Breast and Cervical Cancer Early Detection Program	Cost assessment tool for 51 grantees of NBCCEDP during 2010–2012	Cost–utility analysis/societal/direct medical costs including in-kind donations	Quality-adjusted life-years saved	Breast cancer screening offered by the program improved life-years (incremental life-years gained were 0.025 and 0.075) and QALYs (incremental QALYs gained were 0.024 and 0.071) compared to No Program and No Screening scenarios, respectively. The ICER for the Program was $51,754 per QALY compared to the No Program and $50,223 per QALY compared to the No Screening
Allaire, 2019 Cost-effectiveness of patient navigation for breast cancer screening in the National Breast and Cervical Cancer Early Detection Program	Cost assessment tool for 51 grantees of NBCCEDP during 2010–2012. Costs of patient navigation were obtained from a survey of 42 subcontractors participating in Colorado's "Connect-to-Care" component of the state's NBCCEDP-funded program in 2011	Cost–utility analysis/societal/direct medical costs including in-kind donations	Quality-adjusted life-years saved	NBCCEDP programs with patient navigation resulted in a greater number of mammograms per woman (4.23 vs. 4.14), lower lifetime mortality from breast cancer (3.53% vs. 3.61%), and fewer missed diagnostic resolution per woman (0.017 vs. 0.025). The estimated incremental cost-effectiveness ratios for a program with PN was $32,531 per quality-adjusted life-years relative to programs with no PN

Table 4 Quality assessment results

	Checklist questions/study	Ekwueme 2007	Ekwueme 2008	Subramanian 2008	Ekwueme 2014	Subramanian 2019	Trogdon 2019	Rim 2019	Allaire 2019
1	Is the study population clearly described?	Yes	Yes	Yes	Yes	Partially	Yes	Yes	Yes
2	Are competing alternatives clearly described?	NA	NA	NA	NA	NA	Yes	Yes	Yes
3	Is a well-defined research question posed in answerable form?	Yes	Yes	Partially	Yes	Yes	Yes	Yes	Yes
4	Is the economic study design appropriate to the stated objective?	Partially	Yes	Yes	Yes	Yes	Partially	Yes	Yes
5	Is the chosen time horizon appropriate to include relevant costs and consequences?	Yes	Partially	Partially	Partially	Partially	Partially	Yes	Partially
6	Is the actual perspective chosen appropriate?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	Are all important and relevant costs for each alternative identified?	Yes	Yes	Yes	Yes	Yes	Yes	No	No
8	Are all costs measured appropriately in physical units?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	Are costs valued appropriately?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	Are all important and relevant outcomes for each alternative identified?	NA	NA	NA	NA	NA	Partially	Yes	Yes

Table 4 (continued)

	Checklist questions/study	Ekwueme 2007	Ekwueme 2008	Subramanian 2008	Ekwueme 2014	Subramanian 2019	Trogdon 2019	Rim 2019	Allaire 2019
11	Are all outcomes measured appropriately?	NA	NA	NA	NA	NA	Yes	Yes	Yes
12	Are outcomes valued appropriately?	NA	NA	NA	NA	NA	Yes	Yes	Yes
13	Is an incremental analysis of costs and outcomes of alternatives performed?	NA	NA	NA	NA	NA	Yes	Yes	Yes
14	Are all future costs and outcomes discounted appropriately?	NA	Yes	NA	NA	No	No	Yes	Yes
15	Are all important variables, whose values are uncertain, appropriately subjected to sensitivity analysis?	No	Yes	No	No	No	Yes	Yes	Yes
16	Do the conclusions follow from the data reported?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
17	Does the study discuss the generalizability of the results to other settings and patient/client groups?	No	Yes	Yes	No	No	Yes	Yes	No
18	Does the article indicate that there is no potential conflict of interest of study researcher(s) and funder(s)?	No	No	No	Yes	No	Yes	Yes	Yes

Table 4 (continued)

	Checklist questions/study	Ekwueme 2007	Ekwueme 2008	Subramanian 2008	Ekwueme 2014	Subramanian 2019	Trogdon 2019	Rim 2019	Allaire 2019
19	Are ethical and distributional issues discussed appropriately?	No	No	Yes	No	No	No	Yes	No

additional woman served, decentralized programs saved costs of $281 for each woman served for breast cancer and $284 for cervical cancer. Compared with decentralized programs, for each additional woman served, mixed programs added an additional $109 cost for each woman served for breast cancer but saved $1,777 for cervical cancer [38].

Ekwueme et al. is the only study that examined personal non-medical direct costs and indirect cost incurred by women who use NBCCEDP services. Women with an annual income less than $10,000 incurred a personal cost of $17 per screening and a lifetime discounted cost of $262, whereas women with annual income ranging from $10,000 to $20,000 incurred a personal cost of $31 per screening and a lifetime discounted cost of $475. Ekwueme et al. also reported that non-Hispanic white women ($7 per screening and $102 in lifetime discounted costs among women with annual income < $10,000 and $13 per screening and $190 in lifetime discounted costs among women with annual income between $10,000 to $20,000) had the highest personal costs whereas non-Hispanic women of other races ($2 per screening and $25 in lifetime discounted costs among women with annual income < $10,000 and $3 per screening and $45 in lifetime discounted costs among women with annual income between $10,000 to $20,000) incurred the lowest personal costs [39].

Rim et al. examined the cost-effectiveness of breast cancer screening in the NBCCEDP. Breast cancer screening offered by the program improved life-years (incremental life-years gained were 0.025 and 0.075) and QALYs (incremental QALYs gained were 0.024 and 0.071) compared to No Program and No Screening scenarios, respectively. The ICER for the program was $51,754 per QALY compared to the No Program and $50,223 per QALY compared to the No Screening [40]. Allaire et al. examined the cost-effectiveness of implementing patient navigation services within the NBCCEDP. NBCCEDPs with patient navigation resulted in a greater number of mammograms per woman (4.23 vs. 4.14), lower lifetime mortality from breast cancer (3.53% vs. 3.61%), and fewer missed diagnostic resolution per woman (0.017 vs. 0.025). The estimated incremental cost-effectiveness ratios for a program with PN were $32,531 per quality-adjusted life-years relative to programs with no PN [41].

Discussion

This study presented a brief overview of economic analysis methods followed by a systematic review of existing literature that applied these methods for evaluation of the NBCCEDP. Six program cost analysis and two cost–utility studies were reviewed. Some papers also examined variation in these estimates among NBCCEDP grantees. Most of these papers utilized cost assessment data prior to 2012. There is a dearth of economic analysis of NBCCEDP using newer data. Most of the reviewed studies excluded data from tribes and territories and restricted to 50 states and DC. There is no literature regarding program cost analysis and variation among these costs for tribe and territory grantees of the NBCCEDP. Only one paper examined direct non-medical and indirect costs incurred by patients using data that are nearly two decades old. While the studies by Rim et al. and Allaire et al. suggest that they employ a societal perspective, these studies did not include all direct non-medical and indirect costs associated with receiving services under the NBCCEDP. No cost–benefit analysis or budget impact analysis of the NBCCEDP were identified in previous literature. Thus, there are considerable gaps in the literature on economic evaluation of the NBCCEDP.

Economic evaluation of public health programs for underserved populations, such as CDC's NBCCEDP, can help identify effective and efficient use of public health resources. A systematic, transparent economic analysis can help to demonstrate value and guide decisions to implement effective public health programs that may improve efficiency and equity in allocating resources to all subgroups of the population. While the heterogeneity of the included studies prevented a quantitative synthesis of evidence across studies, the results of this study may guide future researchers to address the gaps in the literature on evaluation of the NBCCEDP identified in this paper. These gaps can be addressed by using more recent cost data, including all grantees, adding costs other than direct medical costs, and evaluating the budget impact of the existing program or any future changes to the program.

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