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A Decade of the National Center for HIV, Viral Hepatitis, STD, and TB Prevention's Epidemiologic and Economic Modeling Agreement

Taiwo O. Abimbola, PhD[1], **Michelle Van Handel, MPH**[1], **Suzanne M. Marks, MPH**[2], **Garrett R. Beeler Asay, PhD**[2], **Amy Sandul, PhD**[3], **Thomas L. Gift, PhD**[4], **Marcus D. Durham, MPH**[5], **Sanjana Pampati, PhD**[6], **Joshua A. Salomon, PhD**[7], **Erika G. Martin, PhD**[8], **Jonathan Mermin, MD**[1]

[1]Office of the Director, National Center for HIV, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention, Atlanta, GA, USA

[2]Division of TB Elimination, National Center for HIV, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention, Atlanta, GA, USA

[3]Division of Viral Hepatitis, National Center for HIV, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention, Atlanta, GA, USA

[4]Division of STD Prevention, National Center for HIV, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention, Atlanta, GA, USA

[5]Division of HIV Prevention, National Center for HIV, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention, Atlanta, GA, USA

[6]Division of Adolescent and School Health, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, GA, USA

[7]Department of Health Policy, Stanford University School of Medicine, Stanford, CA, USA

[8]Department of Public Administration and Policy, Rockefeller College of Public Affairs and Policy, University at Albany, State University of New York, Albany, NY, USA

Abstract

In 2014, the Centers for Disease Control and Prevention (CDC) expanded capacity to conduct infectious disease and economic modeling through the National Center for HIV, Viral Hepatitis, STD, and TB Prevention Epidemiologic and Economic Modeling Agreement (NEEMA). NEEMA brought together CDC scientists, academic partners, and public health practitioners at state and local levels to use epidemiologic and economic modeling to support the understanding of

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Corresponding Author: Taiwo O. Abimbola, PhD, Centers for Disease Control and Prevention, National Center for HIV, Viral Hepatitis, STD, and TB Prevention, Office of the Director, 1600 Clifton Rd, Atlanta, GA 30329, USA. tabimbola@cdc.gov.

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the efficiency, outcomes, cost-effectiveness, return on investment, and impact of programs and policies related to the center's disease foci, priority populations, and settings. In collaboration with state and local health departments, NEEMA activities included the development of tools to aid forecasting and decision-making. This article summarizes the scientific contributions and lessons learned from the NEEMA collaboration. During 2014–2024, NEEMA produced 136 peer-reviewed studies and 8 decision support tools. These studies have been cited 2697 times in peer-reviewed literature and referenced more than 70 times in policy documents. NEEMA has expanded the knowledge base on effective and cost-effective high-impact interventions for HIV, viral hepatitis, STD, and tuberculosis programs and continues to be responsive to changing needs for evidence to inform decision-making and policy.

Keywords

STD/STI; HIV; tuberculosis; viral hepatitis; adolescent health

Mathematical models incorporating epidemiologic and economic factors can estimate potential future public health effects, costs, and cost-effectiveness of interventions and programs and can be used to provide insight into the impact and economics of policy changes and initiatives. The Centers for Disease Control and Prevention (CDC) has a responsibility to detect and respond to existing and emerging health threats, determine the most effective and efficient methods to prevent morbidity and mortality, and use science, technology, and other tools to prevent disease, save lives, and improve health. CDC leverages models to project disease and health outcome trends, assess the value of public health programs, and inform evidence-based decision-making through intramural and extramural arrangements.[1–3] Before NEEMA, CDC's National Center for HIV, Viral Hepatitis, STD, and TB Prevention (NCHHSTP) had epidemiologists and economists working in this area in several divisions, using modeling to aid in understanding the efficiency, outcomes, and impact of programs and policies. However, a noticeable gap existed in NCHHSTP's capacity to answer the public health questions that required novel modeling efforts to address. In response, NCHHSTP issued the NCHHSTP Epidemiologic and Economic Modeling Agreement (NEEMA) through a competitive process.[4] NEEMA brought together CDC scientists, academic partners, and public health practitioners at the state and local levels in a collaborative structure.

The first NEEMA cooperative agreement began in 2014 (CDC-RFA-PS14-1415).[5] The original cooperative agreement (henceforth, NEEMA-1) aimed to facilitate timely and rigorous science and address challenging epidemiological topics such as estimating future trends in disease incidence and prevalence and cost-effectiveness of health interventions. NEEMA-1 was the first cooperative agreement by NCHHSTP to foster cross-division and external collaboration on disease modeling across HIV, viral hepatitis, sexually transmitted disease (STD), tuberculosis, and adolescent and school health programs. NCHHSTP launched NEEMA-2 (CDC-RFA-PS19-1905) in 2019 and expanded the scope for NEEMA-2 in 2021 through the American Rescue Plan (ARP) Act.[6]

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NEEMA-1 focused on disease models (eg, epidemic forecasting, estimates of population-level disease incidence and prevalence) and economic models (eg, economic burden of illness, cost analysis of interventions, cost-effectiveness analysis, resource allocation studies). NEEMA-2 expanded the scope with ARP funding to include predictive modeling, machine learning, budget impact analysis, and policy analysis. The expansion of NEEMA-2 increased the dissemination of tools for use by public health practitioner and policy-making audiences.

NEEMA-2 funded 2 consortia: the Prevention Policy Modeling Lab (PPML) and the Coalition for Applied Modeling for Prevention (CAMP). The PPML consortium was led by Harvard University in NEEMA-1 and by Stanford University in NEEMA-2, in partnership with the same modelers from Boston Medical Center, Boston University, Brown University, Yale University, the University of Michigan, and the Massachusetts Department of Public Health. PPML has used simulation modeling, modeling of epidemiology and disease burden, decision analysis, and economic evaluation to assess the effectiveness, impact, costs, and cost-effectiveness of prevention and treatment interventions.[7] CAMP, led by Emory University in NEEMA-1 and the University at Albany, State University of New York, in NEEMA-2, includes modelers from Johns Hopkins University, the University of Washington, Georgia State University, Oregon Health Sciences University, the University of California San Diego, and the Public Health Accreditation Board. CAMP created and adapted models to support public health decision-making and effectiveness at the national, state, and local levels.[8] CAMP also engages with 2 advisory groups, the Public Health Advisory Group and the National Policy Advisory Group, comprising leaders from national and local nongovernmental organizations, state and local health departments, and community-based organizations to support translation and dissemination of its work.

Methods

We conducted a search of the Scopus and Altmetric databases for NEEMA studies using the digital object identifiers (Supplemental Material), and we summarized key findings from NEEMA-funded research from 2014 to 2024. This activity was reviewed by CDC and was conducted consistent with applicable federal law and CDC policy (eg, protection of human subjects, 45 CFR part 46 [2018]; institutional review board, 21 CFR part 56 [1981]; public health and welfare, research and investigations generally, 42 USC §241[d] [2018]; public information; agency rules, opinions, orders, records, and proceedings: records maintained on individuals, 5 USC §552a [2012]; and the Paperwork Reduction Act, 44 USC §3501 et seq [1995]). The CDC Human Research Protections Office issued a nonresearch determination for this activity, which did not collect data from individuals.

Outcomes

NEEMA collaboration activities have informed and improved NCHHSTP programs through the development of analytic tools and publication of peer-reviewed scientific products that support the evidence base for public health action and decision-making. NEEMA collaborators produced web-based and spreadsheet analytic tools for use by public health practitioners (Table).[9–23] Each tool has been disseminated through a peer-reviewed

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publication and has provided ongoing technical assistance for use. Another NEEMA tool was developed for the Division of STD Prevention to generate customizable surveillance aberration data reports to jurisdictions to help identify aberrations in surveillance data.

Since 2014, NEEMA collaborators have supported the development of 136 peer-reviewed articles (Figure 1), expanding our knowledge of HIV, viral hepatitis, STDs, tuberculosis, and adolescent/school health. These peer-reviewed articles include estimates of the prevalence and incidence of disease across selected areas in the United States, size of key populations, and potential impact and costs of prevention, testing, and treatment interventions. The extensive impact of the overall portfolio of NEEMA studies is in part reflected by numerous citations of NEEMA work, starting in 2016 when the first NEEMA article was published (Figure 2). As of October 2024, the articles published during 2018 and 2019 had received the greatest number of citations. Findings from NEEMA models have been used in policy-making primarily through 2 mechanisms: (1) by the CDC Advisory Committee for Immunization Practices and (2) to support the development of guidelines and recommendations for CDC, the US Preventive Services Task Force, the World Health Organization, and other institutions.[24–46] From 2017 through 2024, NEEMA-funded studies were referenced 70 times as policy citations according to Altmetric, which compiles mentions of journal articles in policy sources including government guidelines, reports, and white papers, by using text mining to match the records from a policy document to the journal article.[47] These NEEMA studies addressed prevention, screening, testing, and treatment of HIV, STDs, hepatitis A, hepatitis B, hepatitis C, tuberculosis, and latent tuberculosis infection (LTBI).[48–78]

HIV

NEEMA models have made noteworthy contributions to the scientific literature on HIV diagnosis, treatment, and prevention.[48,61,64,79–110] A NEEMA modeling study was the first to estimate the overall effect of implementing CDC's 2014 clinical practice guideline for preexposure prophylaxis (PrEP) use among men who have sex with men (MSM).[48] NEEMA investigators found that implementing PrEP consistent with the 2014 CDC guideline could facilitate decreased HIV prevalence and incidence, averting 33% of new infections among MSM during the 10 years after initiation of the guideline, assuming PrEP coverage of 40% and 62% drug adherence. This NEEMA publication was the first to explicitly incorporate behavioral indications for PrEP use among MSM using a dynamic sexual network model after the US Food and Drug Administration's approval of PrEP and the publication of the 2014 CDC clinical practice guideline.[111,112]

Viral Hepatitis

The past decade ushered in renewed attention to viral hepatitis in the United States. NEEMA-funded studies have contributed to closing knowledge gaps in the health and economic benefits of viral hepatitis prevention and treatment in the United States.[22,27,53,55,58,63,113–132] In 2023, CDC recommended 1-time universal screening for hepatitis B among adults.[129] The new recommendation incorporated findings from a NEEMA study that estimated that, compared with risk-based testing, universal hepatitis B screening of adults could result in 135 quality-adjusted life years gained per 100 000 adults

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screened.[127] During 2021–2022, a NEEMA modeling study was used to determine the most cost-effective timing and type of testing approach for infants born to pregnant women with hepatitis C. Findings were used to show efficacy and cost-effectiveness considerations in CDC's 2023 recommendations for hepatitis C testing among perinatally exposed infants and children in the United States.[27,124] The NEEMA investigators found that testing infants at age 2 to 6 months with a nucleic acid test could result in increased diagnosis, improved health outcomes, and potential cost savings compared with testing hepatitis C–exposed children at age ≥18 months.[124]

STDs

NEEMA has supported modeling of STD strategies and interventions to guide public health decisions and policies during the past decade.[49,59,60,62,78,89,96,97,133–156] NEEMA-2 supported updates of 2 sexually transmitted infection (STI) tools: the STI Prevention Allocation Consequences Estimator (SPACE) Tool and the STI Costs (STIC) Figure tool.[17,19] The SPACE Tool was originally developed by CDC staff to assist health departments with estimating the effect of changes in STI prevention budgets on health care costs and averted infections in their jurisdictions. The STIC Figure and SPACE tools were updated by using a human-centered design process.[16,18] The STI tools update included revisions to model parameters and scientific methods and engagement with national, state, and local public health officials to modify the algorithm, user interface, and functionalities based on users' feedback on the original tool. NEEMA-2 launched a comprehensive dissemination strategy to promote both STI tools.

Adolescent/School Health

NEEMA has also focused on modeling interventions to promote health and disease prevention among young people.[20,21,80,82,87,92,97,101,105,143,157–159] Some NEEMA studies on adolescent and school health interventions focused on estimating the effects of STI screening and behavior change in areas with various prevalence of infection. For example, a chlamydia transmission model was adapted to epidemiological data for 2 cities with a high prevalence of chlamydia (Philadelphia and Chicago) and 1 setting with a low prevalence of chlamydia (rural Iowa) to measure the effects of STI screening coverage on chlamydia prevalence.[141] This study found that sustained high coverage levels of STI screening and high program participation levels in a school-based screening program were required to reduce chlamydia transmission among adolescents in settings with a high or low risk of chlamydia.[141] Another NEEMA study evaluated the effect of sexual risk behavior change on STIs among adolescents in New York State based on the NEEMA teen STI Prevention and Risk Calculator for Adolescents (teen-SPARC) tool.[20,21] Application of the teen-SPARC tool to New York State data estimated the effect of decreased condom use among adolescents on the risk of acquiring chlamydia, gonorrhea, and HIV. The study demonstrated how state and local health departments can use a publicly available tool to model the effects of behavioral interventions for STI prevention among adolescents.

Tuberculosis

NEEMA-1 focused on estimating time to tuberculosis elimination and on interventions for tuberculosis and LTBI.[50,57,73–75,77,160–163] Tuberculosis studies during NEEMA-1 are

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described elsewhere.[164] NEEMA-2 tuberculosis studies focused on estimating racial and ethnic disparities in tuberculosis incidence and outcomes and their associated medical and socioeconomic factors, transmission, progression rates of nonrecent infections, and the future effects on the United States as the result of combined domestic and international tuberculosis interventions.[52,65–72,165–174] A NEEMA study found persistent disparities in tuberculosis incidence among US-born patients with tuberculosis, by race and ethnicity, with greater relative disparities among American Indian/Alaska Native people, females, and people aged 0 to 14 and 15 to 24 years, and absolute disparities greater for males than for females.[168]

While tuberculosis prevention and treatment efforts have improved outcomes among US-born people overall, a higher risk of any adverse tuberculosis disease outcome (eg, diagnosis after death, treatment discontinuation, death during treatment) persists for some US-born people, relative to non-Hispanic White people.[171,173] Racial and ethnic disparities were estimated to be associated with 45% of tuberculosis cases and 44% of tuberculosis deaths during 2023–2035, and an economic cost of $914 million.[172] The biggest contributors to tuberculosis disparities for Black and Hispanic people were end-stage renal disease, HIV, and census tract–level racialized economic segregation or poverty.[171] A NEEMA model of 4 US states (California, Florida, New York, and Texas) estimated that 0.24% of people with tuberculosis generate 19% of secondary transmissions in those states.[166] People aged ≥50 years were estimated to have declining tuberculosis reactivation rates as time since infection increased, while LTBI testing and treatment among Medicare-eligible adults aged ≥65 years with elevated tuberculosis risk were found to be effective at preventing cases and deaths.[174] Other NEEMA modeling found that combining hypothetical domestic and international interventions could avert 101 000 tuberculosis cases and 13 000 deaths during 2025–2050 and achieve US tuberculosis pre-elimination (<1 case per 100 000 people) by 2033.[169]

Syndemics

NCHHSTP has leveraged NEEMA to bring expertise together from across the agency to address interrelated issues such as the syndemic of viral hepatitis, HIV, STIs, and injection drug use. A syndemic in the context of HIV, viral hepatitis, STD, and tuberculosis is when one of these infections clusters with ≥1 other infection or health condition within a specific population, driven by contextual, structural, and social factors, increases the adverse effects on the health of people and communities.[175] STIs such as gonorrhea and chlamydia can increase acquisition and transmission of HIV.[76] NEEMA modelers estimated that 10% of incident HIV infections among MSM were attributable to chlamydia and gonorrhea infections.[61] Several NEEMA studies analyzed the effect of STI prevention and treatment interventions on HIV incidence in the United States. These studies estimated the attributable effects of STI screening, HIV PrEP, and STI treatment interventions on reduced risk for HIV acquisition. Increasing annual screening for gonorrhea and chlamydia by 60% among MSM was estimated to reduce HIV infections during 10 years by 4.7% overall and by 9.8% among MSM with multiple recent sex partners.[104] Another study estimating the effects of STI screening and adherence to PrEP on HIV incidence found that 60% screening uptake and 60% adherence to PrEP (based on earlier 2014 CDC PrEP guidelines), compared with

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no PrEP, could reduce HIV incidence among MSM in Baltimore City, Maryland, by 12.4% during a 20-year period.[98]

Lessons Learned

NEEMA has resulted in an improved understanding of effective and cost-effective high-impact interventions for HIV, viral hepatitis, STD, and tuberculosis programs and continues to be responsive to changing needs for evidence to inform decision-making and policy. The NEEMA cooperative agreement exemplifies CDC's role as a collaborator (not only as the funder), bringing academic partners and internal disease experts together to use modeling studies to inform decisions and policies for HIV, viral hepatitis, STD, and tuberculosis programs. A new era of NEEMA is outlined in the most recent funding opportunity announced by CDC on February 5, 2024 (NEEMA-3, CDC-RFA-PS24-0028).[176] NEEMA-3 applies lessons learned from NEEMA-1 and NEEMA-2. The objectives of NEEMA-3 are to (1) maximize the use of models to drive public health improvement efforts for HIV, viral hepatitis, STD, tuberculosis, and related syndemics; (2) support scientific discovery and evaluation of programs and interventions; and (3) translate findings for broader public health use and elimination efforts for HIV, viral hepatitis, STD, and tuberculosis. One key change is that NEEMA-3 allows for the development and implementation of federally funded research that aligns with NCHHSTP-related public health priorities; such work was not in scope for NEEMA-1 and NEEMA-2.[177] This additional capacity facilitates activities that produce generalizable results and expands the extent to which new epidemiologic and economic data can be collected to support NCHHSTP priorities. Another key change is an expanded focus on partnerships with state and local health departments to facilitate real-world adaptations and applications of NEEMA tools. Lastly, in addition to disease-specific modeling priorities, the new cooperative agreement expands the syndemic approach to modeling and provides additional support for novel approaches to modeling.

The changes incorporated into NEEMA-3 address the increasing need for advanced modeling techniques and collection of new data—especially cost data—to close information gaps and translate model findings into actions that state and local public health partners can take to address interrelated underlying factors for HIV, viral hepatitis, STD, and tuberculosis. Through NEEMA-3, NCHHSTP will continue to build the evidence base to support and guide informed decision-making to improve prevention, screening, testing, and treatment; reduce new infections; and improve health equity for people with and at increased risk for HIV, viral hepatitis, STD, and tuberculosis.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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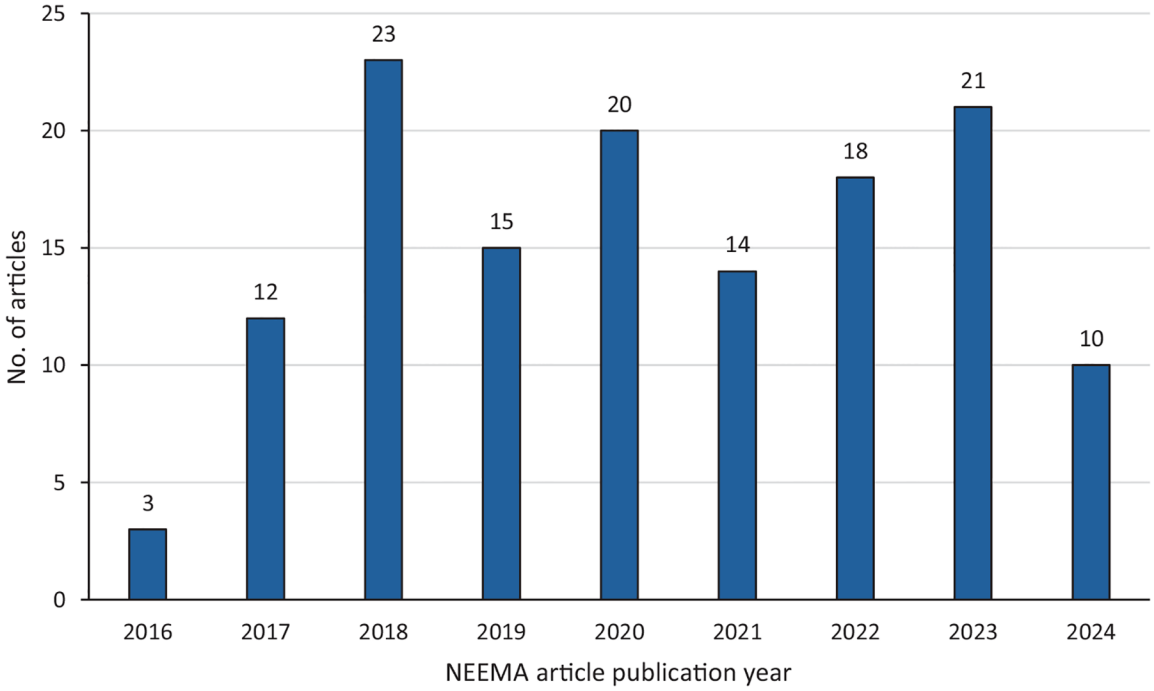


Figure 1.
Published articles by year of publication for National Center for HIV, Viral Hepatitis, STD, and TB Prevention's Epidemiologic and Economic Modeling Agreement (NEEMA), United States, 2016–2024. Articles published by NEEMA collaborators as of October 23, 2024.

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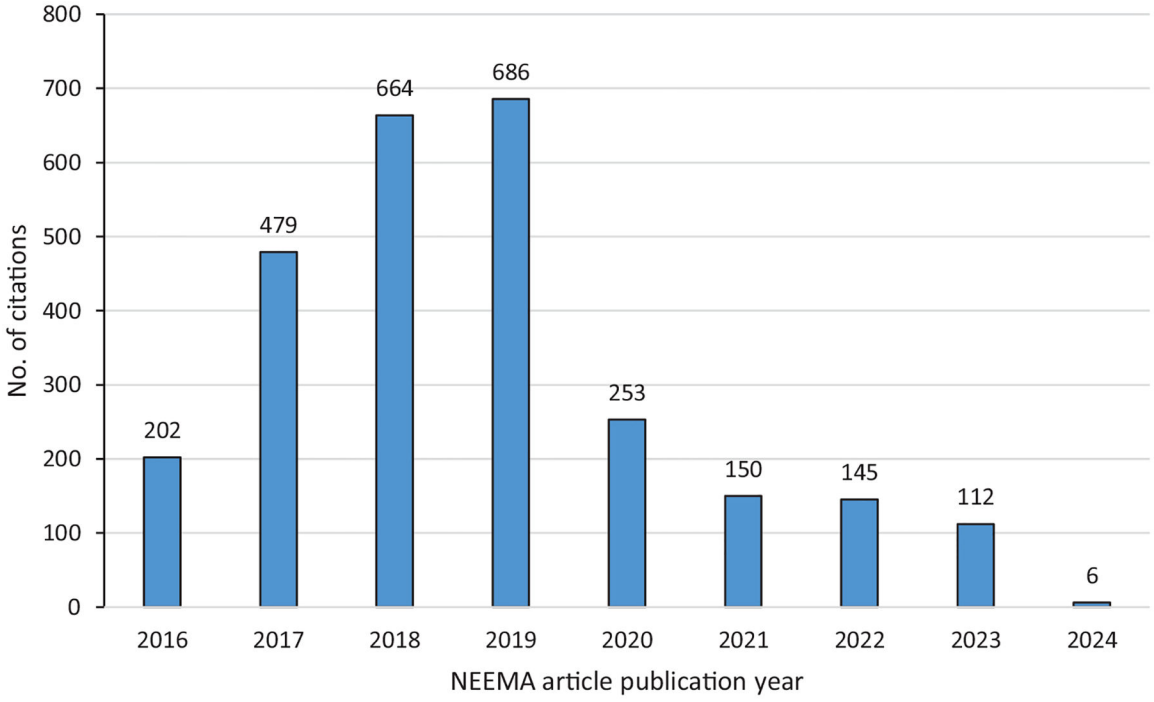


Figure 2.

Number of citations by original article publication year for National Center for HIV, Viral Hepatitis, STD, and TB Prevention's Epidemiologic and Economic Modeling Agreement (NEEMA) publications, United States, 2016–2024. Data source: Citations of NEEMA publications captured in Scopus as of October 23, 2024, including self-citations. The *x*-axis reflects the year of original NEEMA publication. For example, the 3 NEEMA publications in 2016 (Figure 1) resulted in 202 citations as of October 23, 2024. The citation count by year of citation is presented in the supplement.

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Table.

Decision support tools developed for the National Center for HIV, Viral Hepatitis, STD, and TB Prevention's Epidemiologic and Economic Modeling Agreement (NEEMA), United States, 2014–2024

Disease and tool[a]	Objectives and scope	Audience and perspective	Methods and scenarios	How the tool can be used
Tuberculosis (TB)				
Tabby2: a user-friendly web tool for forecasting state-level TB outcomes in the United States[9,10]	This tool explores the impact of TB elimination strategies on outcomes, including costs, disease outcomes, and cost-effectiveness, by US state and nationally.	Audience: state and local health departments Perspective: TB program and societal perspective	Transmission-dynamic model that incorporates disease progression risk, treatment history, mortality risk, nativity (ie, US-born and non–US-born), and sociodemographic components Five scenarios predefined for latent TB infection (LTBI) testing and treatment: testing and treatment for all new immigrants, increased uptake of LTBI testing and treatment among populations at high risk for TB, improved detection, improved treatment quality, and combination of individual scenarios (all improvements), which were compared with the status quo. Users can also define custom scenarios by modifying assumptions about testing and treatment cascades or adding similar interventions.	To estimate the costs, impact, and cost-effectiveness of different TB prevention strategies TB elimination strategies in the 50 US states and the District of Columbia
Examining the impact, cost, and cost-effectiveness of targeted testing and treatment for LTBI in key populations in California, Florida, New York, and Texas[11,12]	This tool projects the impact, cost, and cost-effectiveness of increased targeted testing and treatment (TTT) of LTBI among various populations at high risk for TB in 4 states (California, Florida, New York, and Texas).	State health departments—health system perspective	Transmission-dynamic model incorporating demographic processes, TB risk factors, and natural history of disease using historical data from 1993 to 2013 Scenario modeled: increased TTT to identify, evaluate, and treat people at high risk for LTBI or at elevated risk for TB disease (populations: non–US-born people, people with diabetes, people with HIV, incarcerated people, and people with a recent history of homelessness)	To generate estimates of impact and cost-effectiveness of TTT for LTBI among key populations in 4 US states
HIV				
Estimates of people with indications for preexposure prophylaxis (PrEP) in 2015[13,14]	This tool estimates the number of individuals indicated for PrEP in 2015 by state and transmission risk group, for US states and nationally.[14,15]	Health systems perspective	Multiplier method Estimates by transmission category (ie, men who have sex with men, heterosexual people, and people who inject drugs)	To estimate the number of adults in the United States who were indicated for PrEP based on 2015 data
STD				
STI data aberration detection tool, an annotated statistical code for use on national STI surveillance data; not publicly available[15]	This tool is used by CDC's Division of STD Prevention to generate customized reports that identify data aberrations in national STI surveillance data, supplementing existing data quality reports sent to jurisdictions. The tool uses data from US states and other jurisdictions submitting STI data to the National Notifiable Diseases Surveillance System.	CDC's Division of STD Prevention—STD program perspective	Annotated statistical code that uses national STI surveillance data to generate charts and tables to facilitate the identification of data aberrations Three statistical methods for data aberration included in the code	To provide customized data quality reports to jurisdictions to help identify aberrations in surveillance data throughout the year, enabling identification and intervention on data quality issues and potential outbreaks more quickly
STI Prevention Allocation Consequences Estimator (SPACE) tool[16,17]	This tool estimates the impact of changes in STI prevention budgets on incidence of and direct medical costs for STI and HIV. The tool adapts data from US states and	States and other directly funded jurisdictions and partners—STD program perspective	Impact of changes in STD resources based on observed relationship between state-level STI funding and subsequent STI rates ("historical formula approach"); model developed through a user-centered design process	To estimate the impact of changes in prevention budget to federally funded entities on STI outcomes

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Disease and tool[a]	Objectives and scope	Audience and perspective	Methods and scenarios	How the tool can be used
	other directly funded jurisdictions (eg, large cities).	(cost impacts are estimated from societal perspective)		
STI Costing (STIC Figure)[18,19] Spreadsheet interface not available online	This tool allows users (ie, states and local jurisdictions, STI clinics, anyone providing STI/HIV prevention services) to estimate the economic benefits of STI/HIV prevention efforts.	STD program personnel—societal perspective	Formulas applied to estimate the direct medical costs and productivity costs averted by STI programs. Estimated health benefits include outcomes for treating and delivering partner services interventions for primary and secondary syphilis, gonorrhea, and chlamydia; and partner services related to HIV (eg, delivering preexposure prophylaxis and linkage to HIV care).	To generate evidence-based estimates of the health and economic impact of STI prevention efforts, including HIV-related prevention activities
STI prevention and risk calculator for adolescents (teen-SPARC)[20,21]	This tool allows health departments to estimate the short-term impact of behavior change on the prevalence of STIs among adolescents, including the cost of interventions.	State and local health departments Health system perspective	Transmission-dynamic model incorporating sexual behavior, demographic characteristics, and HIV/STI Surveillance data among adolescents aged 13 to 18 years The tool includes 1 non-intervention or base case and a second customizable intervention that allows users to select changes to behavioral inputs.	To predict cases of STI prevented among teens based on changes in condom use
Viral hepatitis				
Hepatitis C virus (HCV) prisons simulation tool[22,23]	This tool compares the population health benefits and budget impact of strategies for hepatitis C prevention and treatment in corrections and detention facilities.	Corrections departments—facility perspective	Transmission-dynamic model of HCV screening, treatment, and linkage to care Fifteen predefined strategies based on 3 permutations of testing, treatment, and linkage to care	To estimate and compare the population health benefits and budgetary impact of hepatitis C testing, treatment, and linkage to care

Abbreviations: CDC, Centers for Disease Control and Prevention; HCV, hepatitis C virus; STD, sexually transmitted disease; STI, sexually transmitted infection.

[a]The Preexposure Prophylaxis (PrEP) Populations tool was developed as a proof of concept based on Smith et al[13] and has not been updated.