Benchmarks for Reducing Emergency Department Visits and Hospitalizations Through Community Health Workers Integrated Into Primary Care

A Cost-Benefit Analysis

Sanjay Basu, MD, PhD,†‡ Helen E. Jack, BA,§‖ Sophia D. Arabadjis, MSc,§ and Russell S. Phillips, MD§¶*

Background: Uncertainty about the financial costs and benefits of community health worker (CHW) programs remains a barrier to their adoption.

Objectives: To determine how much CHWs would need to reduce emergency department (ED) visits and associated hospitalizations among their assigned patients to be cost-neutral from a payer's perspective.

Research Design: Using a microsimulation of patient health care utilization, costs, and revenues, we estimated what portion of ED visits and hospitalizations for different conditions would need to be prevented by a CHW program to fully pay for the program's expenses. The model simulated CHW programs enrolling patients with a history of at least 1 ED visit for a chronic condition in the prior year, utilizing data on utilization and cost from national sources.

Results: CHWs assigned to patients with uncontrolled hypertension and congestive heart failure, as compared with other common conditions, achieve cost-neutrality with the lowest number of averted visits to the ED. To achieve cost-neutrality, 4–5 visits to the ED would need to be averted per year by a CHW assigned a panel of 70 patients with uncontrolled hypertension or congestive heart failure—approximately 3%–4% of typical ED visits among such patients, respectively. Most other chronic conditions would require between 7% and 12% of ED visits to be averted to achieve cost-savings.

Conclusion: Offsetting costs of a CHW program is theoretically feasible for many common conditions. Yet the benchmark for reducing ED visits and associated hospitalizations varies substantially by a patient's primary diagnosis.

Key Words: community health workers, health care utilization, microsimulation, health care costs, chronic disease management

(*Med Care* 2016;00: 000–000)

Common, chronic medical conditions are associated with much of morbidity, mortality, and health care costs in the United States.[1,2] A small proportion of patients with chronic medical conditions are responsible for a disproportionate fraction of costs, particularly costs associated with emergency department (ED) visits and inpatient hospitalizations.[1,3,4] Some programs have employed community health workers (CHWs) to help improve disease management for patients with chronic conditions, potentially reducing ED visits and hospitalizations. The CHW movement has blossomed in an attempt to address social determinants of health and provide culturally competent care for underserved populations, often focusing on the prevention and treatment of common chronic diseases. Typically, CHWs are employed by primary health care practices to connect with patients at their home or in other community sites, providing health education; assisting with medication adherence, social services, and appointments; and/or facilitating health-related behavior change.[5] Despite prior demonstration projects and randomized trials revealing both improved medical outcomes and cost-savings from CHW programs,[6–8] uptake of CHWs within primary care has been slow.[9] Most CHW programs are grant supported, with few sustainably funded by traditional payers, such as health insurance companies.[10,11]

Evidence from randomized trials reveals that CHW interventions may decrease ED visits or hospitalizations for patients with asthma [hospitalizations: RR = 0.61 (0.45–0.83)],[12] recently incarcerated patients with multiple chronic conditions [annual ED visit: IRR = 0.49 (0.34–0.70)],[6] and patients with diabetes [ED visits: RR = 0.77 (0.59–1.00)].[13] Nonrandomized trials have reported reductions in ED visits or hospitalizations

From the *Centers for Health Policy, Primary Care and Outcomes Research; †Prevention Research Center; ‡Center on Poverty and Inequality, Stanford University, Stanford, CA; §Center for Primary Care, Harvard Medical School, Boston, MA; ‖Institute of Psychiatry, Psychology, and Neuroscience, King's College London, London, UK; and ¶Division of General Medicine and Primary Care, Beth Israel Deaconess Medical Center, Boston, MA.

Research reported in this publication was supported by the National Institute On Minority Health And Health Disparities of the National Institutes of Health under Award Number DP2MD010478. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Supported by the Harvard Medical School Center for Primary Care and the Massachusetts Department of Public Health (grant number: 225307).

For the duration of this research, R.S.P. was an advisor to Rise Labs, a start-up that provides web-based nutrition coaching to individuals. He no longer serves in this role. The other authors declare no conflict of interest.

Reprints: Helen E. Jack, BA, Harvard Medical School Center for Primary Care, 635 Huntington Avenue, Second floor, Boston, MA 02115. E-mail: helen_jack@hms.harvard.edu.

ISSN: 0025-7079/16/000-000

for patients with asthma[14–18]; hypertension, type II diabetes, or heart failure[19]; and high utilizing patients with chronic conditions.[20,21] Effects of CHW interventions on health care utilization, however, have been variable; although some CHW interventions reduce utilization for patients with chronic conditions, others have no effect when evaluated against a randomized control population.[22–25]

Although reductions in utilization provides an important indicator of cost reduction and improvement in disease management, it does not answer a critical question for many payers: what benchmark level of success must be achieved in averting ED visits and associated hospitalizations to render CHW programs cost-saving? A number of programs have demonstrated that CHW interventions decrease overall costs for patients with asthma[15,24]; those with hypertension, diabetes, or heart failure[19]; and high utilizing patients with at least 1 chronic condition.[26] These studies, however, examined a limited number of chronic diseases and varied in what expenses (such as supervision, training, and overhead costs) they included when determining the cost of the CHW program. Only 1 was conducted as a randomized trial,[24] and all based cost calculations on a single CHW program, which may not provide cost benchmarks that are generalizable to CHW programs in other settings.

Here, we sought to determine what levels of reduced ED visits and associated hospitalizations are necessary for a CHW program to be cost-neutral from the perspective of a payer that funds both CHW costs at primary care clinics as well as ED and hospitalization expenditures, as is typical under a global budget. One of the primary goals of CHW programs is to improve care for patients with chronic illness; 1 measure of quality of care for ambulatory-sensitive conditions is to reduce ED visits and hospitalizations.[27] Using a previously validated microsimulation model of health care utilization, costs, and revenues,[28,29] we estimated the degree to which ED visits and associated hospitalizations would need to be prevented by a CHW program to fully pay for the program's expenses. We focused on several key conditions that our literature review suggested were common conditions for CHW engagement or were key areas for future CHW engagement[30–33]: asthma, congestive heart failure, type II diabetes, human immunodeficiency virus, hypertension, and substance use.

METHODS

Overview of the Design

We used a microsimulation model to calculate a single outcome measure: the reduction in ED visits and associated

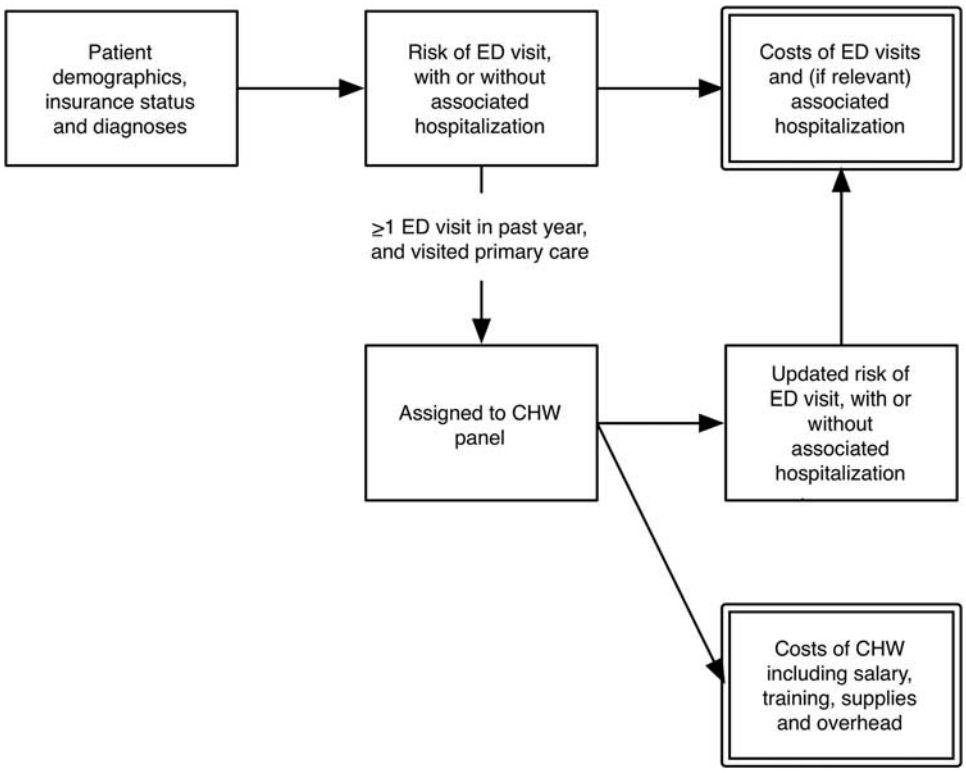

FIGURE 1. Model diagram. We simulate a national population of patients divided into state-representative populations for all 50 states and Washington DC. Patients are defined by demographic characteristics (age, sex, race/ethnicity, income), insurance status, and ICD-9 diagnoses including comorbid conditions. On the basis of national ED utilization and associated inpatient hospitalization rates specific to ICD-9 diagnoses, the simulated patients experience ED visits, associated hospitalizations, and costs. Patients with at least 1 ED visit in the past year who had visited a primary care provider in the prior year were eligible for enrollment into the panel of a CHW. We calculate what the lower rate of ED visits and associated hospitalizations would need to be among patients assigned a CHW for the costs of the CHW program to be fully paid for by averted ED visits and hospitalizations. See Table 1 for a summary of data sources. CHW indicates community health worker; ED, emergency department.

inpatient hospitalizations among a panel of CHW patients that would be necessary for a CHW program to be cost-neutral. Cost-neutrality was defined by net costs over a 1-year time horizon from the perspective of a payer that funds both CHW costs at primary care clinics, as well as the ED and hospitalization expenditures for patients eligible for the CHW program. We used a microsimulation because this model type simulates individual patients rather than an average, overall population rate of disease and health care utility. The microsimulation approach captures how different patients have distinct probabilities of care utilization and cost based on their demographics, insurance, and diagnoses, including comorbidities.[34] Figure 1 provides a conceptual diagram for the analysis. As shown in the Figure 1, we simulated the rates of ED visits and hospitalizations before and patients are assigned to a CHW. We assigned a CHW to patients who had at least 1 ED visit related to their chronic condition in the prior year. We then estimated what reduction in the rate of ED visits and associated inpatient hospitalizations would be needed to fully offset the costs of operating the CHW program.

Data Sources

Data on the panel sizes and costs of CHW programs and the usual caseload of patients seen by a CHW, specific to diagnosis, were obtained from the Massachusetts Department of Public Health (Table 1); this was the only state-specific data source in the model, because the authors were not aware of a nationally representative source for these data.[35] Data on patient demographics and insurance status was from the US Census.[36] Data on diagnoses by demographics and insurance status, rates of ED and inpatient hospitalization by diagnosis, and associated costs were from the Agency for Healthcare Research and Quality (specifically, the National ED and National Inpatient files for the ED and inpatient utilization rates, respectively, and the Medical Expenditure Panel Survey for costs, Table 2).[37–39]

Sampling Strategy

To simulate the national population, we simulated state-representative populations for all 50 states and Washington DC, defined by cohorts of <5, 5–13, 14–17, 18–24, 25–44, 45–64, 65–84, and above 84 years old, sex (dichotomous), race/ethnicity (in standard Census categories of non-Hispanic white, non-Hispanic black, Hispanic, and other), and income (expressed as a poverty income ratio to correct for household size, in 5 standard categories of <100% federal poverty level, 100%–138% FPL, 139%–250% FPL, 251%–400% FPL, and >400% FPL) to match current Census Bureau data for each state's population.[36] Individual patients are assigned a predicted insurance status (private, Medicare, Medicaid/Children's Health Insurance Program, or self-pay) from the Census data based on their demographic characteristics and state of residence, incorporating enrollment increases from the Affordable Care Act.[40] Using data from the Medical Expenditure Panel Survey, individual patients were also assigned ICD-9 diagnoses (including all possible ICD-9 codes to capture comorbidities) to match the frequency of diagnoses among each demographic group by insurance status.[39] To assign simulated individuals these characteristics, we used a Monte Carlo sample from the joint probability distributions of the patient features using a copula function, which allows the correlation between variables to be taken into account[41] (ie, the correlation between specific demographics, insurance status, and diagnoses).

TABLE 1. Input Data for CHW Programs[34]

Input	Mean	Low	High
Annual caseload by diagnosis			
HIV	45	40.00	50.00
Asthma	70	60.00	80.00
Mood disorders	70	60.00	80.00
Diabetes	90	80.00	100.00
Heart failure	70	80.00	100.00
Uncontrolled HTN	70	80.00	100.00
Substance abuse	70	80.00	100.00
Supervisor salary	$5289.60	$4531.20	$6048
CHW salary	$42,480	$31,860	$53,100
Supplies	$5000	$5000	$5000
Core training (once)	$600	$400	$800
Ongoing training	$375	$375	$375

CHW indicates community health worker; HIV, human immunodeficiency virus; HTN, hypertension.

Given estimates of the frequency of ED visits and the probability of inpatient hospitalization from the National ED and National Inpatient datasets, respectively,[37,38] we simulated how often each patient would be likely to visit the ED and be hospitalized, based on their specific diagnostic code combination. This approach incorporates the impact of comorbidities on the heightened probability of ED visits and hospitalizations. We linked this information to the cost of each ED visit and, if the ED visit resulted in hospitalization, the cost of inpatient hospitalization.[39] The cost data were specific to a patient's demographic characteristics, insurance status, state of residence, and ICD-9 diagnostic code(s). These costs reflect payer expenses adjusted by geographic practice cost index and refer to actual payments, rather than visit-related charges. The model's estimates of diagnosis frequency, patient health care utilization, and cost were validated in a previous publication[28] by ensuring that they differed by <5% absolute error from estimates in the National Ambulatory Medical Care Survey for each age-specific, sex-specific, race/ethnic-specific, and state-specific population.

Benchmark Analysis

We performed 2 primary analyses.

Baseline Analysis

First, we estimated the expected costs of the caseload before any impact of a CHW on the rate of ED visits or hospitalizations. We calculated the typical ED visit rate and associated rate of inpatient hospitalizations, with their associated costs, for a caseload of patients assigned to a CHW, making these estimates specific to principal diagnosis or diagnosis group. The typical caseload for CHWs, specific to each type of diagnosis, is specified in Table 1.

TABLE 2. Utilization and Cost Estimates for Patients in CHW Panels

	Monthly ED Visit Probability Per Person			Monthly Inpatient Hospitalization Probability Per Person			Typical ED Costs Per Visit Per Person			Typical Inpatient Costs Per Visit Per Person			Annual Cost of ED Visits and Hospitalizations Per CHW Panel		
Condition	**Mean**	**Low**	**High**	**Mean**	**Low**	**High**	**Mean**	**Low**	**High**	**Mean**	**Low**	**High**	**Mean**	**Low**	**High**
HIV	0.146	0.145	0.146	0.009	0.009	0.010	$490	$250	$731	$19,126	$18,254	$19,998	$134,237	$93,978	$181,533
Asthma	0.088	0.088	0.088	0.020	0.020	0.021	$1182	$697	$1668	$8847	$4196	$13,499	$236,486	$103,157	$405,656
Mood disorders	0.087	0.087	0.088	0.057	0.055	0.059	$916	$308	$1525	$5316	$5126	$5506	$411,930	$314,242	$524,678
Diabetes	0.086	0.086	0.086	0.057	0.055	0.060	$849	$683	$1015	$4304	$4055	$4553	$267,918	$288,113	$405,480
Heart failure	0.089	0.089	0.090	0.088	0.086	0.091	$933	$341	$1525	$11,412	$11,089	$11,735	$916,075	$899,580	$1,370,579
Uncontrolled HTN	0.084	0.084	0.084	0.072	0.069	0.076	$757	$670	$844	$11,673	$11,163	$12,183	$761,944	$663,588	$1,100,019
Substance abuse	0.085	0.085	0.085	0.030	0.030	0.031	$269	$151	$387	$5579	$5312	$5846	$104,231	$83,494	$127,269

The table lists typical rates and costs of ED visits and hospitalizations for patients with a history of at least 1 ER visit for each diagnostic condition and a visit to a primary care provider in the past year—the criteria for CHW assignment in the model. Each diagnosis is considered separately. The rates and costs listed are typical from a caseload of CHW patients, by diagnosis, before any benefits from the CHW program are incurred.

For the purposes of the model, HIV is restricted to persons with detectable viral load, hypertension to individuals with uncontrolled hypertension and/or complications of hypertension, diabetes to type II diabetes with complications, and substance abuse to any principal diagnosis that is within the ICD range classified by the Centers for Medicare and Medicaid as a substance abuse diagnosis (including alcohol abuse).

CHW indicates community health worker; ED, emergency department; HIV, human immunodeficiency virus; HTN, hypertension.

We considered only those diagnoses for which CHW literature currently suggests that CHWs are typically assigned or are of interest for future placement[30–32]: poorly controlled asthma, congestive heart failure, diabetes (type II), human immunodeficiency virus with detectable viral load, hypertension (uncontrolled or with cardiovascular complications), and substance use (a principal diagnosis including alcohol abuse or dependence, opiate abuse or dependence, or other substance abuse or dependence excluding tobacco). Because comorbid conditions are included in the model, we capture the heightened risk for ED visits and hospitalizations among patients with comorbidities. Accordingly, we capture overall visits for any condition among such patients, no matter their primary diagnosis associated with CHW program enrollment or their primary reason for the ED visit or hospitalization.

Benchmark Analysis for Cost-Neutrality

Second, we estimated the absolute number of ED visits and associated inpatient hospitalizations for panel of CHW patients that would be necessary for a CHW program to be cost-neutral. Patients who visited the ED at least once in the prior year and had visited a primary care provider in the prior year were included in the eligible pool. We assigned these patients to a CHW based on their principal diagnosis for the ED visit, and filled CHW caseloads to meet the typical annual caseload of each CHW for each diagnosis, based on caseload information from the Massachusetts Department of Public Health (Table 1).[35]

Specific to each principal diagnosis, we estimated the number of ED visits and associated inpatient hospitalizations that must be averted for the CHW program to "break even"—that is, financially pay for the CHW program costs through offsets from averted ED visit and inpatient hospitalizations. Following national cost-effectiveness modeling guidelines,[42] a comprehensive accounting of total costs from a payer perspective was taken into account, including on-the-job training costs and material expenses associated with the CHW program, which provides a conservative estimate of per-CHW costs to set a "high threshold" for program achievement. These costs are summarized in Table 1. For the purposes of presentation, all costs reflect utilization and associated costs per annum in 2015 US dollars, using the Consumer Price Index to adjust for inflation.[43]

Sensitivity Analyses

We performed 3 sensitivity analyses to evaluate the degree to which the "break even" benchmarks for CHW cost-neutrality would change under alternative scenarios.

First, we examined what would happen if each ED visit was associated with a different probability of inpatient hospitalization than in the base-case scenario. In this scenario, we recalculated the benchmark for cost-neutrality if CHWs only eliminated lower acuity ED visits that had half of the risk of associated hospitalizations, with a higher probability of hospitalization for the remaining visits to reach the overall baseline average rate of hospitalization. In a second sensitivity analysis, we examined what would happen if CHWs converted ED visits to primary care visits, to examine a likely strategy for ED visit deferral. We incorporated the typical cost of each primary care visit specific to the patient's demographics, insurance status, state of residence, and diagnosis per the Medical Expenditure Panel Survey.[39] In a third sensitivity analysis, we estimated how much our results might change if patients with comorbid uncontrolled hypertension and type II diabetes were to be assigned to a CHW, given the high frequency of these 2 conditions as comorbid diagnoses; we specifically wanted to examine the impact of having these 2 diagnoses together a program inclusion criteria, versus the case where any patient with either uncontrolled hypertension or type II diabetes would be eligible for a CHW.

In all scenarios, probabilistic sensitivity analysis was also conducted by rerunning the model 10,000 times, while repeatedly sampling from the probability distributions around all input data points, to estimate 95% confidence

intervals around our results based on the uncertainty in model input data values.

All modeling was performed in the program *R* (v. 3.2.3, The R Foundation for Statistical Computing, Vienna). The study was deemed exempt from human subjects research ethics review by the Stanford University IRB.

RESULTS

Baseline Analysis

We estimated the typical costs of a CHW program to be $47,800 per year per CHW (95% CI, $42,200–$65,300) in 2015 US Dollars, including salary, overhead, initial training, and annual continuing education. We estimated that the ED and inpatient hospitalization costs associated with a typical CHW caseload would vary by principal diagnosis of the patient. Table 2 summarizes the typical ED visit and inpatient hospitalization rates and costs incurred by each patient assigned to a CHW, by principal diagnosis or diagnosis group; these costs reflect the expected costs per patient before any impact of a CHW on the rate of ED visits or hospitalizations.

Because the overall cost estimates include utilization and cost by diagnosis, as well as different risks of inpatient hospitalization given an ED visit, each diagnostic category had widely varying costs. For example, although substance use disorders were common and resulted in frequent ED visits, the cost of each ED visit and the probability of inpatient hospital admission was lower than for stroke. Hence, the total cost for a caseload of patients with substance use disorders was still lower than for a caseload of patients with stroke, given the high probability and cost of recurrent inpatient hospitalization among patients with stroke versus the lower frequency of their ED visits.

Benchmark Analysis for Cost-Neutrality

Figure 2 illustrates the estimated benchmark number of ED visits and subsequent hospitalizations that a CHW must prevent for the payer of the CHW program to "break even" and achieve cost-neutrality. As shown in Figure 2A, some conditions such as asthma may require more ED visits to compensate for the cost of the CHW, as the cost of the ED visit and the probability of inpatient hospitalization may be lower than for other conditions. For example, a CHW who specializes in asthma (and has 70 patients enrolled) would need to prevent about 14 ED visits (or 15% of the ED visits), of which 23% would be expected to result in a hospitalization. By contrast, a CHW who specializes in heart failure (and has 70 patients enrolled) would need to prevent about 4 ED visits (or 3% of the ED visits), of which over 90% would be expected to result in a hospitalization. Figure 2B illustrates the same data in terms of the percentage of visits from a caseload that must be averted from an ED visit to achieve cost-neutrality, accounting for the differential visit rate across diagnoses.

As shown in Figure 2, to achieve cost-neutrality, 4–5 visits to the ED would need to be averted per year by a CHW assigned a panel of 70 patients with uncontrolled hypertension or congestive heart failure—which is 3%–4% of typical ED visits among such patients, respectively. Most other chronic conditions would require between 7% and 21% of ED visits to be averted to achieve cost-neutrality. By contrast, CHWs assigned to assist patients with a primary substance abuse diagnosis would need to avert the greatest number of visits (23 visits per panel, or 37% of ED visits) to achieve cost-neutrality.

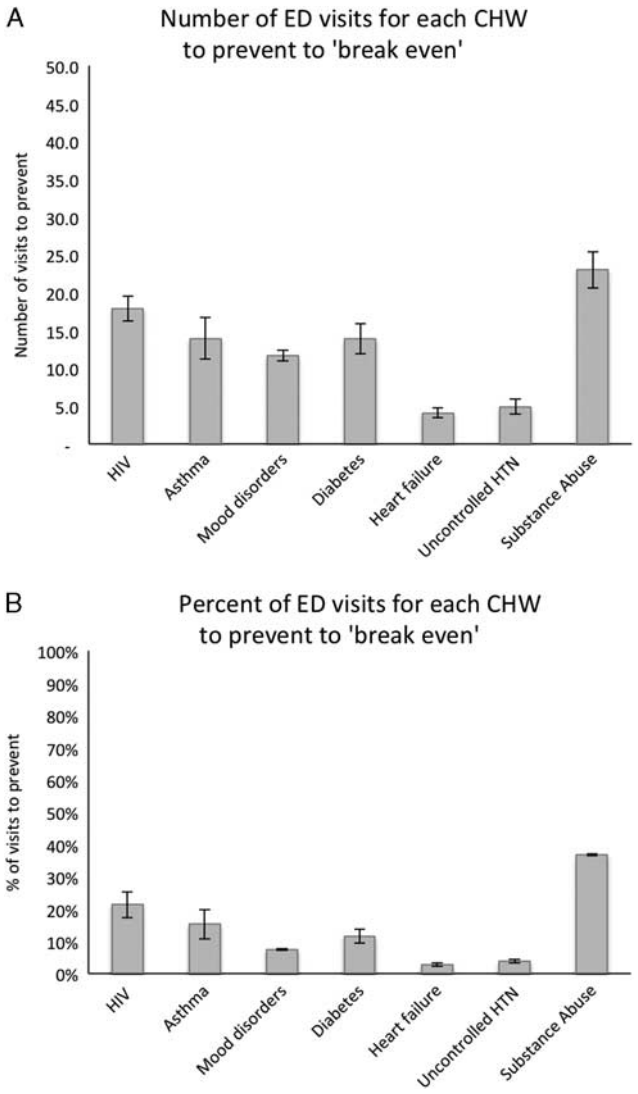

FIGURE 2. Benchmarks for cost-neutrality. The minimum number of ED and associated inpatient hospitalizations from a typical CHW caseload that must be prevented to fully pay for the CHW program: (A) in terms of the number of ED visits and (B) in terms of the percent of ED visits. In each case, we assume no change in the probability of inpatient hospitalization given an ER visit for each given condition. Each diagnosis is considered separately; 95% confidence intervals from 10,000 repeated samples from the input data are reflected as error bars. CHW indicates community health worker; ED, emergency department.

Sensitivity Analyses

In our first sensitivity analysis, we examined changes to the cost-neutrality benchmark if CHWs only eliminated

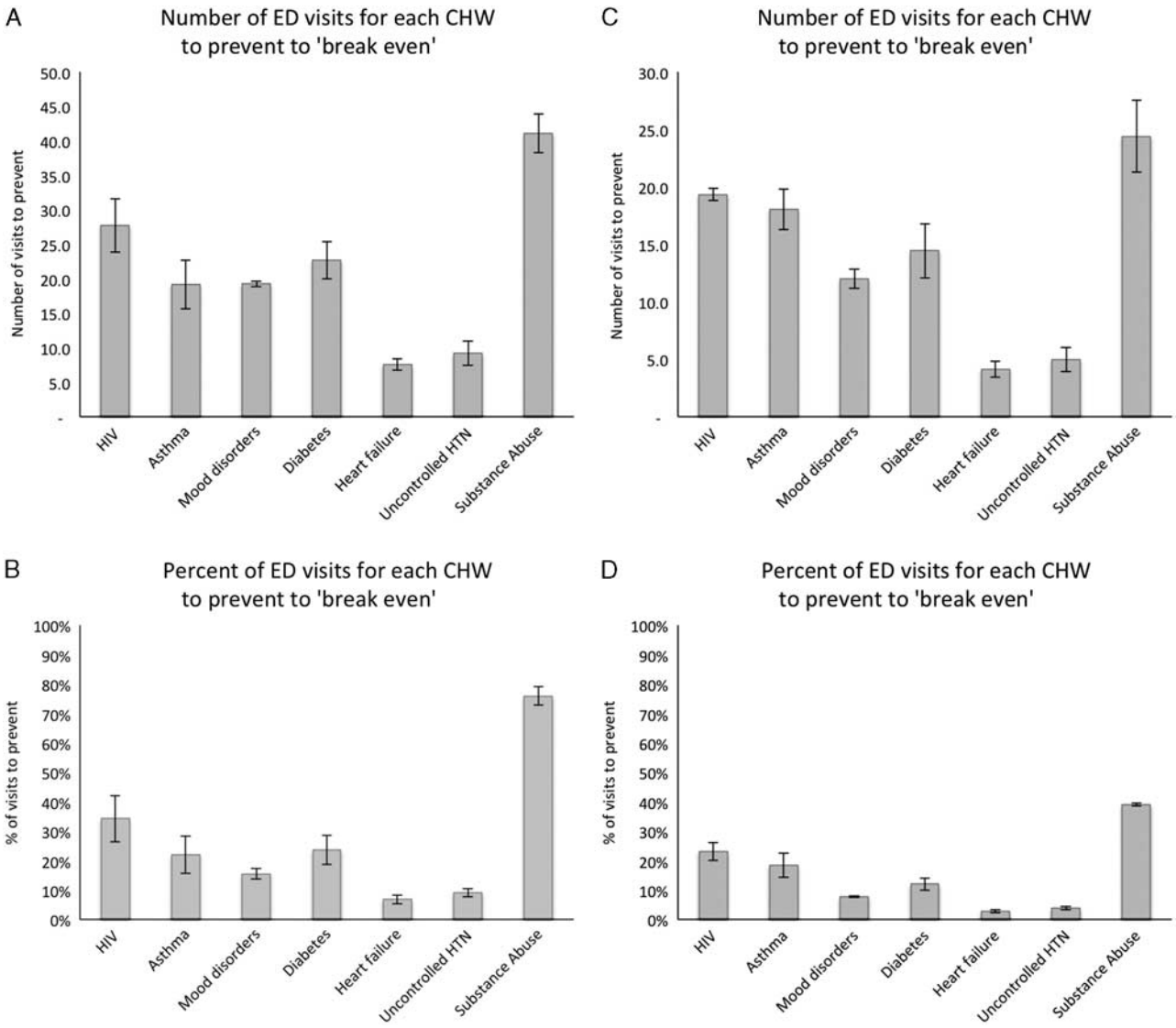

FIGURE 3. Sensitivity analysis around the benchmarks for cost-neutrality. The minimum number of ED and associated inpatient hospitalizations from a typical CHW caseload that must be prevented to fully pay for the CHW program: (A) in terms of the number of ED visits, if CHWs only eliminated lower acuity ED visits that had half of the risk of associated hospitalizations, with a higher probability of hospitalization for the remaining visits to reach the overall baseline average rate of hospitalization; (B) in terms of the percent of ED visits, if CHWs only eliminated lower acuity ED visits that had half of the risk of associated hospitalizations, with a higher probability of hospitalization for the remaining visits to reach the overall baseline average rate of hospitalization; (C) in terms of the number of ED visits, if deferred ED visits are converted to primary care visits, incorporating the distribution of cost of primary care visits by diagnosis; and (D) in terms of the percent of ED visits, if deferred ED visits are converted to primary care visits, incorporating the distribution of cost of primary care visits by diagnosis. Each diagnosis is considered separately; 95% confidence intervals from 10,000 repeated samples from the input data are reflected as error bars. CHW indicates community health worker; ED, emergency department.

lower acuity ED visits that had half of the risk of associated hospitalizations, with a higher probability of hospitalization for the remaining visits. As shown in Figure 3A, the number of ED visits that must be averted was generally inflated by 1.7 times above the base-case simulation, because a greater number of lower acuity ED visits had to be averted to pay for the CHW program costs.

In our second sensitivity analysis, we estimated the benchmarks if CHWs converted ED visits to primary care visits. As shown in Figure 3B, the number of ED visits that must be averted is generally inflated by 1.1 times above the base-case simulation to pay for the primary care visits.

Finally, we estimated the benchmarks if patients with both uncontrolled hypertension and diabetes were eligible for

a CHW. When isolated to these particularly high-risk patients, the percent of ED visits that would need to be averted to achieve cost-savings would lower to just 3% to reach the cost-neutrality benchmark.

DISCUSSION

We sought to answer a critical question for many payers: what benchmark level of success must be achieved in averting ED visits and associated hospitalizations to render CHW programs cost-saving? We estimated the reduction in ED visits and associated hospitalizations necessary for a CHW program to be cost-neutral from the perspective of a payer who funds both CHW program costs and ED and hospitalization expenditures. We found that offsetting the costs of a CHW program would be theoretically feasible (always <100% of current ER visits among typically selected patients) for the chronic conditions to which CHWs are typically assigned. Yet the benchmark level of reduction in ED visits and associated inpatient hospitalizations would vary substantially by the primary diagnosis for a patient.

This study adds significant knowledge to the existing literature on CHW programs, and particularly provides critical information to payers that can be used for making decisions on appropriate payment models. Given the variability in the effects of CHW programs on health care utilization, and the wide range of diagnoses potentially amenable to CHW intervention, it is important to note that from a cost-benefit analysis standpoint, common cardiovascular conditions may offer the greatest opportunity to achieve cost-savings, as they require CHWs to avert the lowest number of ED visits. Our study also suggests the data published from studies on patients with type II diabetes,[13] asthma,[14–18,44] and hypertension[19] would suggest that CHWs are capable of achieving cost-neutrality for these conditions as well, by passing the benchmarks we estimated here. In addition to establishing such benchmarks, our study also adds the important tool of microsimulation modeling to the broader literature on CHWs. Our use of a microsimulation technique is advantageous over older Markov cohort modeling techniques, which are only able to simulate the average rate of disease or health care visits in a population, ignoring the fact that some patients (eg, those patients to whom CHWs would typically be assigned) are often in most need of assistance and commonly utilize the most health care resources. Older modeling strategies may underestimate the benefits of CHW programs and overestimate the benchmark required to achieve cost-neutrality.

As with any analysis based on simulation modeling, our study conclusions are bounded by the limitations of the data used for modeling. First, we limited our analysis to patients with a history of at least 1 ED visit in the prior year who also visited a primary care provider in the prior year. This criterion may vary among CHW programs, and in general, the selection of patients without such a history would render it more difficult for CHW programs to become net cost-neutral or cost-saving, as more general patient populations would have a low rate of expected ED visits or admissions. Conversely, our model can only accommodate simulations of patient groups that are clearly identified and have sufficiently stable sample size in our input data sources to precisely characterize their rates of ED visits and associated hospitalizations. Patients in many demographic categories (eg, recent immigrants, rural patients) may benefit from CHW programs but not identified in the data. Second, we did not account for the costs of hospitalizations that did not occur through the ED (ie, direct admissions), which reflect a minority of admissions. We also did not account for other cost-savings that may result from CHW programs, including reductions in "no shows," urgent care visits, or use of emergency medication. Excluding these potential savings may make our benchmarks a conservative estimate of reductions needed for cost-neutrality. Third, we adopted estimates of cost of CHW program administration from personal communications with administrators at the Massachusetts Department of Public Health, where the regional price parity for personnel costs for service delivery is slightly higher (at most, 1.1 times) the national average, making our estimates of the cost of personnel slightly high on average, and therefore making our benchmarks conservative.[45]

Our findings highlight a number of directions for future investigation. First, given the variability in benchmark outcomes across diagnoses, researchers should continue to evaluate the most effective strategies for CHW interventions among patients with a broader range of chronic conditions to understand what intervention characteristics and patient caseloads facilitate improved health outcomes and cost-savings. Second, because the challenges faced in financing CHWs are similar to those faced in financing other members of the primary care team who are not currently reimbursed through the standard fee-for-service model (eg, social workers, pharmacists, etc.), benchmarking analyses for cost-neutrality should be conducted for a broader range of primary care team members.

Overall, our results suggest that although CHW services are generally not billable under a fee-for-service payment systems, global health care spending and budgeting would potentially allow CHW programs to achieve cost-neutrality or cost-savings. Our model offers the opportunity to compare CHW program data against a national benchmark, which can assist programs to develop meaningful targets and track progress toward the goal of achieving cost-neutrality through reducing avoidable ED visits and hospitalizations associated with chronic medical conditions.

ACKNOWLEDGMENT

The authors thank Jessica Alpert, Paulius Mui, Erin E. Sullivan, Lucy Sun, and the staff of the Office of Community Health Workers at the Massachusetts Department of Public Health for their assistance with this study.

REFERENCES

1. Robert Wood Johnson Foundation. *Chronic Care: Making the Case for Ongoing Care*. Princeton, NJ: Robert Wood Johnson Foundation; 2010.
2. Vogeli C, Shields AE, Lee TA, et al. Multiple chronic conditions: prevalence, health consequences, and implications for quality, care management, and costs. *J Gen Intern Med*. 2007;22:391–395.
3. Hasselman D. *Super-Utilizer Summit: Common Themes From Innovative Complex Care Management Programs*. Trenton, NJ: Center for Health Care Strategies; 2013.

4. Soni A. *Trends in the Five Most Costly Conditions Among the US Civilian Noninstitutionalized Population, 2002 and 2012 Medical Expenditure Panel Survey*. Rockville, MD: Agency for Healthcare Research and Quality; 2015.
5. Community health workers. 2015. Available at: https://www.apha.org/apha-communities/member-sections/community-health-workers. Accessed June 2, 2015.
6. Wang EA, Hong CS, Shavit S, et al. Engaging individuals recently released from prison into primary care: a randomized trial. *Am J Public Health*. 2012;102:e22–e29.
7. Kangovi S, Mitra N, Grande D, et al. Patient-centered community health worker intervention to improve posthospital outcomes: a randomized clinical trial. *JAMA Intern Med*. 2014;174:535–543.
8. Bryant-Stephens T, Li Y. Outcomes of a home-based environmental remediation for urban children with asthma. *J Natl Med Assoc*. 2008;100:306–316.
9. Shah MK, Heisler M, Davis MM. Community health workers and the Patient Protection and Affordable Care Act: an opportunity for a research, advocacy, and policy agenda. *J Health Care Poor Underserved*. 2014;25:17–24.
10. Behforouz HL. Bridging the gap: a community health program saved lives, then closed its doors: a program connecting community health workers with patients in Boston shows benefits but is shuttered after funds dry up. *Health Aff*. 2014;33:2064–2067.
11. Kangovi S, Grande D, Trinh-Shevrin C. From rhetoric to reality — community health workers in post-reform US health care. *N Engl J Med*. 2015;372:2277–2279.
12. Fisher EB, Strunk RC, Highstein GR, et al. A randomized controlled evaluation of the effect of community health workers on hospitalization for asthma: the asthma coach. *Arch Pediatr Adolesc Med*. 2009;163:225–232.
13. Gary TL, Batts-Turner M, Yeh HC, et al. The effects of a nurse case manager and a community health worker team on diabetic control, emergency department visits, and hospitalizations among urban African Americans with type 2 diabetes mellitus: a randomized controlled trial. *Arch Intern Med*. 2009;169:1788–1794.
14. Fox P, Porter PG, Lob SH, et al. Improving asthma-related health outcomes among low-income, multiethnic, school-aged children: results of a demonstration project that combined continuous quality improvement and community health worker strategies. *Pediatrics*. 2007;120:e902–e911.
15. Margellos-Anast H, Gutierrez MA, Whitman S. Improving asthma management among African-American children via a community health worker model: findings from a Chicago-Based Pilot Intervention. *J Asthma*. 2012;49:380–389.
16. Postma JM, Smalley K, Ybarra V, et al. The feasibility and acceptability of a home-visitation, asthma education program in a rural, Latino/a population. *J Asthma*. 2011;48:139–146.
17. Turyk M, Banda E, Chisum G, et al. A multifaceted community-based asthma intervention in Chicago: effects of trigger reduction and self-management education on asthma morbidity. *J Asthma*. 2013;50:729–736.
18. Bryant-Stephens T, Kurian C, Guo R, et al. Impact of a household environmental intervention delivered by lay health workers on asthma symptom control in urban, disadvantaged children with asthma. *Am J Public Health*. 2009;99:S657–S665.
19. Adair R, Christianson J, Wholey DR, et al. Care guides: employing nonclinical laypersons to help primary care teams manage chronic disease. *J Ambul Care Manag*. 2012;35:27–37.
20. Michelen W, Martinez J, Lee A, et al. Reducing frequent flyer emergency department visits. *J Health Care Poor Underserved*. 2006;17:59–69.
21. Johnson D, Saavedra P, Sun E, et al. Community health workers and Medicaid managed care in New Mexico. *J Community Health*. 2012;37:563–571.
22. Krieger J, Song L, Philby M. Community health worker home visits for adults with uncontrolled asthma: the HomeBASE trial randomized clinical trial. *JAMA Intern Med*. 2015;175:109–117.
23. Babamoto KS, Sey KA, Camilleri AJ, et al. Improving diabetes care and health measures among Hispanics using community health workers: results from a randomized controlled trial. *Health Educ Behav*. 2009;36:113–126.
24. Krieger JW, Takaro TK, Song L, et al. The Seattle-King County Healthy Homes Project: a randomized, controlled trial of a community health worker intervention to decrease exposure to indoor asthma triggers. *Am J Public Health*. 2005;95:652–659.
25. Nelson KA, Highstein GR, Garbutt J, et al. A randomized controlled trial of parental asthma coaching to improve outcomes among urban minority children. *Arch Pediatr Adolesc Med*. 2011;165:520–526.
26. Enard KR, Ganelin DM. Reducing preventable emergency department utilization and costs by using community health workers as patient navigators. *J Healthc Manag*. 2013;58:412–427.
27. Johnson PJ, Ghildayal N, Ward AC, et al. Disparities in potentially avoidable emergency department (ED) care: ED visits for ambulatory care sensitive conditions. *Med Care*. 2012;50:1020–1028.
28. Basu S, Landon BE, Song Z, et al. Implications of workforce and financing changes for primary care practice utilization, revenue, and cost: a generalizable mathematical model for practice management. *Med Care*. 2015;53:125–132.
29. Basu S, Phillips RS, Bitton A, et al. Medicare chronic care management payments and financial returns to primary care practices: a modeling study. *Ann Intern Med*. 2015;163:580–588.
30. Viswanathan M, Kraschnewski JL, Nishikawa B, et al. Outcomes and costs of community health worker interventions: a systematic review. *Med Care*. 2010;48:792–808.
31. Wennerstrom A, Hargrove L, Minor S, et al. Integrating community health workers into primary care to support behavioral health service delivery: a pilot study. *J Ambul Care Manag*. 2015;38:263–272.
32. Kenya S, Chida N, Symes S, et al. Can community health workers improve adherence to highly active antiretroviral therapy in the USA? A review of the literature. *HIV Med*. 2011;12:525–534.
33. Fingar KRB, Marguerite L, Elixhauser A, et al. *Trends in Potentially Preventable Inpatient Hospital Admissions and Emergency Department Visits*. Rockville, MD: Agency for Healthcare Research and Quality; 2015.
34. Basu S, Andrews J. Complexity in mathematical models of public health policies: a guide for consumers of models. *PLoS Med*. 2013;10:e1001540.
35. Office of Community Health Workers at the Massachusetts Department of Public Health. Basu S. Inputs and assumptions for HMS simulation modeling for CHW business case. Boston, MA: Office of Community Health Workers at the Massachusetts Department of Public Health; 2015.
36. Current Population Survey. *Annual Social and Economic Supplements*. Washington, DC: US Census Bureau; 2014.
37. HCUP National Inpatient Sample (NIS). *Agency for Healthcare Research and Quality*. Rockville, MD: Healthcare Cost and Utilization Project (HCUP); 2013.
38. HCUP Nationwide Emergency Department Sample (NEDS). *Agency for Healthcare Research and Quality*. Rockville, MD: Healthcare Cost and Utilization Project (HCUP); 2013.
39. Medical Expenditure Panel Survey (MEPS). *Q Agency for Healthcare Research and Quality*. Rockville, MD: Medical Expenditure Panel Survey (MEPS); 2014.
40. Congressional Budget Office. *Effects of the Affordable Care Act on Health Insurance Coverage—Baseline Populations*. Washington, DC: Congressional Budget Office; 2015.
41. Hofert M, Michler M. Nested Archimedean copulas meet R: the nacopula package. *J Stat Softw*. 2011;39:1–20.
42. Weinstein MC, Siegel JE, Gold MR, et al. Recommendations of the panel on cost-effectiveness in health and medicine. *JAMA*. 1996;276:1253–1258.
43. Consumer Price Index. 2015. Available at: http://www.bls.gov/cpi/. Accessed December 1, 2015.
44. Primomo J, Johnston S, DiBiase F, et al. Evaluation of a community-based outreach worker program for children with asthma. *Public Health Nurs*. 2006;23:234–241.
45. Aten B, Figueroa E, Martin T. Notes on estimating the multi-year regional price parities by 16 expenditure categories: 2005-2009. WP2011-03. 2011.