ORIGINAL RESEARCH

# Estimating the Cardiovascular Disease Risk Reduction of a Quality Improvement Initiative in Primary Care: Findings from EvidenceNOW

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***Background:*** **This study estimates reductions in 10-year atherosclerotic cardiovascular disease (ASCVD) risk associated with EvidenceNOW, a multi-state initiative that sought to improve cardiovascular preventive care in the form of (A)spirin prescribing for high-risk patients, (B)lood pressure control for people with hypertension, (C)holesterol management, and (S)moking screening and cessation counseling (ABCS) among small primary care practices by providing supportive interventions such as practice facilitation.**

***Design:*** **We conducted an analytic modeling study that combined (1) data from 1,278 EvidenceNOW practices collected 2015 to 2017; (2) patient-level information of individuals ages 40 to 79 years who participated in the 2015 to 2016 National Health and Nutrition Examination Survey ($n$ = 1,295); and (3) 10-year ASCVD risk prediction equations.**

***Measures:*** **The primary outcome measure was 10-year ASCVD risk.**

***Results:*** **EvidenceNOW practices cared for an estimated 4 million patients ages 40 to 79 who might benefit from ABCS interventions. The average 10-year ASCVD risk of these patients before intervention was 10.11%. Improvements in ABCS due to EvidenceNOW reduced their 10-year ASCVD risk to 10.03% (absolute risk reduction: −0.08, $P \leq .001$). This risk reduction would prevent 3,169 ASCVD events over 10 years and avoid $150 million in 90-day direct medical costs.**

***Conclusion:*** **Small preventive care improvements and associated reductions in absolute ASCVD risk levels can lead to meaningful life-saving benefits at the population level. (J Am Board Fam Med 2023;00:000–000.)**

***Keywords:*** **Cardiology, Cardiovascular Diseases, Nutrition Surveys, Preventive Health Care, Primary Health Care, Quality Improvement**

## Introduction

Cardiovascular disease (CVD) is the leading cause of mortality in the United States (US). In 2016, more than 750,000 deaths were attributed to the disease, and approximately 25 million adult Americans were living with the condition.[1] The annual direct cost of the disease, including costs of health care services and prescription medications, currently exceeds $150 billion.

Preventive care in the form of (A)spirin prescribing for high-risk patients, (B)lood pressure control

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for people with hypertension, (C)holesterol management, and (S)moking screening and cessation counseling (the "ABCS") is effective in reducing CVD.[2,3] Yet, adoption of ABCS has been low.[4,5] This is despite substantial attention to this issue directed by national improvement efforts such as the Million Hearts Initiative, increased use of electronic health records (EHR) and points of care decision support tools.

Improving ABCS may be especially challenging for smaller primary care practices. Although these practices serve a large number of people in the US, they often lack capacity to implement evidence-based care.[6,7] In 2015, the Agency for Health care Research and Quality (AHRQ) launched EvidenceNOW, a large multi-state initiative to help small practices, with limited internal quality improvement resources, improve their ABCS by providing external support that primarily included facilitation, performance benchmarking, and audit and feedback.[8] To accomplish its goal, AHRQ funded 7 regional cooperatives spanning 12 US states to recruit practices and provide external support (eg, facilitation, access to audit and feedback, performance benchmarking data). A study assessing the overall effectiveness of external support strategies across all cooperatives found, on average, moderate improvements in ABCS levels attributable to the initiative,[9] which was consistent with cooperatives' assessment of their own interventions.[10–14]

This study estimates overall reductions in atherosclerotic cardiovascular disease (ASCVD) risk (defined as nonfatal myocardial infarction, coronary heart disease death, or fatal or nonfatal stroke[15]) that might be expected from improvements in the ABCS brought about by the external support of EvidenceNOW cooperatives. We did not have access to cardiovascular risk factor data for individual patients in many of the practices. To address this limitation, we developed a new analytic modeling approach that used patient-level information from the National Health and Nutrition Examination Survey (NHANES) in combinat-ion with EvidenceNOW practice-level data and 10-year ASCVD risk prediction equations to estimate the number of ASCVD events that might be prevented in response to the overall risk reduction observed in EvidenceNOW. We also assessed differences in risk reduction by population groups.

## Methods

### *Data*

We used the 2015 to 2016 NHANES as the primary data source to predict the impact of risk factor changes on ASCVD event risk. The NHANES is a national survey that reports respondents' health and nutritional status. We started with an initial population of 9,971 respondents. We focused on individual respondents age 40 to 79 years because estimates of external ASCVD risk prediction equations were based on that age range (see below; sample size after exclusion: 3,390). We also excluded respondents with missing smoking status (sample size after exclusion: 1,552) and missing information about their blood pressure (sample size after exclusion: 1,362) or cholesterol levels (sample size after exclusion: 1,295) because this information was required for our calculations. Our final individual-level adult sample for this analysis included 1,295 of the 9,971 NHANES respondents.

The secondary data source included data from 1,278 primary care practices that participated in the EvidenceNOW initiative. Practice data included (1) average ABCS levels at baseline; (2) selected patient characteristics at the practice-level (eg, the fraction of black patients and the percentage of patients ages 60 to 75); and (3) information about the number of clinicians per practice and the number of patients per clinician. In-depth descriptions of EvidenceNOW practice-level data have been published previously.[16,17]

### *Analyses*

To estimate the number of ASCVD events that might be prevented in response to overall ABCS improvements observed in EvidenceNOW, our approach proceeded in 3 steps: (1) we estimated 10-year ASCVD risk in the absence of ABCS treatment for each NHANES respondent; (2) we estimated 10-year ASCVD risk reduction among NHANES respondents, had they been exposed to ABCS improvements due to EvidenceNOW; and (3) we calculated weighted average 10-year ASCVD risk at baseline and 10-year ASCVD risk reduction due to the intervention. We present each step below, with further technical details described in the Online Appendix.

#### *Step 1: Estimation of 10-Year ASCVD Risk Absent ABCS Treatment*

For each NHANES respondent, we used an ASCVD risk prediction model developed by the

American College of Cardiology and American Heart Association to estimate 10-year ASCVD risk in the absence of ABCS treatment.[15,18] Model predictions are based on pooled cohort equations and multiple cohort studies of adults ages 40 to 79.

*Step 2: Estimation of ASCVD Risk Reduction Due to EvidenceNOW*

For this step, we identified NHANES patient groups that corresponded to the ABCS, then connected EvidenceNOW ABCS levels to these patient groups, and finally calculated implied ASCVD risk reductions.

First, we identified mutually exclusive patient groups in the NHANES using ABCS clinical quality metrics denominator definitions and information reported by NHANES respondents. ABCS denominator definitions were based on Centers for Medicaid and Medicare Services electronic clinical quality measure (eCQM) specifications used in EvidenceNOW (see Online Appendix Table A-3). Each denominator definition characterized a patient population for whom treatment was recommended, that is, patients who were eligible for this treatment. We applied these definitions to our NHANES sample using demographic and health information (eg, diagnosis of hypertension or coronary heart disease).

Because populations eligible for the ABCS metrics overlapped (eg, a person with diabetes and hypertension was eligible for both blood pressure and cholesterol interventions), we identified the following distinct, mutually exclusive patient groups: NHANES respondents eligible for (1) smoking screening and cessation counseling only (henceforth smoking screening/cessation counseling; denoted by $G_s$ (2) blood pressure control and smoking screening/cessation counseling (denoted by $G_{BS}$); (3) cholesterol management and smoking screening/cessation counseling (denoted by $G_{cs}$); (4) aspirin prescribing, cholesterol management, and smoking screening/cessation counseling (denoted by $G_{ACS}$); (5) blood pressure control, cholesterol management, and smoking screening/cessation counseling (denoted by $G_{BCS}$); and (6) all 4 treatment options (denoted by $G_{ABCS}$). Every NHANES respondent in our sample was included in the smoking screening/cessation counseling denominator, because smoking screening applied to all adults ages 18 years and older. People were eligible for aspirin if they had an active diagnosis of an ischemic vascular disease or were discharged alive from for acute myocardial infarction, coronary artery bypass graft, or percutaneous coronary interventions (see Online Appendix Table A-3 for details).

Second, we connected ABCS treatment rates to the 6 patient groups by assigning possible treatment options and corresponding probabilities to them. For instance, NHANES patients eligible for cholesterol management and smoking intervention had 4 possible treatment options: (1) no treatment; (2) receiving a statin prescription; (3) smoking screening/cessation counseling; and (4) receiving both treatments.

Treatment probabilities were based on ABCS baseline levels, improvements due to EvidenceNOW, and postintervention levels, as follows: 61.9%, +3.4%, 65.3% (aspirin); 63.3%, +1.6%, 67.7% (blood pressure); 60.2%, +4.4%, 64.6% (cholesterol); 58.4%, 7.4%, 65.8% (smoking screening/cessation counseling). Improvements due to the intervention were based on an event study that assessed overall changes in ABCS across cooperatives.[9]

Improvements in the ABCS shifted the probability distribution to more intensive treatment. For instance, the probability of receiving both cholesterol management and smoking screening/cessation counseling for NHANES patients eligible for these treatments increased from 35.1% to 42.5%.

Third, we defined risk reduction factors, which specified how much ASCVD risk was reduced if a patient follows a certain treatment. Following literature, we assigned a number ranging from 0 (full risk reduction) to 1 (no risk reduction).[2] For instance, if a patient had a 10-year ASCVD risk of 10%, then a risk reduction factor of 0.8 for a treatment option implied that 10-year ASCVD risk would be 8% if a patient consistently used the treatment, corresponding to a 20% risk reduction.

We used the following relative risk reduction factors: 0.75 for prescribing aspirin; 0.73 for controlling blood pressure, defined as less than 140 mm Hf systolic and less than 90 mmHg diastolic blood pressure; 0.75 for managing cholesterol with a statin; and 0.99 for smoking intervention. We obtained risk reduction factors for blood pressure control and cholesterol management from a systematic review.[2] The relative risk reduction factor for aspirin prescribing was based on a meta-analysis of high-risk patients who were similar to our patient population.[19] Risk reduction for the smoking screening/cessation counseling was small because screening included both smokers and nonsmokers, and evidence suggested

that counseling was not very effective for patients who did smoke.[20–22]

We assigned relative risk factors to the 6 mutually exclusive eligibility groups by first identifying all hypothetical treatment options for each group and then attributing corresponding relative risk factors to them. Relative risk factors of treatment combinations were obtained by multiplying relative risk reduction factors of single treatments components. For instance, people eligible for cholesterol management and smoking intervention had 4 possible treatment options: (1) no treatment; (2) receiving a statin prescription; (3) receiving smoking intervention; and (4) receiving both treatments. Corresponding relative risk factors were 1.0, 0.75, 0.99, and $0.75 \times 0.99 = 0.7425$.

*Step 3: Calculation of Weights and Weighted Average ASCVD Risk*

We created weights for each NHANES respondent in our sample so that NHANES-based risk and risk reduction calculations were representative of the EvidenceNOW population. We used an optimization algorithm that selected weights by minimizing the sum of squared differences of average standardized patient characteristics based on the NHANES and EvidenceNOW sample (see Online Appendix, section A.2.4, for details). Patient characteristics for the 2 populations were similar after reweighing.

Next, we calculated the weighted average 10-year ASCVD risk at baseline across all NHANES respondents, repeated this calculation for postintervention ASCVD risk levels, and calculated the estimated reduction in 10-year ASCVD risk by subtracting the average postintervention ASCVD risk from the average baseline ASCVD risk.

To account for uncertainty in ABCS reduction estimates, we calculated bootstrapped standard errors of ASCVD risk and risk reduction using 1000 iterations. For each iteration, we first sampled ABCS improvement estimates using a normal distribution with mean equal to the respective point estimate (e.g., +3.39 for aspirin and the full sample) and standard deviation equal to the estimate's respective standard error. We then calculated postintervention ASCVD risk and risk reduction using sampled ABCS estimates. After repeating these steps 1000 times, we calculated standard deviation of the simulated 1000 postintervention ASCVD risk and risk reduction estimates to obtain standard errors.

As a sensitivity check, we repeated these step 1 to 3 calculations with average changes for practices that had higher than median changes in outcomes, because ABCS improvements varied widely across practices. Respective changes were 12.9 percentage points (aspirin prescribing); 9.4 percentage points (blood pressure control); 12.0 percentage points (cholesterol management); and 20.0 percentage points (smoking intervention). These calculations provide an estimate of ASCVD reductions associated with high-performing practices.

***Validation: Using NHANES for ASCVD Risk Calculations***

Our calculations required that our approach for constructing weights accurately estimated 10-year ASCVD risk of the EvidenceNOW patient population. Although we did not have access to individual-level risk factors of EvidenceNOW patients that would have permitted us to directly calculate ASCVD risk for them, we were able to work together with 2 cooperatives who did have such patient-level information. These cooperatives calculated 10-year ASCVD risk absent treatment for their practices' patient population using individual risk factors and the same risk prediction model as we used in our calculations. They then provided us with average 10-year ASCVD risk levels absent treatment for the full patient population at the practice level. They also shared practice-level estimates of 10-year ASCVD risk for those eligible for each of the 4 ABCS interventions. We validated our weighting approach by comparing our estimated ASCVD risk to theirs. For this validation, we created separate weights for each cooperative using respective patient characteristics. All calculations were performed in R, version 3.5.1. The Institutional Review Board of Oregon Health & Science University approved this study.

## Results

NHANES respondents corresponding to EvidenceNOW patients tended to be female, white, and less than 60 years old (Table 1). Patient population group sizes ranged from 1.6% (people only eligible for cholesterol management and smoking intervention) to 49.8% (people only eligible for smoking intervention).

EvidenceNOW practices provided care to patients with an average 10-year ASCVD baseline risk of

**Table 1. Sample Characteristics**

| | |
|---|---|
| Patient characteristics (percent) | |
| Female | 56.5 |
| White | 59.4 |
| Black | 15.5 |
| Hispanic | 19.5 |
| Age 40 to 59 | 57.3 |
| Age 60 to 75 | 39.0 |
| Age 76 to 79 | 3.6 |
| Patient population groups (percent) | |
| $G_S$ | 49.8 |
| $G_{BS}$ | 33.9 |
| $G_{CS}$ | 1.6 |
| $G_{ACS}$ | 2.8 |
| $G_{BCS}$ | 4.2 |
| $G_{ABCS}$ | 7.8 |
| Number of patients | |
| NHANES sample | 1295 |
| EN patient population | 3,961,384 |

Notes: The table shows characteristics of the NHANES sample. Weights are used for all patient characteristics and patient population group values. The number of EvidenceNOW patients corresponding to the NHANES sample is based on calculations using number of clinicians and number of patients per clinicans (see Online Appendix for details).
Abbreviations: EN = EvidenceNOW; $G_S$ = people in the denominator only requiring smoking intervention; $G_{CS}$ = people in the denominator for cholesterol management and smoking intervention; $G_{BS}$ = people in the denominator for blood pressure control and smoking intervention; $G_{ACS}$ = people in the denominator for aspirin prescription, cholesterol management and smoking intervention; $G_{BCS}$ = people in the denominator for blood pressure control, cholesterol management and smoking intervention; $G_{ABCS}$ = people in the denominator for aspirin prescription, blood pressure control, cholesterol management and smoking intervention.

10.11% (Table 2). Improvements in ABCS measures due to EvidenceNOW reduced the average 10-year ASCVD risk to 10.03%, corresponding to an absolute reduction of 0.08 percentage points ($P \leq .01$), or a risk reduction relative to the baseline risk of 0.79%. This risk reduction implied an expected prevention of 3,169 ASCVD events among the 3,961,384 EvidenceNOW patients over a 10-year period. A recent study estimated that the average direct 90-day medical cost of a major cardiovascular event was $47,433.[23] Thus, the prevention of 3,169 ASCVD events would save approximately $150 million in direct medical costs.

Improvements in blood pressure control or cholesterol management alone would each reduce 10-year ASCVD risk among the EvidenceNOW population by approximately 0.03 percentage points, or 0.30 and 0.28% relative to the baseline risk, respectively. Improvements in aspirin prescribing and smoking intervention alone would have resulted in smaller ASCVD risk reductions among the EvidenceNOW population (absolute 10-year ASCVD risk reduction: 0.01; relative 10-year ASCVD risk reduction: 0.14 and 0.07, respectively). Corresponding $p$-values for these estimates were not statistically significant.

In the sensitivity analyses that focused on practices that demonstrated improvements at the median or higher, we estimated that there would have been an absolute reduction in 10-year ASCVD risk of 0.32 ($P \leq .001$). This absolute risk reduction corresponds to a 3.28% decline in relative risk.

Approximately 50% percent of individuals were only eligible for smoking screening/cessation counseling of smokers (ie, individuals with no health conditions that would have made them eligible for aspirin, blood pressure control, or statin management; Table 3). Approximately 1/3 were eligible only for blood pressure control, and 7.8% were eligible for all 4 treatments. The average 10-year ASCVD risk by eligibility group ranged from 7.7% (people only eligible for smoking intervention) to 24.6% (people eligible for all 4 treatment options). The contribution to the overall ASCVD reduction varied from 3.6% (those only eligible for smoking intervention) to 31.1 and 41.2% for those eligible for blood pressure control and all treatment options, respectively. Validation estimates of 10-year ASCVD risk levels at baseline were similar to estimates based on our approach for both cooperatives (see Online Appendix, section A.3).

## Discussion

This study calculated reductions in 10-year risk of an ASCVD event (which includes nonfatal myocardial infarction, coronary heart disease death, or fatal or nonfatal stroke) associated with EvidenceNOW, a large multi-state initiative to improve cardiovascular risk prevention among smaller primary care practices that served approximately 4 million adult patients. We developed a novel method to estimate that adult EvidenceNOW patients had an average 10-year ASCVD risk of 10.11 percentage points at baseline, and that improvements in the ABCS due to EvidenceNOW reduced 10-year ASCVD risk by 0.08 percentage points. This risk reduction implied that EvidenceNOW would prevent approximately 3,169 ASCVD events over 10 years if improvements

**Table 2. Average ASCVD Risk and ASCVD Risk Reductions Due to Improvements in the ABCS**

| Average | Improvement in clinical outcomes | | | | |
|---|---|---|---|---|---|
| ASCVD | All ABCS | Aspirin Only | Blood Pressure Only | Cholesterol Only | Smoking Only |
| Baseline | 10.11 | 10.11 | 10.11 | 10.11 | 10.11 |
| All practices | | | | | |
| Post-intervention | 10.03 | 10.10 | 10.08 | 10.08 | 10.10 |
| Absolute change (*p*-value) | −0.08 (*P* < .001) | −0.01 (*P* > .05) | −0.03 (*P* > .05) | −0.03 (*P* > .05) | −0.01 (*P* > .05) |
| Relative change | −0.79 | −0.14 | −0.30 | −0.28 | −0.07 |
| Practices with median or higher improvement | | | | | |
| Post-intervention | 9.79 | 10.06 | 9.93 | 10.04 | 10.09 |
| Absolute change | −0.32 (*P* < .001) | −0.05 (*P* > .05) | −0.18 (*P* > .05) | −0.08 (*P* > .05) | −0.02 (*P* > .05) |
| Relative change | −3.28 | −0.53 | −1.79 | −0.75 | −0.20 |

Notes: The table shows estimated average ASCVD risk in the EvidenceNOW patient population at baseline and post-intervention as well as the absolute and relative change in ASCVD risk for five scenarios: improvement in all ABCS; improvement only in aspirin prescribing; improvement only in blood pressure control; improvement only in cholesterol monitoring; and improvement only in smoking intervention. Results for absolute changes also include bootstrapped *p*-values in parenthesis. Baseline ASCVD risks are identical for all interventions displayed in the table because they are all based on the full study sample. Baseline levels of ABCS were as follows: 61.9 (aspirin prescribing); 63.3 (blood pressure control); 60.2 (cholesterol management); 58.4 (smoking intervention). Changes in ABCS (if assumed for a scenario) for all practices were: 3.4 (aspirin prescribing); 1.6 (blood pressure control); 4.4 (cholesterol management); 7.4 (smoking intervention). Changes in ABCS (if assumed for a scenario) for practices with median or higher improvements were: 12.9 (aspirin prescribing); 9.4 (blood pressure control); 12.0 (cholesterol management); 20.1 (smoking intervention).
Abbreviation: ASCVD = atherosclerotic cardiovascular disease.

in the ABCS were sustained, saving $150 million in direct, 90-day medical costs alone. We found that this risk reduction is greater among higher performing practices, and for patients with multiple risk factors.

Although other EvidenceNOW cooperatives have conducted assessments of their practice-based interventions, most did not include assessments of change in cardiovascular disease risk as outcomes.[10,12–14] Identifying small improvements in health at the population level requires collecting granular, comprehensive information as precisely as possible. Obtaining such data often necessitates prior investment in data infrastructure (eg, practices' EHR system) that is currently not in place in primary care.[7] One of the unique attributes of our work was that we were able to provide estimates of cardiovascular disease risk reduction due to the initiative despite a general lack of such data infrastructure.

**Table 3. Relative Risk Factors and Risk Reduction Due to Improvements in ABCS**

| Groups | Relative Population Size (%) | ASCVD Risk at baseline (%) | Contribution to ASCVD reduction (%) |
|---|---|---|---|
| $G_S$ | 49.8 | 7.7 | 3.6 |
| $G_{BS}$ | 33.9 | 14.9 | 31.1 |
| $G_{CS}$ | 1.6 | 17.7 | 4.1 |
| $G_{ACS}$ | 2.8 | 13.1 | 7.8 |
| $G_{BCS}$ | 4.2 | 17.2 | 12.2 |
| $G_{ABCS}$ | 7.8 | 24.6 | 41.2 |
| Total | 100 | 10.1 | 100.0 |

Notes: The table shows the relative population size, average ASCVD risk at baseline, and contribution to ASCVD reduction. The contribution to ASCVD reduction for each group is calculated as the change in ASCVD risk relative to the overall change in ASCVD risk.
Abbreviations: $G_{CS}$ = people in the denominator for cholesterol management and smoking intervention; $G_{BS}$ = people in the denominator for blood pressure control and smoking intervention; $G_{ACS}$ = people in the denominator for aspirin prescription, cholesterol management and smoking intervention; $G_{BCS}$ = people in the denominator for blood pressure control, cholesterol management and smoking intervention; $G_{ABCS}$ = people in the denominator for aspirin prescription, blood pressure control, cholesterol management and smoking intervention. ASCVD = atherosclerotic cardiovascular disease.

One cooperative, North Carolina, was able to estimate cardiovascular disease reduction due to their intervention. This cooperative reported a larger reduction in 10-year ASCVD risk than we found.[11] Several reasons can explain this discrepancy. First, North Carolina implemented an informatics tool to calculate ASCVD risk for all patients aged 40 to 79 years and to focus statin and aspirin preventive care improvement efforts on patients with 10-year ASCVD risk above 10%. Only 147,000 of the 430,000 patients included in their study met this definition of high-risk patients. As a result, patients in the North Carolina study population had a much higher average 10-year ASCVD risk score at baseline than our study population (23.4 vs 10.13 percentage points in our study), which resulted in a correspondingly higher absolute ASCVD risk reduction. Second, the North Carolina study identified the patient population eligible for statin based on ASCVD risk as well as more traditional factors used in EvidenceNOW (e.g., presence of high cholesterol or ASCVD). They were able to achieve strong cholesterol management improvements for this patient population. Third, they used exact blood pressure levels based on electronic health records (EHR). This allowed them to calculate 10-year ASCVD reductions due to any reduction in systolic blood pressure, whereas our study was limited to estimating the effects of reductions below a specific threshold. Our imprecision in estimating the full effect of EvidenceNOW interventions, especially with regard to blood pressure, suggests that our results understate the full effect of the initiative on cardiovascular disease reduction.

It is also important to note that North Carolina was among the most experienced cooperatives in the EvidenceNOW cohort. An ability to leverage regional health information exchange and target high-risk patients, among other attributes of their cooperative's work, is evidence of that. This experience led to larger ABCS changes than less experienced cooperatives, and suggests that effectiveness of initiatives, such as EvidenceNOW, could be further strengthened by investing in cooperatives' expertise and infrastructure, and at very least needs to take experience into account when contextualizing outcomes.[24]

Our study contributes to a growing body of work examining the effectiveness of initiatives to improve cardiovascular health. One such initiative was the Cardiovascular Health Awareness Program (CHAP) in Ontario, Canada, which focused on outreach and educational effort at the community level.[25,26] This intervention led to a 9% relative improvement in a composite measure of hospital admissions for acute myocardial infarction, stroke, and congestive heart failure.[27] Related hospitalization costs declined by 14% relative to baseline, which offset the costs of the intervention.[28] These studies, together with our findings, suggest that intervening at the community and practice level are promising and potentially complementary strategies to improve cardiovascular health at the population level.

### *Limitations*

Our study had several limitations. First, our risk calculation was based on 2 separate samples, and we might not have been fully successful in balancing them along all ASCVD risk factors. However, our validation suggested that our approach was relatively accurate. Second, our calculations were based on an external risk prediction model that might not be accurate for some population groups. Third, estimates of ABCS improvements were based on an observational study and might reflect unrelated trends; however, other studies have shown no general improvements in the ABCS during our study period.[29–31] Fourth, our calculations assumed that improvements would persist for 10 years, and we overstate the number of ASCVD events prevented otherwise. Conversely, we focused on patients 40 to 79 years old and assumed that only the current, but not future patient cohorts, would be affected by the intervention. This assumption by itself implied that we underestimated the number of prevented ASCVD events. Fifth, calculations for above-median practices may suffer from regression to the mean. Sixth, we did not include measures of morbidity and well-being, and therefore may not have captured the full health effects of the intervention. Seventh, qualitative data from EvidenceNOW shows that documentation changes, such as improving documentation of smoking interventions in the EHR, may explain some of the improvements observed in ABCS.[32] Although we considered improving documentation a quality improvement, it was not one that is likely to have an impact on ASCVD events and thus by itself would lead to an overstatement of ASCVD reductions. Eighth, interventions for lower risk

patients may have included lifestyle changes (e.g., diet and exercise), the effects of which were imperfectly captured by the ABCS, and thus not fully accounted for in our calculations. Finally, we only included 13% of NHANES respondents in our analysis, partially due to missing information about smoking, blood pressure, and chol-esterol.

## Conclusion

This study showed how external support strategies for smaller primary care practices, when implemented at a large-scale via regional cooperatives, could meaningfully reduce cardiovascular population health risk levels while being nearly cost neutral.[33,34] Findings from this study, and the overall EvidenceNOW initiative,[7–9,16,17,24,32,35–39] suggest that policy-makers should support long-term investment in organizations, such as the primary care cooperative extension, that can reach large numbers of smaller practices and provide care enhancing external support.

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# Appendix

## A.1 NHANES sample selection

The following table shows sample selection steps and corresponding NHANES sample sizes.

Appendix Table A-1: Sample selection steps and corresponding sample size in NHANES

| Selection step | Sample size [N (percent)] |
|---|---|
| Initial sample | 9,971 (100.0 %) |
| Excluded individuals younger than 40 / older than 79 years | 3,390 (34.0%) |
| Exclude individuals with missing smoking information | 1,552 (15.6%) |
| Exclude individuals with missing blood pressure information | 1,362 (13.6%) |
| Exclude individuals with missing cholesterol informatin | 1,295 (13.0%) |

## A.2 Details of ASCVD calculations

### A.2.1 Overview of calculations

Our approach for calculating ASCVD risk may be written as follows:

$$Risk = \left(\sum_i \omega_i \widetilde{r}_i\right) = \left(\sum_i \omega_i r_i \pi_j\right) \tag{1}$$

where $i$ are individuals in the NHANES who are 40 years or older, $j$ are mutually exclusive denominator groups, $\omega_i$ are weights to make NHANES-based estimates representative of the EvidenceNOW patient population, and $\widetilde{r}_i = r_i \cdot \pi_i$ is the treatment-adjusted ASCVD risk of individual $i$, which is obtained by multiplying 10-year ASCVD risk absent of treatment $r_i$ with the group-specific average risk-reduction factor $\pi_j$.

Our calculations of equation (1) proceeded in three steps:

1. Estimate 10-year ASCVD risk in the absence of ABCS treatment for each NHANES respondent;
2. Estimate 10-year ASCVD risk reduction among NHANES respondents had they been exposed to ABCS improvements due to EvidenceNOW; and
3. Calculation of weights $\omega_i$ and weighted average 10-year ASCVD risk reduction due to EvidenceNOW.

### A.2.2 Calculation of 10-year ASCVD risk absent treatment

We calculated ASCVD risk absent treatment using the 2013 ACC/AHA Guideline on the Assessment of Cardiovascular Risk.[1] The guidelines present results of pooled cohort equations to estimate 10-year risk of ASCVD, stratified by sex and race (see Appendix Table A-2). We used these estimated parameter values to calculate ASCVD risk for individuals in NHANES 40-79 years of age. We restricted our calculations to this age group because estimates were based than age range as well. People who reported a different race or ethnicity than "white" or "black" are subsumed under the category "white", as in the 2013 guidelines. We validated our calculation using an online risk calculator, which is based on the same estimates.[1]

Appendix Table A-2: Estimates of 10-year risk of ASCVD, stratified by sex and race (reproduction of Appendix 7, 2013 ACC/AHA Guideline on the Assessment of Cardiovascular Risk[1])

| | Women | | Men | |
|---|---|---|---|---|
| Variable | White | Black | White | Black |
| Log age (years) (y) | -29.799 | 17.114 | 12.344 | 2.469 |
| Log age, squared (years) | 4.884 | 0.000 | 0.000 | 0.000 |
| Log total cholesterol (mg/dL) | 13.540 | 0.940 | 11.853 | 0.302 |
| Log age x log total cholesterol | -3.114 | 0.000 | -2.664 | 0.000 |
| Log HDL-C (mg/dL) | -13.578 | -18.920 | -7.990 | -0.307 |
| Log age x log HDL-C | 3.149 | 4.475 | 1.769 | 0.000 |
| Log treated systolic BP (mm Hg) | 2.019 | 29.291 | 1.797 | 1.916 |
| Log age x log treated systolic BP | 0.000 | -6.432 | 0.000 | 0.000 |
| Log untreated systolic BP (mm Hg) | 1.957 | 27.820 | 1.764 | 1.809 |
| Log age x Log untreated systolic BP | 0.000 | -6.087 | 0.000 | 0.000 |
| Current smoker | 7.574 | 0.691 | 7.837 | 0.549 |
| Log age x current smoker | -1.665 | 0.000 | -1.795 | 0.000 |
| Diabetes | 0.661 | 0.874 | 0.658 | 0.645 |

### A.2.3 Calculation of 10-year ASCVD risk reduction

#### A.2.3.1 Identification of denominator populations in NHANES

ABCS denominator definitions were based on Centers for Medicaid and Medicare Services electronic clinical quality measure (eCQM) specifications used in EvidenceNOW. We identify people eligible for each of the ABCS using a combination of NHANES variables. Table A-3 provides details.

[1] See https://professional.heart.org/professional/GuidelinesStatements/ASCVDRiskCalculator/UCM_457698_ASCVD-Risk-Calculator.jsp

Appendix Table A-3: Definition of ABCS denominator populations and NHANES specification

| Measure | Measure definition | NHANES specification |
|---|---|---|
| Aspirin | Adults 18 years or older with at least one face-to-face visit and (i) an active diagnosis of ischemic vascular disease during the measurement period; or (ii) being discharged alive for acute myocardial infarction, coronary artery bypass graft or percutaneous coronary interventions in the 12 months prior to the measurement period. | Patient diagnosed with congestive heart failure (mcq160b) or heart attack (mcq160e). |
| Blood pressure | Adults 18-85 with at least one face-to-face visit and an active diagnosis of essential hypertension any time prior to the first day of month 7 of the measurement period; excluding (i) pregnant women and (ii) patients with end stage renal disease, dialysis, or renal transplant prior or during the measurement period. | Patient diagnosed with hypertension (bpq020) who are not currently pregnant (rhd143), have a failing kidney (kiq022) or received dialysis in the past 12 months (kiq025). |
| Cholesterol | Adults 21 years and older with at least one face-to-face visit and (i) An active diagnosis of clinical atherosclerotic cardiovascular disease (ASCVD) during the current measurement period or any time prior; (ii) LDL-C result >= 190 mg/dL at any time during or prior to the measurement period; or (iii) aged 40 to 75 years at the beginning of the measurement period with an active diagnosis of diabetes with the highest LDL-C result of 70 - 189 mg/dL during the current measurement period or two years prior to the beginning of the measurement period; excluding (i) patients with adverse effect, allergy or intolerance to statin medication therapy; (ii) patients who have an active diagnosis of pregnancy or breastfeeding; (iii) patients who are receiving palliative care; (iv) patients with active liver disease or hepatic disease or insufficiency; (v) patients with end stage renal disease; (vi) patients with most recent LDL-C result < 70 mg/dL, a diabetes diagnosis and no current statin medication therapy. | Patients diagnosed with congestive heart failure (mcq160b), coronary heart disease (mcq160c), heart attack (mcq160e) or stroke (mcq160f) who were not pregnant (rhd143), did not breastfeed (rhq200), did not have a liver condition (mcq170l), did not have Hepatitis B or C (heq010, heq030), did not have a failing kidney (kiq022) or did not have a dialysis in the past 12 months (kiq025). |
| Smoking | Adults 18 years or older with at least two visits or one preventive visit | All individuals age 40 years or older |

#### A.2.3.2 Identification of mutually exclusive denominator groups

We then identified mutually exclusive denominator groups (e.g., those in the denominator for aspirin and blood pressure but not in other denominators). We denoted groups $G$ using subscripts for the measure denominators that the group belongs to. For instance, $G_S$ denotes all individuals included in the smoking denominator but not included in any of the other denominators, and $G_{ACS}$ denotes all individuals included in the aspirin, cholesterol and smoking denominator, but not in the blood pressure denominator.

In general, there can be 15 mutually exclusive groups using all possible combinations of the four denominator groups. In our case, there were six such groups, for two reasons: (i) everyone was included in the smoking denominator; and (ii) everyone in the aspirin denominator was also in the cholesterol denominator. The six mutually exclusive denominator groups were:

1. Those only included in the smoking denominator ($G_S$);
2. Those only included in the blood pressure and smoking denominator ($G_{BS}$);
3. Those only included in the cholesterol and smoking denominator ($G_{CS}$);
4. Those only included in the aspirin, cholesterol and smoking denominator ($G_{ACS}$);
5. Those only included in the blood pressure, cholesterol and smoking denominator ($G_{BCS}$); and
6. Those included in all four denominators ($G_{ABCS}$).

Note that all NHANES patients were in at least one denominator because the smoking denominator included all adults ages 18 and older.

#### A.2.3.3 Identification of treatment combinations and associated relative risk factors

For each of the six mutually exclusive denominator groups, we identified all possible treatment combinations, and assigned a relative risk factor to each of them. The number and types of possible treatment combinations depended on the denominator groups. For instance, individuals included in the denominator group $G_{CS}$ (i.e., those included in both the cholesterol and smoking denominator but no other denominators) could have received no treatment, only statin treatment, only smoking intervention, or both statin and smoking cessation counseling.

For each possible treatment combination, we then calculated its associated ASCVD relative risk factor. Risk reduction factors range from 0 to 1, with a lower number corresponding to a higher risk reduction. We used the following 10-year ASCVD relative risk factors based on a comprehensive literature review [2]:

- Aspirin: 0.90.
- Blood pressure: 0.73
- Cholesterol (statin): 0.75.
- Smoking: 0.99. We used a less strong relative risk factor for smoking as suggested by the literature (0.85 for a 1-year smoking cessation period and 0.73 for a 2-year smoking cessation period) because the intervention considered here only included smoking intervention, which translates into smoking cessation in only a small percent of all cases.

The systematic review further "found no evidence of an interaction among these combinations in terms of effects on ASCVD events, blood pressure, or lipid levels" (p. 1624). Therefore, we assumed that the combinations of multiple treatments results in a risk reduction equal to the product on the relative risk factors of each singular treatment. For instance, people eligible for cholesterol management and smoking intervention had four possible treatment options: (i) no treatment; (ii) receiving a statin prescription; (iii) receiving smoking intervention; and (iv) receiving both treatments. Corresponding relative risk factors were 1.0, 0.75, 0.99, and 0.75x0.99=0.7425.

#### A.2.3.4 Calculating of risk and risk reduction for each eligibility group

To calculate ASCVD risk at baseline for each eligibility group, we assigned probabilities to each treatment combination using treatment rates at baseline from EvidenceNOW practices. For this calculation, we assumed that receiving treatment are independent events, and therefore, the probability of receiving a combination of treatment types is the product of the probability of receiving each singular treatment. Using treatment probabilities and corresponding risk reduction factors, we then calculated the average ASCVD risk for individuals in each of the six mutually exclusive denominator groups.

We calculated the average ASCVD risk after intervention using the same steps as described above and post-intervention treatment rates. ABCS rates at baseline line and improvements due to EvidenceNOW were based on published estimates from an event study.[**?** ] Specifically, baseline levels for the ABCS were as follows: 61.9 percent; 63.3 percent; 60.2 percent; and 58.4 percent, respectively.Improvements due to the intervention were estimated to be +3.39 percentage points; +1.60 percentage points; 4.37 percentage points; and 7.44 percentage points, respectively. We also repeated these calculations for for practices that had higher than median changes in outcomes as a sensitivity check. Respective changes were 12.9 percentage points (aspirin prescribing); 9.4 percentage points (blood pressure control); 12.0 percentage points (cholesterol management); and 20.0 percentage points (smoking intervention).

### A.2.4 Calculation of weights

We created weights for the NHANES sample to minimize the sum of squared differences of patient characteristics between the NHANES sample and EvidenceNOW sample:

$$\underset{\omega}{arg\,\min} \sum_j \left(z_j^{EN} - \sum_i \omega_i z_{ij}^{NHANES}\right)^2, \tag{2}$$

where $z_j^{EN}$ is the standardized average patient characteristic $j$ among EvidenceNOW practices and $z_{ij}^{NHANES}$ is the standardized characteristic $j$ for patient $i$ in the NHANES sample. Variables were standardized by subtracting the average and dividing the result by the standard deviation. Patient characteristics included: fraction white; fraction black; fraction Hispanic; percentage of patients ages 60 to 75 relative to percentage of patients 40 years or older; percentage of patients ages 76 and older relative to percentage of patients 40 years or older; percentage female. We set the percentage of patients ages 76 and older in EvidenceNOW to 20 percent of its actual value (or about 4 percent of the patient population ages 40-79) to reflect the truncated age distribution in NHANES. We used the `optimx` package in R to find a solution for equation (2), and selected a box constraint optimization procedure, restricted the optimization to positive weights, and normalized weights to sum to 1 after optimization [3]. Practice characteristics were similar for the two samples after using weights (Appendix Table A-4).

Appendix Table A-4: Characteristics in EvidenveNOW practices and NHANES

| | Mean EN | Mean NHANES (unweighted) | ASMD EN – NHANES (unweighted) | Mean NHANES (weighted) | ASMD EN – NHANES (weighted) |
|---|---|---|---|---|---|
| White | 59.8 | 67.7 | 0.12 | 59.4 | -0.01 |
| Black | 15.6 | 22.7 | 0.13 | 15.5 | 0.00 |
| Hispanic | 19.1 | 29.1 | 0.17 | 19.5 | 0.01 |
| Age 60-75 | 39.8 | 44.9 | 0.07 | 39.0 | -0.01 |
| Age 76 or older | 4.1 | 5.7 | 0.05 | 3.6 | -0.02 |
| Female | 56.5 | 38.7 | -0.26 | 56.5 | 0.00 |

*Notes:* The table shows characteristics of EvidenceNOW practices patients and NHANES respondents. EN: EvidenceNOW; NHANES: National Health and Nutrition Examination Survey; ASMD: average standardized mean difference.

After creating these weights, we inflated them by a population factor so that the sum of the weights equaled the number of EvidenceNOW patients targeted by the initiative. To this end, we calculated an estimate of the number of patients in EvidenceNOW practices targeted by the initiative, proceeding in two steps. First, we multiplied the number of clinicians per practice and the average number of patients per clinician to obtain an estimate of the total number of EvidenceNOW patients. Second, we multiplied this number by the fraction of EvidenceNOW patients ages 40 to 79, the age range of our NHANES sample. The estimated number of EvidenceNOW patients was 3,961,384.

We used these weights to calculate the weighted average 10-year ASCVD risk at baseline across all NHANES respondents. We then repeated this calculation for post-intervention ASCVD risk levels, and calculated the estimated reduction in 10-year ASCVD risk by subtracting the average post-intervention ASCVD risk from the average baseline ASCVD risk.

### A.2.5 Calculation of bootstrapped standard errors

To account for uncertainty in ABCS reduction estimates, we calculated bootstrapped standard errors of ASCVD risk and risk reduction using 1,000 iterations. For each iteration, we first sampled ABCS improvement estimates using a normal distribution with mean equal to the respective point estimate (e.g., +3.39 for Aspirin and the full sample) and standard deviation equal to the estimate's respective standard error. We then calculated post-intervention ASCVD risk and risk reduction using sampled ABCS estimates. After repeating these steps 1,000 times, we calculated standard deviation of the simulated 1,000 post-intervention ASCVD risk and risk reduction estimates to obtain the respective standard errors.

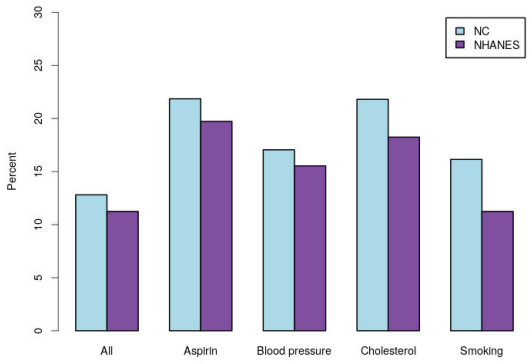
## A.3 Validation of ASCVD calculations

Our calculations required that our approach for constructing weights accurately estimated 10-year ASCVD risk of the EvidenceNOW patient population. While we did not have access to individual-level risk factors of EvidenceNOW patients that would have permitted us to directly calculate ASCVD risk for them, we were able to work together with two cooperatives who did have such patient-level information to compare estimated ASCVD risk at baseline based on our calculations to ASCVD risk at baseline from these cooperatives.

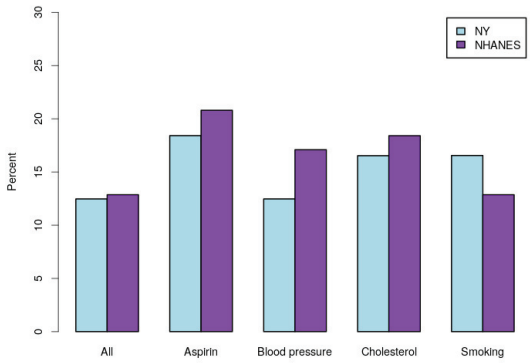
The two cooperatives used patient level information available to them to calculate 10-year ASCVD risk using the same risk estimates from from Goff et al. (2013). They also calculated 10-year ASCVD risk for each of the ABCS denominator patient population. They then aggregated ASCVD risk at the practice level.

We repeated our ASCVD risk calculations as described above, with one difference: instead of creating weights to align practice characteristics for the whole EvidenceNOW sample, we created two sets of weights, one for each cooperative. Afterwards, we calculated average practice characteristics and 10-year ASCVD risk at baseline for each cooperative as well as unweighted and weighted average practice characteristics and 10-year ASCVD risk in our NHANES study population.

Estimated average 10-year ASCVD risk in our NHANES sample were similar to estimates from the first cooperative for all population groups. For the second cooperative, estimates for all patients were similar, but estimates for the denominator groups were somewhat different (Appendix Figures A-1 and A-2).




Appendix Figure A-1: Estimated 10-year ASCVD risk based on NHANES versus patient characteristics from North Carolina




Appendix Figure A-2: Estimated 10-year ASCVD risk based on NHANES versus patient characteristics from New York

## References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