

## METHODS

# Developing a Composite Weighted Quality Metric to Reflect the Total Benefit Conferred by a Health Plan

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Measurement of health system performance is difficult. Quality measures are proliferating<sup>1,2</sup> with >350 suggested metrics in 2014,<sup>3</sup> and these measures are often criticized because they focus on narrow-based interventions (eg, use of angiotensin-converting enzyme inhibitors for patients with congestive heart failure) that fail to provide a global measure of benefit.<sup>4,6</sup> Existing metrics also have varying correlations with health outcomes of interest to patients and patient representatives;<sup>4,8</sup> therefore, it is unknown whether a health plan that exceeds quality measures confers greater health benefit than other health plans.<sup>9,10</sup> Moreover, composite evaluation metrics such as the Healthcare Effectiveness and Data Information Set typically assign the same weight to each item. For example, the percentage of women aged 40 to 69 years who had a screening mammogram in the past 2 years counts as much as the percentage of diabetics aged 18 to 75 years with controlled A1C,<sup>11</sup> even though their contributions to health may differ.

A more appropriate weighting scheme for composite metrics remains subject to debate. Some researchers have suggested all-or-none or 70% standards, in which patients must meet all or  $\geq 70\%$  of identified criteria, respectively, to be included in the numerator.<sup>12-14</sup> Such criteria are used in the evaluation of accountable care organizations for diabetes and coronary artery disease, such as the percent of adults with ischemic vascular disease who received  $\geq 1$  lipid profile within 12 months and whose most recent low-density lipoprotein cholesterol (LDL-C) level was  $< 100$  mg/dL.<sup>1</sup> Others have argued for development of composite weights based on measurement reliability,<sup>15</sup> post surgical quality of life,<sup>16</sup> or population health.<sup>12</sup> No consensus on optimal quality weights has been reached.

More generally, the National Quality Forum requires 4 criteria for endorsement of a quality measure: 1) a focus on a priority area that improves healthcare quality, 2) scientific acceptability (reliability and validity), 3) usability and relevance, and 4) feasibility.<sup>17</sup> To improve their usefulness, some

## ABSTRACT

**Objectives:** To improve individual health quality measures, which are associated with varying degrees of health benefit, and composite quality metrics, which weight individual measures identically.

**Study Design:** We developed a health-weighted composite quality measure reflecting the total health benefit conferred by a health plan annually, using preventive care as a test case.

**Methods:** Using national disease prevalence, we simulated a hypothetical insurance panel of individuals aged 25 to 84 years. For each individual, we estimated the gain in life expectancy associated with 1 year of health system exposure to encourage adherence to major preventive care guidelines, controlling for patient characteristics (age, race, gender, comorbidity) and variation in individual adherence rates. This personalized gain in life expectancy was used to proxy for the amount of health benefit conferred by a health plan annually to its members, and formed weights in our health-weighted composite quality measure. We aggregated health benefits across the health insurance membership panel to analyze total health system performance.

**Results:** Our composite quality metric gave the highest weights to health plans that succeeded in implementing tobacco cessation and weight loss. One year of compliance with these goals was associated with 2 to 10 times as much health benefit as compliance with easier-to-follow preventive care services, such as mammography, aspirin, and antihypertensives. For example, for women aged 55 to 64 years, successful interventions to encourage weight loss were associated with 2.1 times the health benefit of blood pressure reduction and 3.9 times the health benefit of increasing adherence with screening mammography.

**Conclusions:** A single health-weighted quality metric may inform measurement of total health system performance.

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**Take-Away Points**

We developed a weighted quality measure to reflect the total health benefit conferred by a health plan annually to its members.

- Quality was weighted by the gain in life expectancy associated with 1 year of member adherence.
- Health plans that helped members quit smoking or lose weight for 1 year contributed 2 to 10 times as much health benefit as those that improved member compliance with easier-to-follow preventive care services, such as mammography, aspirin, and antihypertensives.
- Weighted metrics may inform overall health plan evaluation—for example, by reporting the total insurance plan quality next to price on health insurance exchanges.

researchers suggest that quality measures must transition to broader, more meaningful metrics, which readily lend themselves to improvement.<sup>4</sup> Yet, the development of appropriate measures and their implementation remain at early stages; for example, while electronic medical records (EMRs) may enable better measurement of patient care and outcomes, they may under- or overestimate appropriate care utilization. A recent study in a federally qualified health center found that EMRs estimated 38% appropriate asthma medication use, compared with 77% when measured manually<sup>18,19</sup>; similar inaccuracies have been found using claims data.<sup>20</sup>

To consider the potential to condense multiple quality metrics into more actionable, useful information, we aimed to develop a health-weighted composite quality metric, which quantified the amount of preventive health benefit conferred by a health system over 1 year to a typical health insurance system membership panel. Such a measure may complement existing quality metrics by giving a more holistic view of the health benefit imparted by health systems, and may be useful for patients and patient representatives (employers) seeking to compare different health systems or to evaluate whether a health system is improving over time.

**METHODS**

We adapted a previously published and validated computer simulation<sup>20</sup> to estimate the increase in life expectancy that would occur from 1 year of exposure to a health system with specified performance on individual quality metrics on a population with specified distributions of characteristics. Briefly, that model estimated life expectancy for an individual patient, personalized for age, gender, race, risk factors, and comorbidity.<sup>21</sup> The model then simulated the change in life expectancy associated with adherence to each US Preventive Services Task Force (USPSTF) grade A and B recommendation, and

rank-ordered results to help identify the most important preventive care guidelines for each patient.<sup>21</sup>

We targeted the question: “How much additional health has a health plan conferred to a particular patient in the past year, through preventive care?” by making 3 main adaptations to this model. First, we teased apart the health benefit attributable to 1 year of health plan intervention (“attributability”), disambiguating it from additional benefit that might occur in successive years if continued intervention made adherence more likely. For example, we only considered the benefit from taking a lipid-lowering medication that arose from 1 year of health plan intervention, assuming that patient’s adherence would decline in succeeding years unless its persistence was reinforced by subsequent care.

Second, because adherence to medications and lifestyle recommendations are important contributors to the success of chronic disease management and prevention, we modeled both intervention-specific adherence rates (for example, assuming that it was easier to take antihypertensive medications than to stop smoking) and variability in adherence rates across health plan members (above- vs below-average member-specific adherence rates). In this context, “adherence” was defined as compliance with each USPSTF recommendation within 1 year of working with a physician: body mass index (BMI) = 24.9; blood pressure (BP) = 120/80 mm Hg; total cholesterol = 190 mg/dL; LDL-C = 70 mg/dL; no tobacco use; no alcohol misuse; for diabetics, A1C = 6% (controlled diabetes); and mammograms, Pap smears, and colonoscopies at recommended frequencies.<sup>21</sup>

Finally, in addition to a baseline lifetime horizon, we considered shorter (5-, 10-, and 20-year) time horizons that may be more relevant to health insurers and employers who expect their members to eventually change insurance plans. **eAppendix A** provides mathematical details (available at [www.ajmc.com](http://www.ajmc.com)).

**Hypothetical Insured Membership Panel**

We constructed a hypothetical health insurance system membership panel using national prevalence of age, race, gender, and comorbidity as a proxy. We focused on individuals aged 25 to 84 years (approximately 64% of the US population)<sup>22</sup> as the core group for preventive healthcare exposure, using the most recent (July 2012) age-gender-race distribution reported by the US Census Bureau.<sup>22,23</sup> We then used data from the National Health Interview

■ **Table 1.** Summary Statistics for Hypothetical Panel of Insured Health System Members, Aged 25 to 84 Years

Age (years)	Gender	N <sup>b</sup>	% of Panel	Distribution of Patient Characteristics Within Age and Gender Group <sup>a</sup>							
				Black (%)	Overweight (%)	Obese (%)	Hypertension (%)	Diabetes (%)	Tobacco (%)	Hyperlipidemia (%)	Hazardous Alcohol (%)
25-34	Male	173	10.6	14.5	34.0	27.1	6.8	3.6	27.5	7.6	19.6
	Female	175	10.5	14.5	25.0	30.4	3.8	3.6	19.5	5.8	5.2
35-44	Male	204	10.3	13.4	43.0	37.2	20.7	3.6	21.2	16.2	19.6
	Female	207	10.4	13.4	26.8	37.1	14.2	3.6	19.9	11.9	5.2
45-54	Male	160	11.2	11.7	40.2	36.6	35.5	13.5	27.0	18.7	12.5
	Female	168	11.6	11.7	29.3	36.9	31.2	13.5	21.6	17.7	4.2
55-64	Male	102	8.7	10.4	42.5	37.3	49.5	13.5	21.4	16.3	9.8
	Female	112	9.4	10.4	28.8	43.4	50.4	13.5	15.0	25.6	2.3
65-74	Male	76	5.0	9.3	36.0	41.5	64.1	25.7	8.9	7.5	6.1
	Female	94	5.7	9.3	33.9	40.3	69.3	25.7	7.1	20.6	0.8
75-84	Male	55	2.8	7.6	46.6	26.6	71.7	25.7	8.9	6.8	2.4
	Female	92	3.9	7.6	34.5	28.7	81.3	25.7	7.1	20.2	0.0
<b>Total</b>		<b>1605</b>	<b>100.0</b>	<b>11.9</b>	<b>34.1</b>	<b>35.3</b>	<b>33.0</b>	<b>11.2</b>	<b>19.1</b>	<b>14.4</b>	<b>8.7</b>

<sup>a</sup>We also assumed that 5% of individuals had a family history of colorectal cancer and 12.5% of females had a family history of breast cancer.

<sup>b</sup>Number of patients per physician participating in the health insurer, based on a typical physician's panel of 2500 patients.

Survey on the prevalence of select comorbidities, by age and gender, including obesity (estimated by the proportion of BMIs 25.0-29.9, 30.0-34.9, 35.0-39.9,  $\geq 40.0$ ), hypertension, hyperlipidemia, diabetes, tobacco use, and hazardous or harmful alcohol use ( $\geq 5$  drinks/day on  $\geq 12$  occasions in the past year).<sup>24</sup> Using the Surveillance, Epidemiology, and End Results Cancer Statistics Review, we also assumed a family history ( $\geq 1$  first-degree relative) of colorectal cancer for 5% of individuals (of all ages/genders) and a family history of breast cancer for 12.5% of women.<sup>25</sup>

Additionally, we recognized that some individuals were more likely to suffer from multiple comorbidities. Therefore, we included prior estimates of the relative risks of diabetes and hypertension in obese (BMI  $\geq 30.0$ ) versus nonobese individuals (relative risk [RR] for diabetes, 5.2 for males and 12.7 for females; RR for hypertension, 2.6 for males and 4.2 for females).<sup>21</sup> For example, among females aged 45 to 54 years, we estimated that 18.7% were obese hypertensive women, 18.1% were obese nonhypertensive women, 12.5% were nonobese hypertensive women, and 50.6% were nonobese nonhypertensive women (eAppendix A). Naturally, a more complete analysis would include representations of all permutations of comorbidities; however, data on correlations across all major comorbidities are not readily available, so we focused on those that were most prevalent and clinically important. We then simulated a basic medical history for each hypothetical health insurance member by sampling

simple distributions for BMI, BP, cholesterol, and diabetes (eAppendix A).

### Intervention-Specific Adherence Rates

For the sake of analytical tractability, we made a simplistic assumption, classifying each USPSTF recommendation as intrinsically “easy” or “difficult” to adhere to—a characteristic distinct from, but potentially interacting with, a patient's propensity to adhere. Reported levels of adherence in published literature are heterogeneous and often dated,<sup>26,27</sup> so we used prior studies in conjunction with our clinical judgment to arrive at these classifications. The set of “difficult” recommendations was composed of weight loss, tobacco cessation, reduction in alcohol use, healthy diet, and lifestyle (nonmedication) components of cholesterol and hypertension management. For difficult recommendations, we assumed adherence rates of 30% during the first year, based on reported adherence rates to tobacco cessation (which ranged from 20% to 40% after 26 weeks).<sup>26</sup> All other recommendations were considered “easy,” for which we assumed adherence rates of 70% during the first year. These adherence rates were primarily based on compliance rates with antihypertensive<sup>26,27</sup> and statin<sup>28,29</sup> medications, though prior literature had a wide range of estimates. The first-year rate of adherence was followed by a lower probability of continued adherence after 1 year, reflecting what might happen if the health system did not effectively reinforce adherence in subsequent years. (eAppendix A provides further details.)

## RESULTS

We developed a composite quality metric with weights that reflected the relative quantities of health benefit conferred across a typical health insurance system membership panel. **Table 1** shows summary statistics: across all ages, the 3 most prevalent conditions were overweight or obesity, hypertension, and tobacco use.

**Table 2** (and eAppendix Table) shows the magnitude of health benefit that would be imparted by an insurer that emphasized adherence to the single USPSTF-based guideline of most importance to each member, as reflected by its personalized benefit to life expectancy. For example, among females aged 55 to 64 years, the 3 greatest-benefit recommendations, or component weights, were weight loss, BP reduction, and mammography. One year of health system intervention to encourage adherence with these recommendations was associated with a mean life expectancy increase per member of 0.70, 0.33, and 0.18 years, respectively. Across all similarly aged women, successful implementation of this strategy would increase mean life expectancy per member, or composite health quality, by 0.47 years (SD = 0.33 years). More generally, in most age/gender categories, lifestyle recommendations such as losing weight or quitting smoking received the highest component weight. For individuals 55 years or older, BP reduction and aspirin chemoprophylaxis also conferred large benefits, as did screening mammography for women aged 35 to 64 years, and decreased alcohol use for men aged 25 to 44 years. Recommendations conferring the greatest health benefit were similar at shorter (5-, 10-, and 20-year) time horizons that may be more relevant to health insurers and employers (eAppendix B).

## DISCUSSION

Researchers have been unable to quantify the health improvement provided by health systems in general, and from increasing patients' adherence to healthcare recommendations in particular.<sup>1-11</sup> As a result, health system performance is often based on multiple individual quality metrics that are either considered separately, or counted equally despite their variation in quantity of health benefit conferred. Previous composite metrics have often been based on an all-or-none approach<sup>1,12-14</sup> or quality weights for outcomes surrounding a single intervention (eg, a single surgery).<sup>16</sup> We have developed a health-weighted composite quality metric that estimates the amount of health benefit attributable to preventive care that is conferred by a particular health plan. It gives higher weights to those processes

that have been associated with greater health gains, and varies these weights based on patient characteristics. This personalization allows a health-weighted composite quality metric to be different for each health plan member.

We found that health plans would contribute the greatest health benefit among preventive care interventions by encouraging the adoption of lifestyle recommendations such as tobacco cessation and weight loss, even taking into account the lower likelihood of continued adherence to these difficult recommendations. One year of adherence with these goals was associated with an estimated 0.5 to 1 year of additional life expectancy for men and women in every age group between 25 and 84 years. That is, even though patients were unlikely to maintain adherence to these recommendations over extended periods, benefits were so high that they remained a high priority for the majority of patients. Some may argue that it would be inappropriate to gauge individual physicians based on patient compliance to these metrics because whether a patient chooses to adhere (for example, by quitting smoking) lies beyond the physician's control, and therefore, may not be a suitable quality metric.<sup>30</sup>

However, health insurers may potentially be held more accountable, as promotion of coordinated care, lifestyle, and other wellness programs—which often involve non-MD time—may provide their members with large benefits. Additionally, easier recommendations that are more under the control of individual physicians (eg, mammography, aspirin use, and antihypertensives) also ranked high. We caution that these results are based on hypothetical patients using characteristics of the overall US population and disease prevalence; practical implementation would require more thorough consideration of model assumptions, quality metric validation, and feasibility studies for health systems.

The attributable health gains estimated by our health-weighted quality metric might be considered a yardstick for health system performance, with plan-to-plan comparison through adjustment for baseline patient characteristics and differential adherence rates. The simplicity of a single holistic, outcomes-oriented measure also may appeal to patients seeking to evaluate the performance of different health plans before enrollment. For example, should future research validate our proposed metric (or a similar measure), health exchanges might consider reporting the overall health benefit conferred by each health insurance plan alongside its price (**Table 3**).

### Limitations

Our approach has several limitations. We considered patient adherence with each recommendation in isola-

**Table 2.** Annual Health Benefit Attributable to Preventive Care in a Health System With Typical Adherence to Preventive Care Measures

Age (years)	Gender	Total Health Benefit (composite quality) <sup>b</sup>	Component Weights <sup>a</sup> (USPSTF recommendations with greatest benefit)		
			#1	#2	#3
25-34	Male	0.67 (0.46)	Quit smoking 1.07* (0.45)	Lose weight 0.92 (.60)	Decrease alcohol use 0.53 (0.15)
	Female	0.50 (0.36)	Lose weight 0.64 (0.35)	Quit smoking 0.55 (0.21)	Lower blood pressure 0.67 (0.00)
35-44	Male	0.61 (0.46)	Lose weight 0.97 (0.57)	Quit smoking 1.00 (0.38)	Decrease alcohol use 0.51 (0.13)
	Female	0.43 (0.30)	Undergo mammogram 0.23 (0.07)	Lose weight 0.67 (0.38)	Quit smoking 0.54 (0.24)
45-54	Male	0.64 (0.47)	Lose weight 0.81 (0.51)	Use aspirin 0.24 (0.06)	Quit smoking 1.07 (0.34)
	Female	0.46 (0.30)	Lose weight 0.70 (0.28)	Undergo mammogram 0.19 (0.05)	Quit smoking 0.58 (0.20)
55-64	Male	0.54 (0.33)	Lose weight 0.82 (0.51)	Quit smoking 0.79 (0.21)	Use aspirin 0.18 (0.03)
	Female	0.47 (0.33)	Lose weight 0.70 (0.33)	Lower blood pressure 0.33 (0.08)	Undergo mammogram 0.18 (0.05)
65-74	Male	0.44 (0.38)	Lose weight 0.66 (0.37)	Use aspirin 0.16 (0.03)	Lower blood pressure 0.24 (0.04)
	Female	0.40 (0.28)	Lose weight 0.57 (0.30)	Lower blood pressure 0.33 (0.07)	Use aspirin 0.17 (0.00)
75-84	Male	0.31 (0.24)	Lower blood pressure 0.15 (0.04)	Lose weight 0.50 (0.22)	Use aspirin 0.08 (0.00)
	Female	0.30 (0.20)	Lower blood pressure 0.19 (0.05)	Lose weight 0.48 (0.23)	Undergo mammogram 0.07 (0.02)

USPSTF indicates US Preventive Services Task Force.

<sup>a</sup>The mean increase in life expectancy associated with 1 year of health system exposure to encourage adherence with a USPSTF Grade A or B recommendation. Component weights for lower-ranked USPSTF recommendations not shown, but were included in the estimate of total health benefit (composite quality). Standard deviation in parentheses.

<sup>b</sup>Mean gain in life expectancy per member from 1 year of successful health system intervention to encourage adherence with the most important USPSTF Grade A or B recommendation, personalized for each insured. Importance defined by rank-ordering the increase in life expectancy associated with adherence to each USPSTF recommendation, based on an individual's age, gender, race, medical comorbidities, and family medical history. Standard deviation in parentheses.

<sup>c</sup>Results >1 occur because of the probability of continued member adherence in future years, without reinforcement by future health system intervention.

tion—for example, losing weight or quitting smoking, but not both. Simultaneous adherence to multiple interventions may result in additional life expectancy that is greater or less than the sum of additional life expectancy for each individual intervention; the direction is unclear and may depend on the specific combination of interventions.<sup>31,32</sup> Second, we did not consider the time it would take a provider to encourage adherence—the inclusion of which would reduce emphasis on time-intensive lifestyle

recommendations and increase emphasis on less time-intensive services, such as medications. However, as health insurers may choose to adopt nurses and other nonphysician healthcare providers for lifestyle recommendations, a weighting scheme based on time should also reflect the lower cost of these providers. Third, we made strong simplifying assumptions regarding adherence rates. While data on adherence rates were heterogeneous and dated, our framework was more sensitive to the distinction between

**Table 3.** Sample Comparison of Health Plans on a Health Exchange

Health Plan	Performance in Helping Its Patients to Live Longer <sup>a</sup>	Cost per Month
A	#1	\$300
B	#2	\$350
C	#3	\$275
D	#4	\$280

<sup>a</sup>Based on rank-order of the amount of health benefit provided. This table compares the amount of health benefit for 4 hypothetical health plans with their cost per month. Using this information, a patient may be more likely to select plans A or C (plans B and D cost more than plans A and C, respectively, despite inferior performance).

difficult versus easy recommendations than to exact adherence rates. Fourth, for analytic tractability, we sometimes modeled adherence to a hard target (eg, 120/80 mm Hg), rather than along a continuous spectrum; more realistic implementation might consider progress in small increments. Fifth, we used national disease prevalence data, which may differ from those of an insured population.<sup>33,34</sup> However, improved access to insurance through healthcare reform may attenuate this limitation. Sixth, we did not consider socioeconomic status because its strong correlation with race would require substantive additional analyses. However, we intend to incorporate this consideration in future work. Finally, we weighted health benefit through the additional life expectancy attributable to a health system, which may differ from additional quality of life.

## CONCLUSIONS

Mathematical models may be used to develop health-weighted composite quality metrics, which weight individual quality metrics by their contribution to patient health. Estimates of the amount of health imparted annually by a health system may be used to inform choices by patients, payers, and clinicians.

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## **eAppendix A. Mathematical Methods**

### **Disease Prevalence**

As described in the main text, we used data from the National Health Interview Survey on the prevalence of select comorbidities, by age and gender, including obesity (estimated by the proportion of body mass indices [BMIs] 25.0-29.9, 30.0-34.9, 35.0-39.9,  $\geq 40.0$ ), hypertension, hyperlipidemia, diabetes, tobacco use, and hazardous or harmful alcohol use ( $\geq 5$  drinks/day on  $\geq 12$  occasions in the past year).<sup>1</sup> Using the Surveillance, Epidemiology, and End Results Cancer Statistics Review, we also assumed a family history ( $\geq 1$  first-degree relative) of colorectal cancer for 5% of individuals (of all ages/genders) and a family history of breast cancer for 12.5% of women.<sup>2</sup>

### **Adherence**

Each hypothetical patient in our model had a probability of adherence to recommendations for preventive care. “Adherence” was defined as compliance, within 1 year of working with a physician, with each US Preventive Services Task Force (USPSTF) recommendation: BMI = 24.9, blood pressure (BP) = 120/80 mm Hg, total cholesterol (TC) = 190 mg/dL, low-density lipoprotein cholesterol (LDL-C) = 70 mg/dL, no tobacco use, no alcohol misuse, and for diabetics, A1C = 6% (controlled diabetes); and mammograms, Pap smears, and colonoscopies at recommended frequencies.<sup>3</sup> In accord with prior literature,<sup>4</sup> we conceptualized adherence by considering 2 factors: First, ease of adherence, which was a variable property of the preventive guideline itself (for example, a one-time painless test would be easier to adhere to than a difficult lifestyle change), and second, propensity of a patient to adhere, which was a variable property of the hypothetical patient.

For the sake of analytical tractability, we made a simplistic assumption, classifying each USPSTF recommendation as intrinsically “easy” or “difficult” to adhere with, a characteristic distinct from but potentially interacting with a patient’s propensity to adhere. Reported levels of adherence in published literature are heterogeneous and often dated<sup>5,6</sup>; we therefore used prior studies in conjunction with our clinical judgment to arrive at these classifications. The set of “difficult” recommendations was composed of weight loss, tobacco cessation, reduced alcohol use, healthy diet, and lifestyle



(nonmedication) components of cholesterol and hypertension management. For difficult recommendations, we assumed adherence rates of 30% during the first year, based on reported adherence rates to tobacco cessation (which ranged from 20% to 40% after 26 weeks).<sup>5</sup> All other recommendations were considered “easy,” for which we assumed adherence rates of 70% during the first year. These adherence rates were primarily based on compliance rates with anti-hypertensive<sup>5-6</sup> and statin<sup>7-9</sup> medications, though prior literature had a wide range of estimates. Of note, our methodology was more sensitive to the distinction between easy versus difficult recommendations than to assumptions surrounding exact numerical adherence rates.

The first-year rate of adherence (attributed to the healthcare system that year) was followed by a lower probability of continued adherence after 1 year (5% decrement, year 3; 10% decrement, year 5; and 20% decrement, year 10), reflecting what might happen if the health system did not effectively reinforce adherence in subsequent years. (Subsequent efforts by the health system to maintain or improve this level of adherence could be attributed to health system benefit in future years; however, this was not the objective of our current analysis.) An exponential curve was fitted to obtain predicted adherence rates at intermediate time points.

We implemented propensity of adherence again by making simple assumptions consistent with published literature; patients who had above-average adherence had their adherence schedules shifted by positive 10% whereas patients who had below-average adherence had their adherence schedules shifted by negative 10%.<sup>10,11</sup> We assumed that 50% of patients would have average adherence rates, with the remainder evenly divided between above- and below-average adherence rates.

### **Attributability**

We assumed that all adherence during the index year was attributable to the health system. However, thereafter, declining rates of adherence could also be attributable to the health system’s impact during that index year. For example, if a hypothetical patient stopped smoking during the index year, there would be some probability that their smoking cessation would persist in subsequent years, even if the health system did not directly promote the need for persistence of smoking cessation (see the next section,

“Mathematical Methods to Incorporate Relative Risks in Obese vs Nonobese Individuals”).

### **Time Horizon**

Our primary analysis followed our hypothetical cohort until death, meaning that we used a lifetime time horizon. However, as secondary measures, we also right-censored attributable benefits after 5, 10, and 20 years. These measures were included to consider the typical horizon that might be considered important by an employer or insurer. It is important to note that time horizon is a distinct concept from persistence of adherence. For example, a particular patient might only adhere to colorectal cancer screening for 1 year. However, the health impact of that 1 year of adherence could produce benefits lasting up to 10 years, and therefore a time horizon of 5 years would not capture all of this benefit.

### **Mathematical Methods to Incorporate Relative Risks in Obese vs Nonobese Individuals**

As described above, we recognized that some individuals were more likely to suffer from multiple comorbidities. Therefore, we included prior estimates of the relative risks of diabetes and hypertension in obese vs nonobese individuals (relative risk [RR] for diabetes, 5.2 for males, 12.7 for females; RR for hypertension, 2.6 for males, 4.2 for females).<sup>11</sup>

We wanted to solve for 4 unknown variables, denoted:

$A$  = number of obese individuals with hypertension

$B$  = number of obese individuals without hypertension

$C$  = number of nonobese individuals with hypertension

$D$  = number of nonobese individuals without hypertension

We solved for these variables using 4 equations:

$$\text{Relative risk of hypertension in obese vs non-obese individuals} = \frac{A/B}{C/D} \quad (1)$$

$$\text{Number of individuals with hypertension} = A + C \quad (2)$$

$$\text{Number of obese individuals} = A + B \quad (3)$$

$$\text{Number of individuals} = A + B + C + D \quad (4)$$

For example, among females aged 45 to 54 years, there was a 31.2% prevalence of hypertension and 36.9% prevalence of obesity.<sup>11</sup> Then,  $(A/B)/(C/D) = 4.2$ ,  $A+C = 31.2\%$ ,  $A+B = 36.9\%$ , and  $A+B+C+D = 100\%$ . Solving this system of equations and rounding to the nearest integer, we obtained  $A = 18.7\%$ ,  $B = 18.1\%$ ,  $C = 12.5\%$ , and  $D = 50.6\%$ .

## **Mathematical Methods for Simulating Hypothetical Health Plan Insurance**

### **Members**

Since BMI was already grouped into 5-point strata, we randomly selected a BMI within each group. For BP, we randomly selected systolic BP between 140 and 160 mm Hg and diastolic BP between 80 and 95 mm Hg for hypertensive patients, and 120/80 mm Hg for nonhypertensive patients. For cholesterol, we randomly selected TC between 240 and 375 mg/dL, and LDL-C between 150 and 200 mg/dL for patients with hyperlipidemia; we set TC = 190 mg/dL and LDL-C = 70 mg/dL for other patients. For diabetes, we set A1C = 9%, because our model simply considered controlled versus uncontrolled diabetes (rather than the extent of uncontrolled diabetes).<sup>3</sup> These levels were selected to be illustrative of values a physician might see in a practice panel, rather than exact distributions.

## **Mathematical Methods for Life Expectancy Attributable to a Health System's Work Over 1 Year**

Below, we argue that the benefit attributable to a health system's work over 1 year with a patient on preventive care guidelines equals the life expectancy accrued to the patient from 1 year of compliance with recommendations, plus the additional life

expectancy associated with the probability that a patient will continue to comply with recommendations in the future.

Let  $B_j$  = personalized benefit of adherence at time  $j$ , and  $a_i$  = probability of adherence  $i$  years into the future. For example, at age 65,  $a_0$ ,  $a_1$ , and  $a_2$  refer to the probabilities of adherence at ages 65, 66, and 67, respectively; at age 66, the same variables refer to the probabilities of adherence at ages 66, 67, and 68, respectively. Finally, denote by  $p_{j,k}$  the probability of surviving from time  $j$  to time  $k$ .

Then, the lifetime benefit of preventive care is the sum of benefits over all future life-years:

$$\begin{aligned}
 & (\textit{Benefit at year 0}) + (\textit{Benefit at year 1}) + (\textit{Benefit at year 2}) + \dots \\
 &= (B_0 a_0 + p_{0,1} B_1 a_1 + p_{0,2} B_2 a_2 + \dots) + (B_1 a_0 + p_{1,2} B_2 a_1 + \dots) + (B_2 a_0 + \dots) + \dots \\
 &= B_0 a_0 + B_1 \sum_{i=0}^1 p_{(1-i),1} a_i + B_2 \sum_{i=0}^2 p_{(2-i),2} a_i + \dots \\
 & \qquad \qquad \qquad = \sum_{j=0}^{\infty} B_j \sum_{i=0}^j p_{(j-i),j} a_i \tag{5}
 \end{aligned}$$

That is, total lifetime benefit is the sum of benefits at each future age multiplied by both the probability that the patient survives to each age and the estimated adherence rate at each age. By defining the benefit attributable to a health system's work over 1 year as the benefit that accrues to the patient (eg, benefit in year 0), we ensure that attribution will not be double-counted over the remainder of a patient's lifetime. For example, at time 0, the benefit attributable to a health system's work over 1 year would be the benefit at year 0 ( $B_0 a_0 + p_{0,1} B_1 a_1 + p_{0,2} B_2 a_2 + \dots$ ). At time 1, the attributable benefit would be the benefit at year 1 ( $B_1 a_0 + p_{1,2} B_2 a_1 + \dots$ ), etc.

Notice that the maximum lifetime benefit occurs under perfect adherence; that is, when  $a_i = 1$  for all  $i$ . We perform sensitivity analyses with perfect adherence and for shorter time horizons that may be more relevant to health insurance plans, using a maximum  $j$  of 5, 10, or 20 years.

## eAppendix A: References

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## eAppendix B. Sensitivity Analyses

The **eFigure** modifies the results in Table 2 to consider time horizons that might be more meaningful to health plans. Specifically, we right-censor the estimated gain in life expectancy after 5, 10, or 20 years.

**eFigure.** Annual Health Benefit Attributable to Preventive Care in a Health System With Typical Adherence to Preventive Care Measures, Right-Censored After 5, 10, or 20 Years

Age (y)	Gender	Recommendation with Greatest Benefit	Quality Component Weight (Mean Increase in Life Expectancy per Member, y)		
			Time Horizon <sup>a</sup>		
			5 y	10 y	20 y
25-34	Male	Decrease Alcohol Use	0.28	0.28	0.30
		Quit Smoking	0.21	0.29	0.48
		Lose Weight	0.12	0.25	0.40
25-34	Female	Lose Weight	0.08	0.19	0.22
		Lower Cholesterol	0.09	N/A	0.19
		Diabetes Testing/Control	0.17	0.25	N/A
35-44	Male	Quit Smoking	N/A	N/A	0.17
		Lose Weight	0.17	0.29	0.51
		Quit Smoking	0.27	0.40	0.63
35-44	Female	Decrease Alcohol Use	0.26	0.28	0.33
		Undergo Mammogram	0.04	0.08	0.10
		Lose Weight	0.09	0.17	0.27
45-54	Male	Quit Smoking	0.09	0.19	0.25
		Use Aspirin	0.08	0.09	0.16
		Lose Weight	0.25	0.42	0.64
45-54	Female	Quit Smoking	0.42	0.59	0.85
		Undergo Mammogram	0.05	0.08	0.11
		Lose Weight	0.14	0.25	0.39
55-64	Male	Quit Smoking	0.16	0.25	0.40
		Quit Smoking	0.45	0.58	0.74
		Use Aspirin	0.08	0.09	0.16
55-64	Female	Lose Weight	0.37	0.47	0.65
		Lose Weight	0.26	0.38	0.55
		Quit Smoking	0.28	0.38	0.49
65-74	Male	Undergo Mammogram	0.08	N/A	N/A
		Lower Blood Pressure	N/A	0.19	0.28
		Lose Weight	0.43	0.57	0.66
65-74	Female	Use Aspirin	0.08	0.08	0.15
		Lower Blood Pressure	0.17	0.21	0.24
		Lose Weight	0.32	0.44	0.56
75-84	Male	Lower Blood Pressure	0.18	0.22	0.31
		Undergo Mammogram	0.08	0.08	N/A
		Use Aspirin	N/A	N/A	0.17
75-84	Female	Lose Weight	0.40	0.48	0.50
		Lower Blood Pressure	0.13	0.15	0.15
		Use Aspirin	0.08	0.08	0.08
75-84	Female	Lose Weight	0.37	0.45	0.48
		Lower Blood Pressure	0.15	0.18	0.19
		Quit Smoking	0.24	0.31	0.33

<sup>a</sup>Bars indicate quality component weights, defined as the mean increase in life expectancy per member (in years) associated with 1 year of health system intervention, right-censored at each time horizon. The quality component weights ranked as the top 3 are shown.

N/A indicates not a top-3 ranked recommendation at specified horizon.

As described in the main text, we estimated the magnitude of health benefit that would be imparted by an insurer that emphasized adherence to the single US Preventive Services Task Force (USPSTF)-based guideline of most importance to each member, as reflected by its personalized benefit to life expectancy. This eAppendix Table shows complete details of Table 2 from the main article.

**eAppendix Table.** Annual Health Benefit Attributable to Preventive Care in a Health System With Typical Adherence to Preventive Care Measures

Age (years)	Gender	Total Health Benefit (composite quality) <sup>b</sup>	Component Weights <sup>a</sup> (USPSTF recommendation with greatest benefit)						
			#1	#2	#3	#4	#5	#6	#7
25-34	Male	0.67 (0.46)	Quit smoking 1.07 <sup>c</sup> (0.45)	Lose weight 0.92 (0.60)	Decrease alcohol use 0.53 (0.15)	Lower blood pressure 0.54 (0.15)	–	–	–
	Female	0.50 (0.36)	Lose weight 0.64 (0.35)	Quit smoking 0.55 (0.21)	Lower blood pressure 0.67 (0.00)	–	–	–	–
35-44	Male	0.61 (0.46)	Lose weight 0.97 (0.57)	Quit smoking 1.00 (0.38)	Decrease alcohol use 0.51 (0.13)	Lower blood pressure 0.52 (0.15)	–	–	–
	Female	0.43 (0.30)	Undergo mammogram 0.23 (0.07)	Lose weight 0.67 (0.38)	Quit smoking 0.54 (0.24)	Lower blood pressure 0.43 (0.12)	Diabetes testing/control 0.50 (0.17)	–	–
45-54	Male	0.64 (0.47)	Lose weight 0.81 (0.51)	Use aspirin 0.24 (0.06)	Quit smoking 1.07 (0.34)	Lower blood pressure 0.45 (0.11)	Decrease alcohol use 0.47 (0.13)	–	–
	Female	0.46 (0.30)	Lose weight 0.70 (0.28)	Undergo mammogram 0.19 (0.05)	Quit smoking 0.58 (0.20)	Lower blood pressure 0.47 (0.13)	Diabetes testing/control 0.54 (0.22)	–	–
55-64	Male	0.54 (0.33)	Lose weight 0.82 (0.51)	Quit smoking 0.79 (0.21)	Use aspirin 0.18 (0.03)	Lower blood pressure 0.47 (0.13)	Diabetes testing/control 0.54 (0.22)	–	–
	Female	0.47 (0.33)	Lose weight 0.70 (0.33)	Lower blood pressure 0.33 (0.08)	Undergo mammogram 0.18 (0.05)	Undergo mammogram 0.18 (0.07)	Use aspirin 0.20 (0.04)	Diabetes testing/control 0.32 (0.13)	Consider breast cancer preventive medication 0.17 (0.00)



<b>65-74</b>	<b>Male</b>	0.44 (0.38)	<b>Lose weight</b> 0.66 (0.37)	<b>Use aspirin</b> 0.16 (0.03)	<b>Lower blood pressure</b> 0.24 (0.04)	<b>Quit Smoking</b> 0.53 (0.14)	<b>Decrease alcohol use</b> 0.46 (0.11)	–	–
	<b>Female</b>	0.40 (0.28)	<b>Lose weight</b> 0.57 (0.30)	<b>Lower blood pressure</b> 0.33 (0.07)	<b>Use aspirin</b> 0.17 (0.00)	<b>Use aspirin</b> 0.17 (0.00)	<b>Quit smoking</b> 0.42 (0.18)	<b>Diabetes testing/control</b> 0.17 (0.00)	–
<b>75-84</b>	<b>Male</b>	0.31 (0.24)	<b>Lower blood pressure</b> 0.15 (0.04)	<b>Lose weight</b> 0.50 (0.22)	<b>Use aspirin</b> 0.08 (0.00)	<b>Diabetes testing/control</b> 0.01 (0.00)	<b>Use aspirin</b> 0.08 (0.00)	<b>Eat a healthier diet</b> 0.08 (0.00)	–
	<b>Female</b>	0.30 (0.20)	<b>Lower blood pressure</b> 0.19 (0.05)	<b>Lose weight</b> 0.48 (0.23)	<b>Undergo mammogram</b> 0.07 (0.02)	<b>Diabetes testing/control</b> 0.17 (0.00)	–	–	–

<sup>a</sup>The mean increase in life expectancy associated with 1 year of health system exposure to encourage adherence with a US Preventive Services Task Force (USPSTF) Grade A or B recommendation. Standard deviation in parentheses.

<sup>b</sup>Mean gain in life expectancy per member from 1 year of successful health system intervention to encourage adherence with the most important USPSTF Grade A or B recommendation, personalized for each insured. Importance defined by rank-ordering the increase in life expectancy associated with adherence to each USPSTF recommendation, based on an individual's age, gender, race, medical comorbidities, and family medical history. Standard deviation in parentheses.

<sup>c</sup>Results >1 occur because of the probability of continued member adherence in future years, without reinforcement by future health system intervention.

A dash (–) indicates no other top-ranked USPSTF recommendation (from the perspective of adherence-adjusted additional life expectancy) for more than 2 members of an age/gender group.