# A model of cardiovascular disease disparities with illustrative policy analysis

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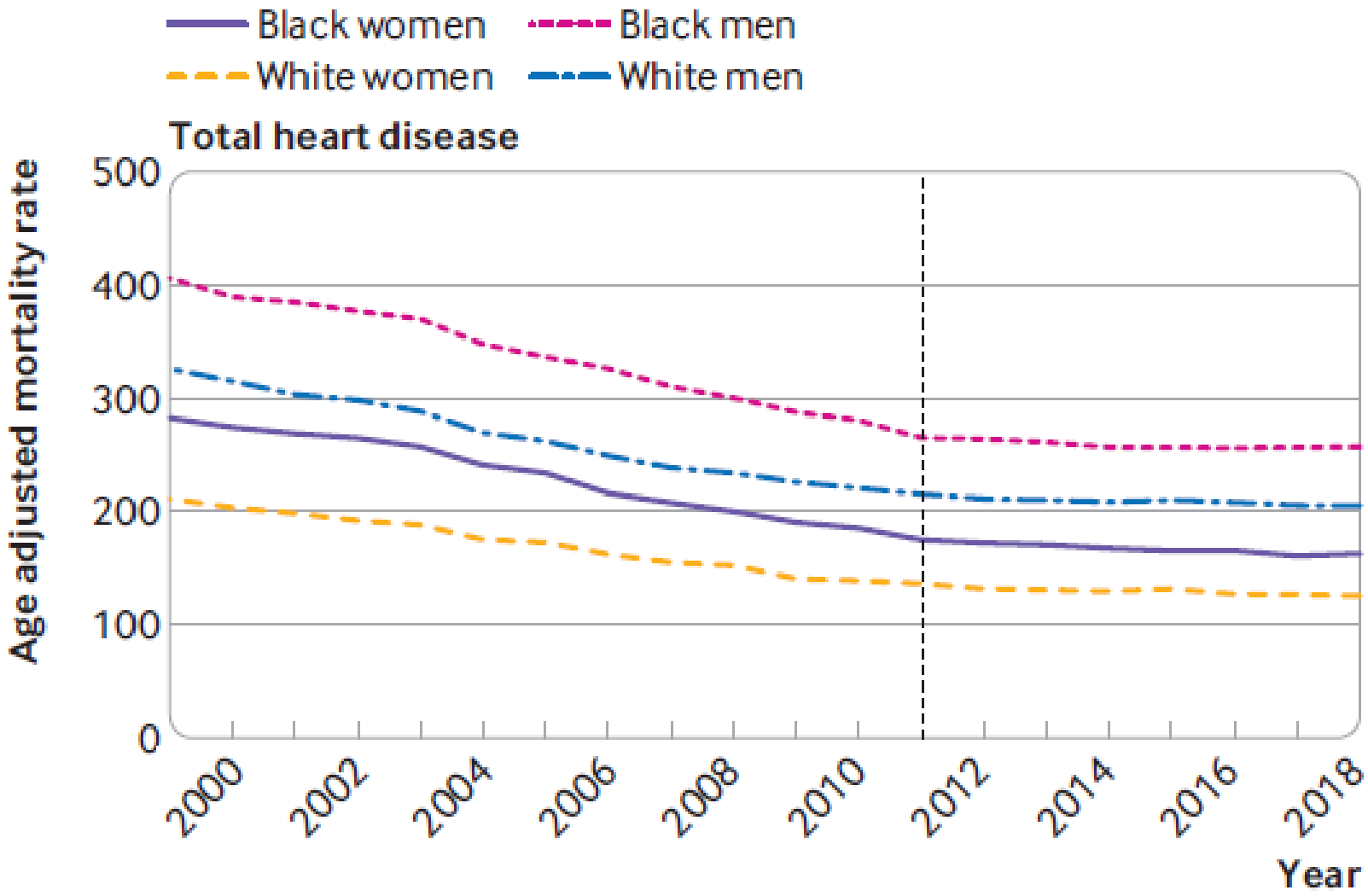
# Persistence of health disparities

## Ex: Heart disease mortality by race/gender 1999-2018




Source: Shah et al. (2020) Heterogeneous trends in burden of heart disease mortality by subtypes in the US, 1999-2018: observational analysis of vital statistics. *BMJ* 370:m2688, 10 pp. (Figure 2).

# Health disparities and interventions
## Basic concepts and a line of research

- Behavioral interventions can improve outcomes for everyone, but the socially disadvantaged (low income, non-white race, less education) face higher barriers to adoption—e.g., lack of time, money, insurance, and proximity to services.
- Population interventions may thus worsen health disparities if the barriers are not addressed.
- An analytic challenge: health surveillance data often not segmented—can't always study disparities at level of individuals.

# Analytic approach
## Finding a solid basis for model disaggregation

- CDC-PRISM model of CVD risk (winner of SD Applications Award 2011) was recently adapted for Colorado using state-level data.*
- We statistically analyzed county-level data (N=64) to create three "social risk index" clusters based on poverty, race, and education, and predictive of health outcomes (e.g., physical/mental distress).
- We disaggregated the Colorado model by these county clusters, with separate intervention levers for each cluster.
- We may now simulate targeted interventions: Can disparities be reduced without sacrificing overall intervention impact?

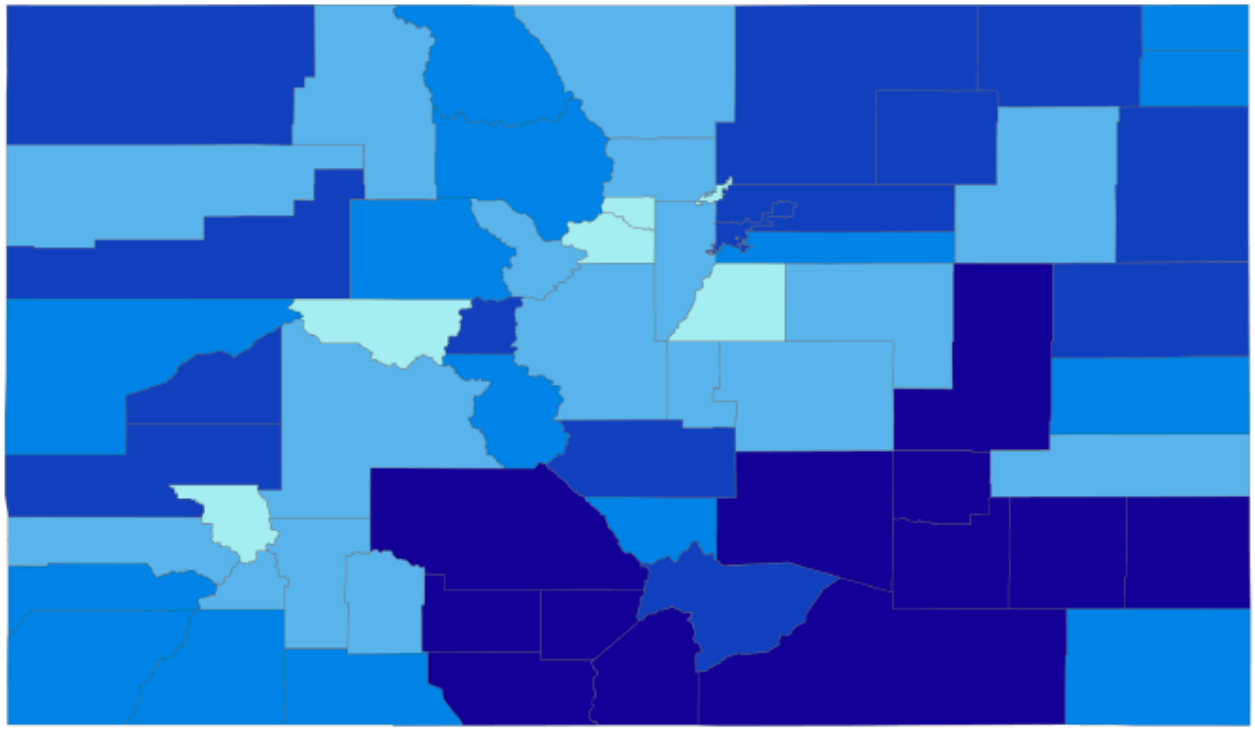

*See, e.g.: Homer et al (2010). Simulating and evaluating local interventions to improve cardiovascular health. *Prev Chron Disease* 7(1). Recent Colorado adaptation was done with Kaiser-Permanente Foundation of Colorado for the Colorado Department of Public Health & Environment.

# Statistical basis for a Social Risk Index (SRI)

| Regression analysis: Colorado (64 counties) | | Explanatory demographic factor | | | |
|---|---|---|---|---|---|
| | | Household poverty % | Hispanic or Black % | No college % (age 25-44) | |
| | State % overall | 10.9 | 25.7 | 28.3 | |
| **Outcome variable** | | Coefficient from regression (N=64 counties)* | | | R-squared |
| Obesity % | 21.8 | 0.09 | 0.04 | 0.22 | 0.38 |
| Physical inactivity % | 15.5 | 0.27 | *-0.02* | 0.15 | 0.30 |
| Food insecure % | 10.6 | 0.22 | *-0.09* | 0.01 | 0.45 |
| Housing unstable % | 6.7 | 0.41 | 0.13 | 0.02 | 0.79 |
| Insufficient sleep % | 27.5 | 0.04 | 0.06 | 0.06 | 0.51 |
| Frequent physical distress % | 10.1 | 0.17 | 0.03 | 0.01 | 0.82 |
| Frequent mental distress % | 11.8 | 0.13 | 0.01 | 0.01 | 0.66 |
| | *shaded box: significance p<.05; italic red: unexpected polarity | | | | |

The demographic factors of income, race, and education have previously been found related to social and health outcomes. Our county-level analysis finds poverty to be somewhat more consistently predictive of adverse outcomes than race or education. **Our Social Risk Index gives 50% weight to poverty prevalence, 25% weight to Hispanic/Black prevalence, and 25% weight to No College prevalence.**

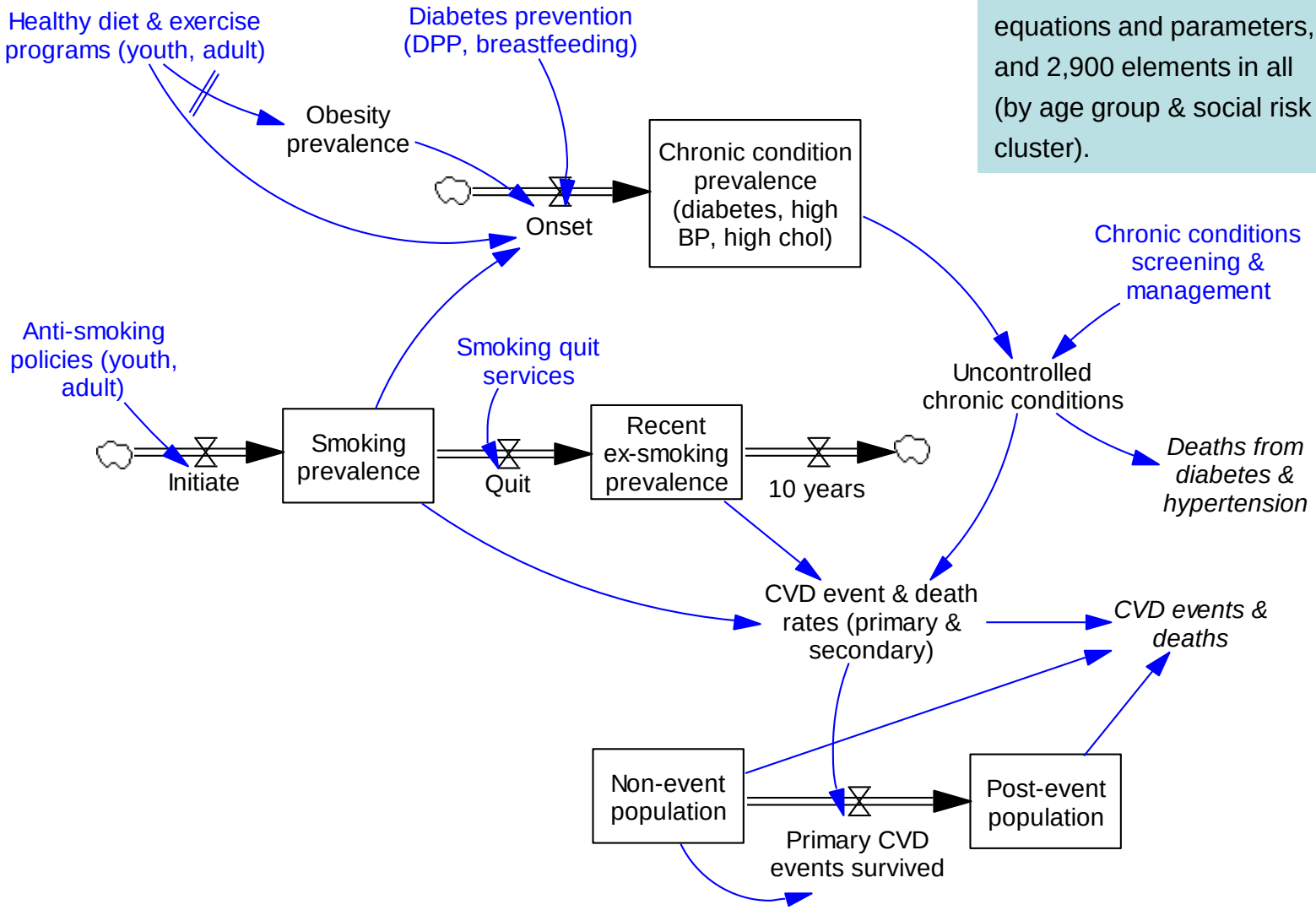
# Colorado counties by SRI level



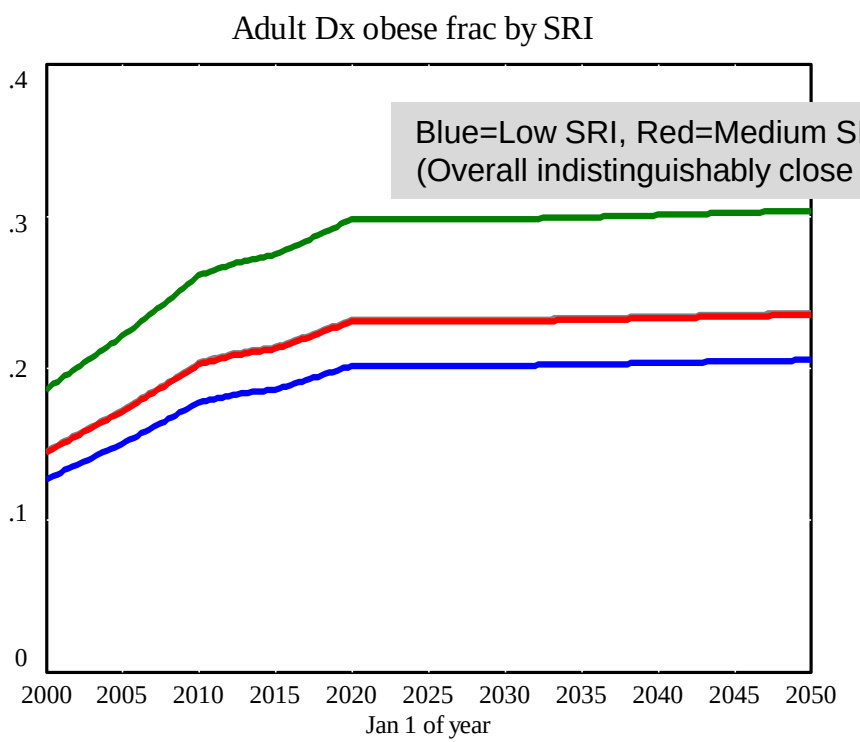

| | # Counties | Population (2018) | Avg. SRI | Ratio to state avg. |
|---|---|---|---|---|
| Low SRI counties: | N=29 | 2.04 million | 12.9 | 0.68 |
| Medium SRI: | N=14 | 2.68 million | 19.5 | 1.03 |
| High SRI: | N=21 | 0.97 million | 28.2 | 1.49 |

# CVD dynamics and policy initiatives
## (with population aging: 2 youth & 3 adult age groups)

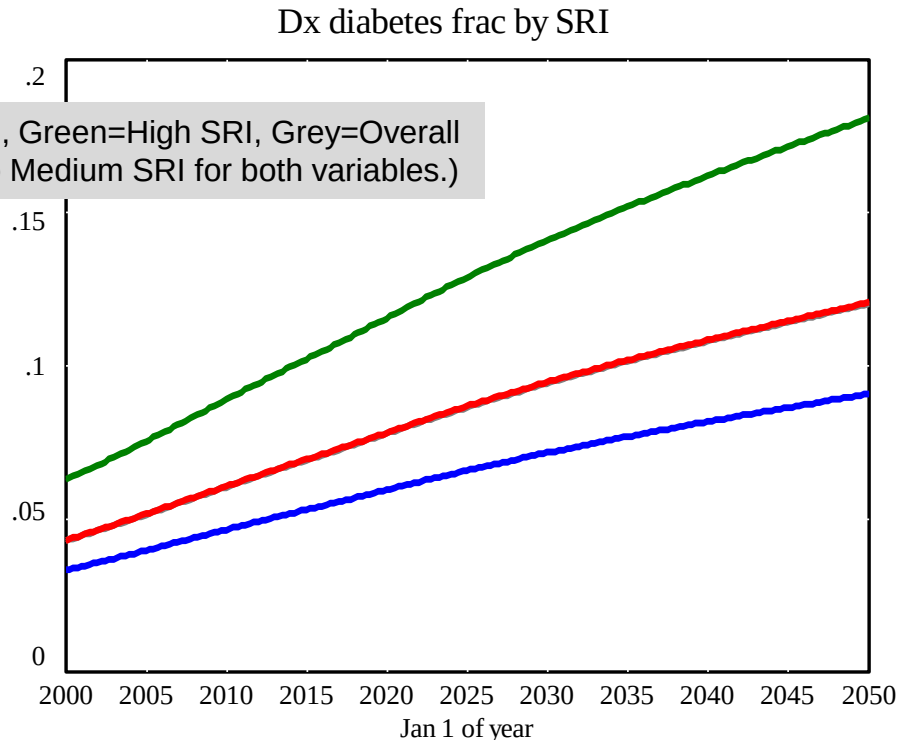
Model has about 540 active equations and parameters, and 2,900 elements in all (by age group & social risk cluster).



# Base run: Obesity and diabetes by SRI level




Blue=Low SRI, Red=Medium SRI, Green=High SRI, Grey=Overall
(Overall indistinguishably close to Medium SRI for both variables.)




Data sources:

Overall: BRFSS 2000-2018 (self-reported vitals**)

SRI ratios: US Diabetes Surveil. System 2016 by county

**Nationally, BRFSS self-reported obesity grew (2001-2007) from 72% to 80% of true obesity prevalence (NHANES).

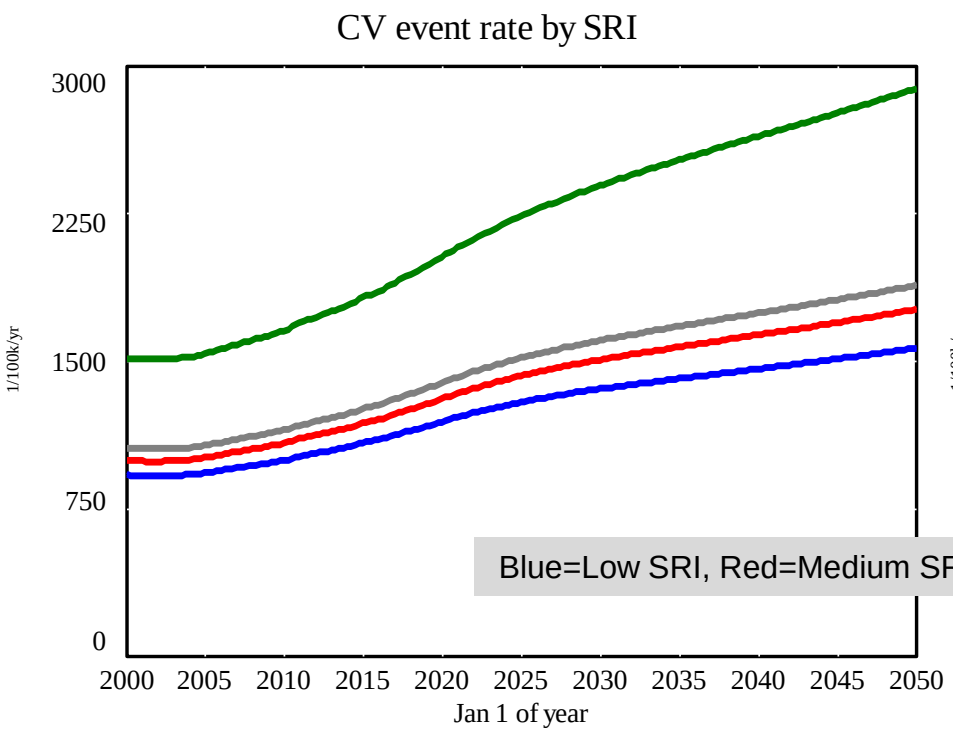
Data sources:

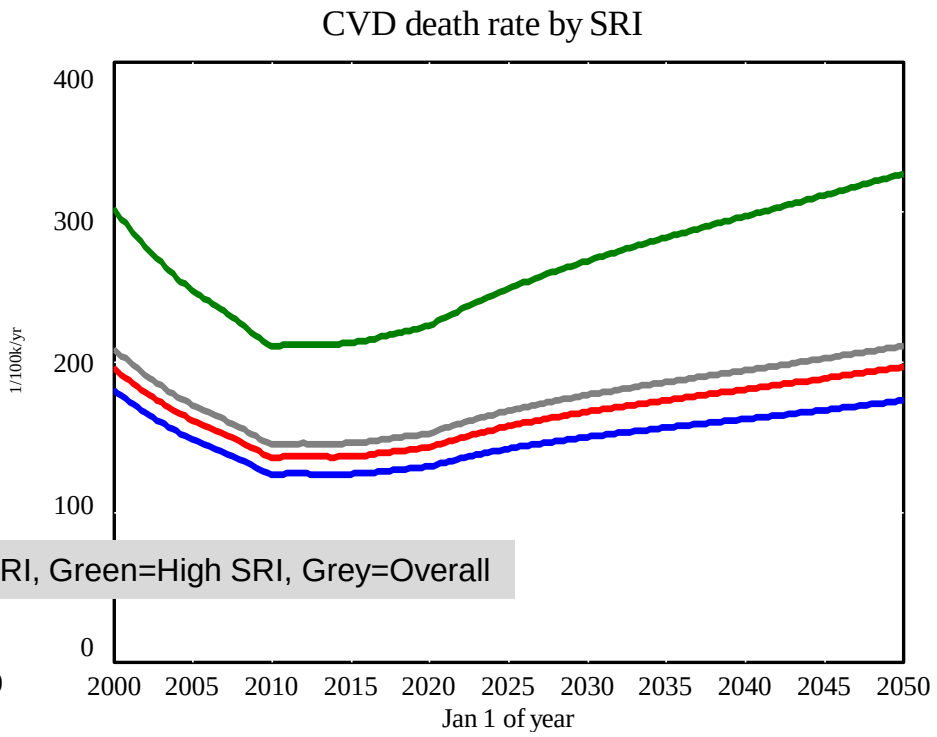
Overall: BRFSS 2000-2018 (“ever told”*)

SRI ratios: BRFSS 2014-2016 by county

*Nationally, BRFSS diagnosed (ever told) diabetes was 72-75% of true diabetes prevalence (NHANES 2001-2007) .

# Base run: CVD event & death rates by SRI level
## per 100,000 population




Blue=Low SRI, Red=Medium SRI, Green=High SRI, Grey=Overall

Data sources:

Overall: (adjusted to fit CO data*)

SRI ratios: BRFSS 2014-2016 CVD* by county

*Event and death initial rates adjusted from US values (PRISM) to fit BRFSS ever-told CVD (MI + CHD + stroke) and vital stats (COHID) CVD deaths. SRI initial ratios for events adjusted to fit 2014-16 ratios for CVD prevalence.

Data sources:

Overall: COHID CVD deaths 2000-2017**

SRI ratios: (assumed identical to CV event ratios)

**Ischemic heart disease + Heart failure + Stroke

→CVD event-fatality rates have declined, but the decline slowed after 2010, and we assume (as PRISM does) no further decline after 2020. This explains the U-shaped pattern seen here.

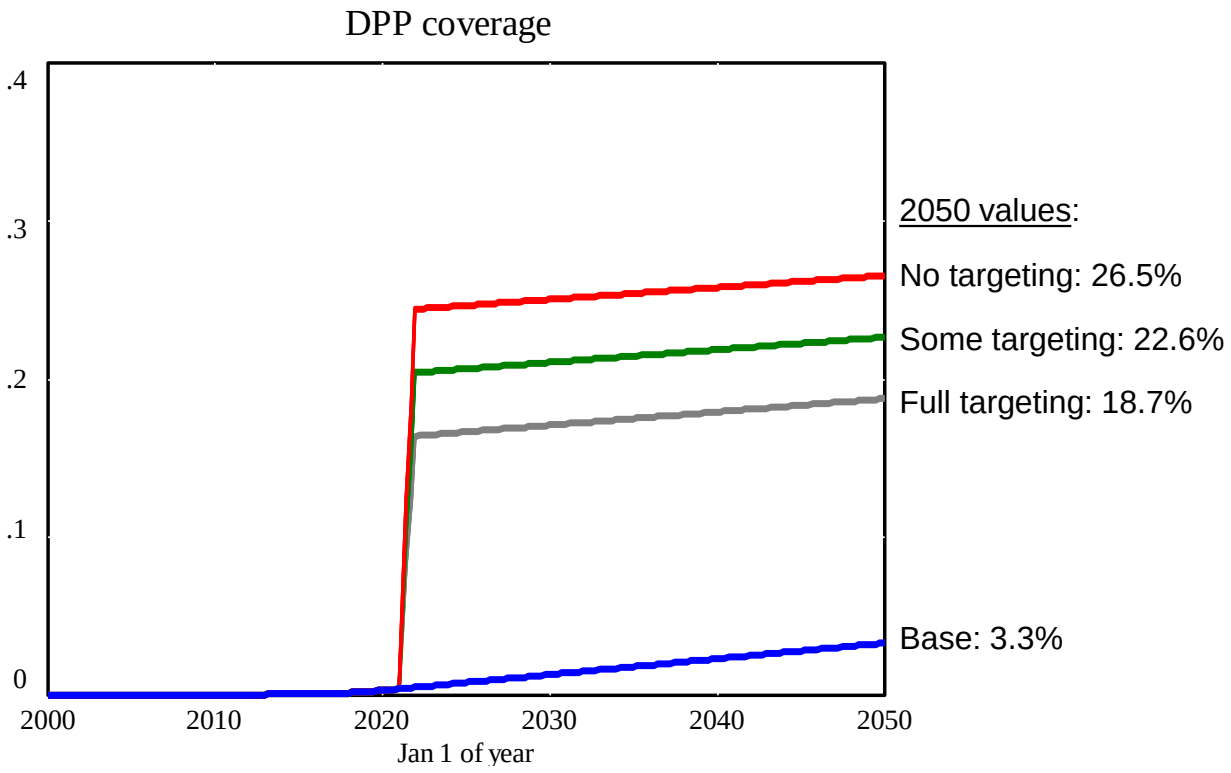
# Testing an intervention: Diabetes Prevention Program (DPP)

- DPP is a CDC-endorsed individualized lifestyle program for prediabetics that reduces their risk of diabetes onset by 60%.*
  - Colorado has slowly rolled out DPP since 2013. About 1.2 million adults in the state have prediabetes, but only 3,000 (0.25%) had successfully completed DPP by 2020.
- What if the state did a large push on DPP starting in 2021?
  - Higher SRI people face multiple barriers in trying to complete a program requiring reliable attendance and long-term compliance.
  - The state might shift some of its DPP resources away from Low SRI counties in order to lower barriers for the High SRI. Such targeting would inevitably mean sacrificing some overall yield for the program.
- Consider 3 scenarios for an aggressive DPP program:
  - "No targeting": ends up boosting DPP most strongly for Low SRI.
  - "Some targeting": partial resource shift, boosts DPP same for all SRI.
  - "Full targeting": boosts DPP only for Medium and High SRI, not Low.

*Knowler WC et al. (2002). Reduction in the incidence of Type 2 diabetes with lifestyle intervention or metformin. *New Engl J Med* 346(6):393-403. (Mean follow-up time 2.8 years.)

# Statewide DPP coverage in the 4 runs
## (base + 3 DPP boost scenarios)

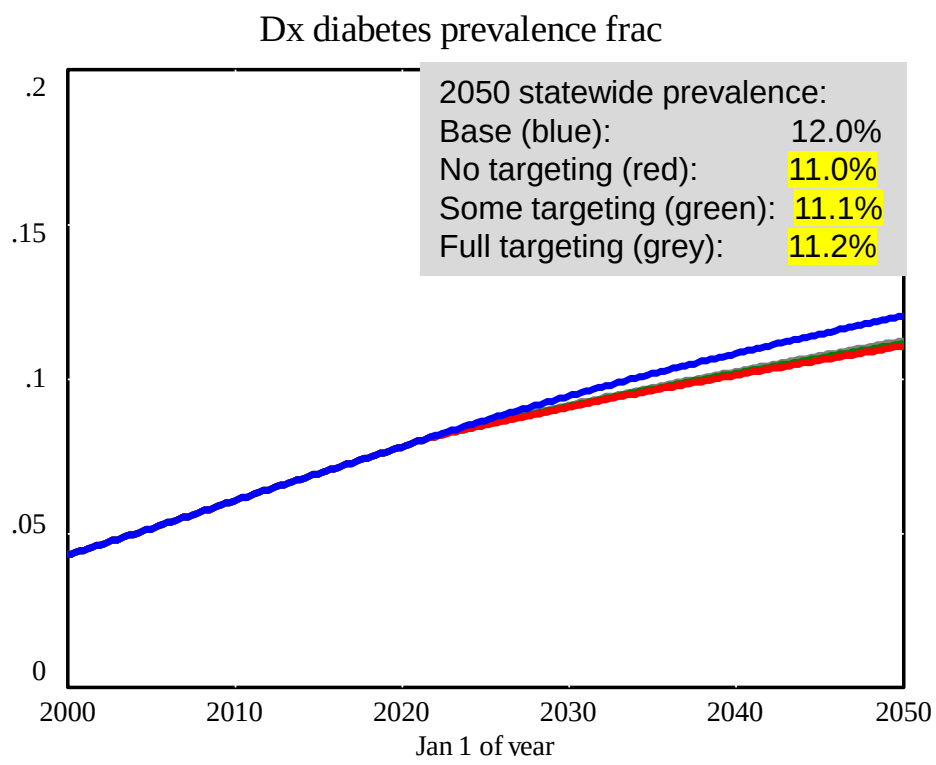
Some overall yield is lost when "easy" LowSRI effort is shifted toward "hard" HighSRI targeting with barrier reduction.

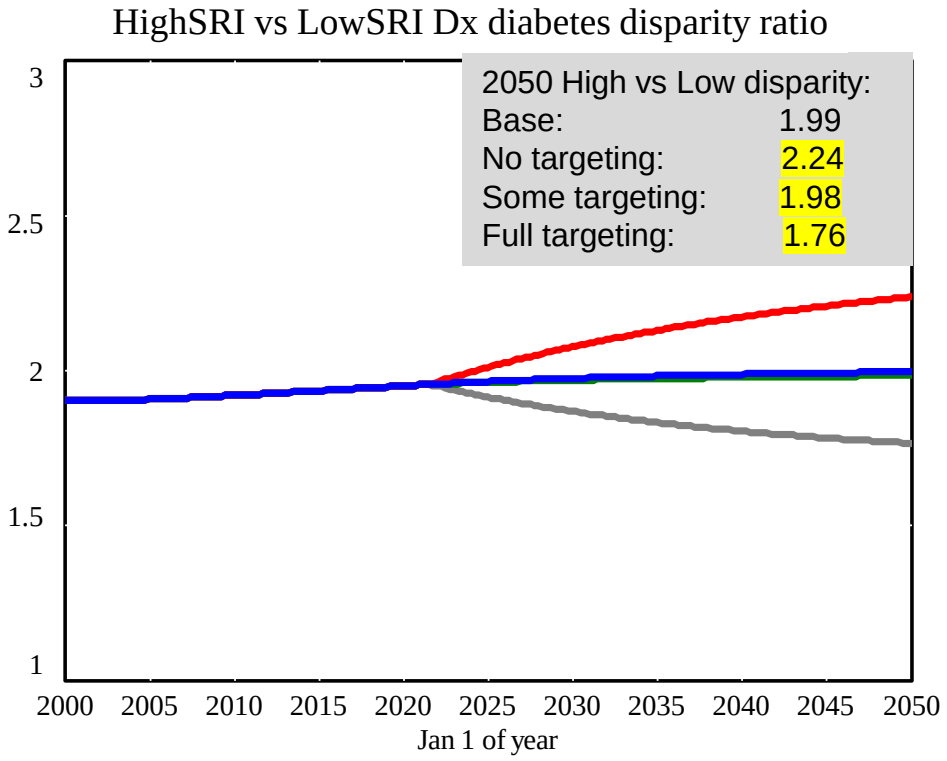



DPP boost assumptions by SRI:

| | |
|---|---|
| Base (blue): | 0% Low, 0% Medium, 0% High |
| No targeting (red): | 40% Low, 20% Medium, 10% High |
| Some targeting (green): | 20% Low, 20% Medium, 20% High |
| Full targeting (grey): | 0% Low, 20% Medium, 30% High: |

# Diabetes prevalence and disparity in the 4 runs (base + 3 DPP boost scenarios)

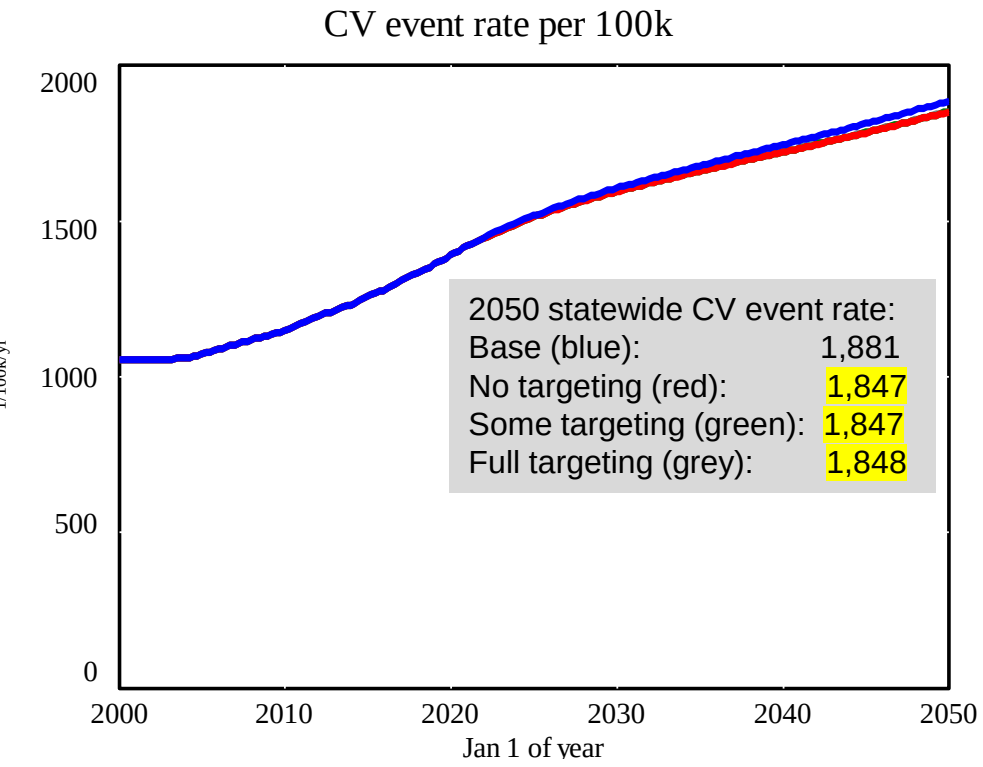


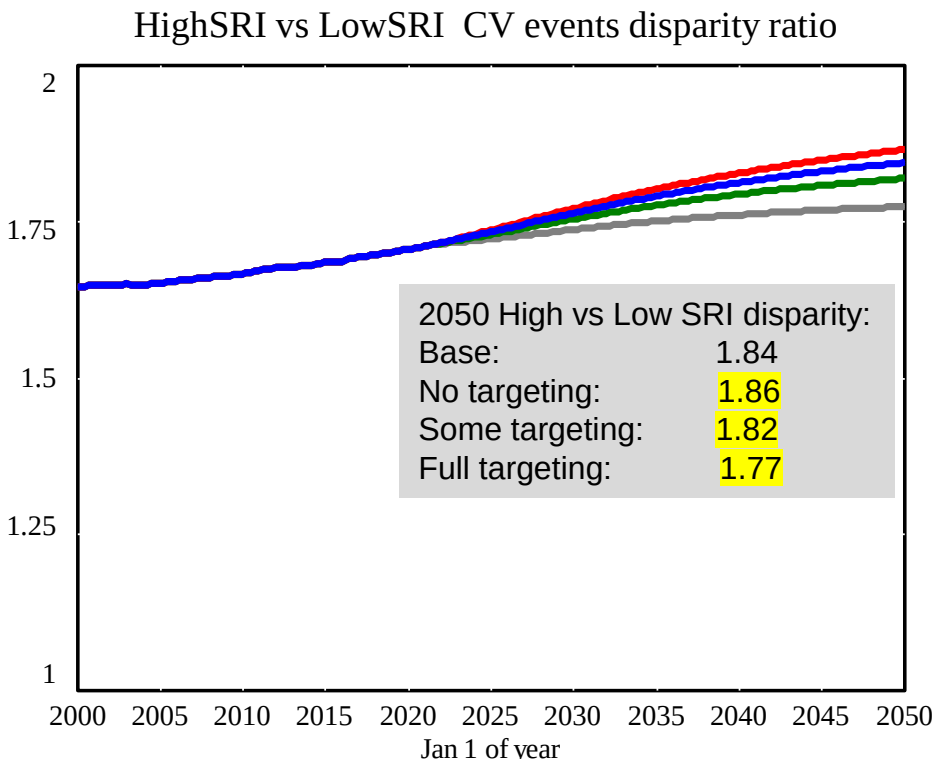




Q: Why do we see some tradeoff here of total impact vs. disparity reduction?

A: When it comes to reducing diabetes prevalence, DPP is as important for the Low SRI population as it is for the High SRI population. Spending effort on lowering DPP barriers for the High SRI consequently causes some loss of potential impact for reducing diabetes overall.

# CV event rate and disparity in the 4 runs
## (base + 3 DPP boost scenarios)




Q: Why do we NOT see a tradeoff here of total impact vs. disparity reduction?

A: When it comes to reducing CV events, DPP is less important for the Low SRI than it is for the High SRI. For the High SRI, CV events are more often driven by diabetes (and smoking); for the Low SRI, they are driven more by high BP and cholesterol. Spending effort on lowering DPP barriers for the High SRI can thus be a highly effective way of lowering their CVD risk.

# Conclusion and next steps

- Focusing on the High SRI (lowering barriers) can be more easily justified if the impact tradeoff is small. A small tradeoff is possible when the targeted condition (e.g., diabetes) is more responsible for adverse outcomes (e.g., CV events) among the High SRI than it is among the Low SRI.
- Further modeling will involve explicit modeling of barriers, plus scenario specification using the RE-AIM framework (Reach, Effectiveness, Adoption, Implementation, Maintenance).*
- The CVD disparities model will inform the planning of a CVD prevention pilot program for the City of Denver involving both healthcare and public health. Stakeholders will use the model to co-design program details, seeking to reduce disparities while avoiding steep tradeoffs.

*See, e.g.: Glasgow RE & Estabrooks PE (2018). Pragmatic applications of RE-AIM for health care initiatives in community and clinical settings. *Prev Chron Disease* 15(E02).

# ADDITIONAL MATERIAL

# CDC's Social Vulnerability Index

FIGURE 1

**Variables and Themes Included in the Social Vulnerability Index Databases**

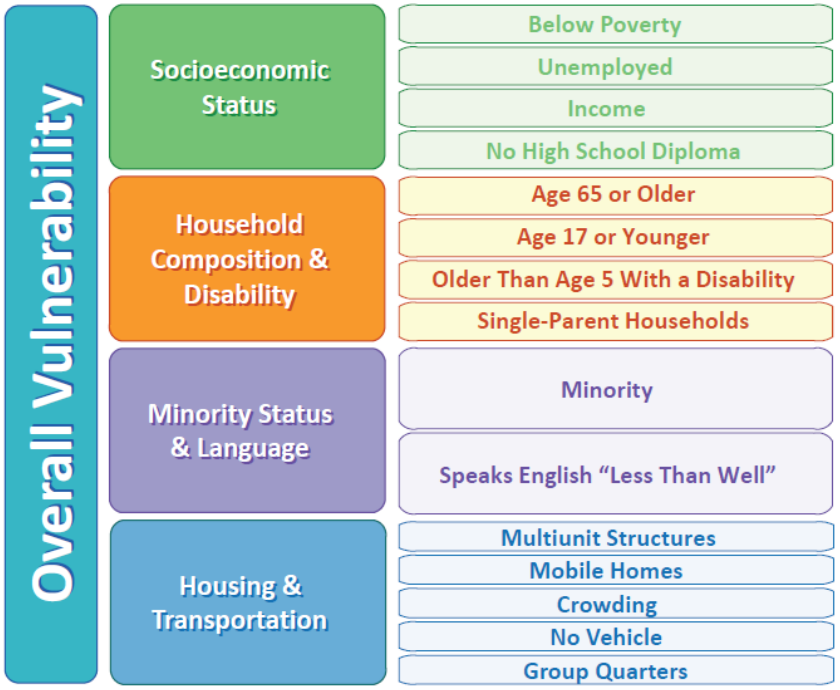
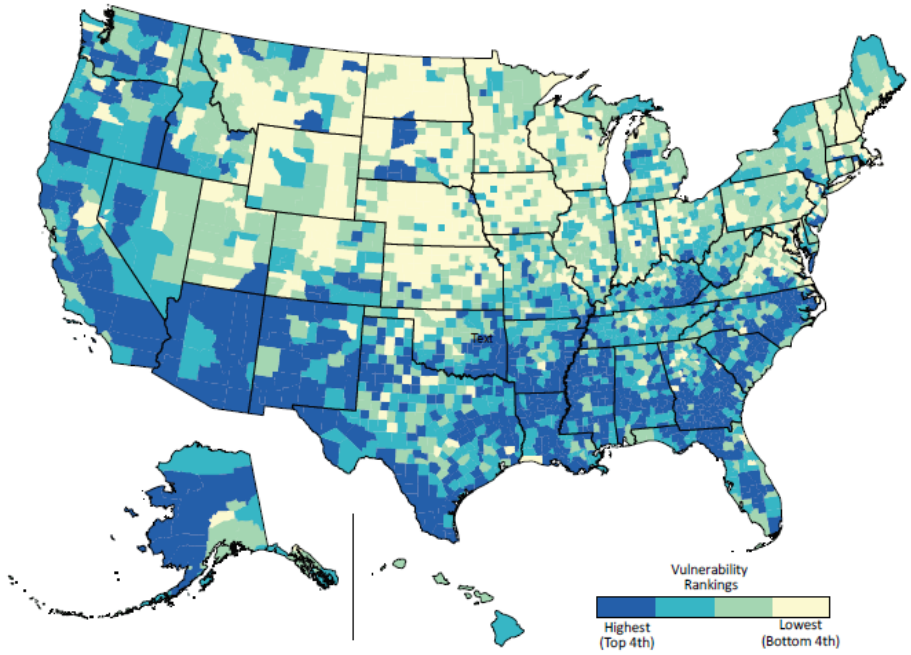



FIGURE 2

**Overall U.S. Vulnerability at County Level as Identified in the Social Vulnerability Index**




Source: Flanagan et al. (2018). Measuring community vulnerability to natural and anthropogenic hazards: the Centers for Disease Control and Prevention's Social Vulnerability Index. *J Envir Health* 80(10):34-36. (Figs. 1 & 2)

# Colorado counties by SRI level (low-med-high)

| | Population (2018) | Household poverty % (2014-2018) | Hispanic or Black % (2018) | No college % (2014-2018) | Social Risk Index (SRI) calculated^ |
|---|---|---|---|---|---|
| State overall | 5,695,564 | 10.9 | 25.7 | 28.3 | 18.9 |
| *LOW SRI COUNTIES (N=29)^^* | | | | | |
| Low SRI counties | 2,039,026 | 8.8 | 14.0 | 20.2 | 12.9 |
| ratio to State | 35.8% | 0.81 | 0.55 | 0.72 | 0.68 |
| *MEDIUM SRI COUNTIES (N=14)^^* | | | | | |
| Medium SRI counties | 2,683,078 | 9.8 | 29.5 | 28.9 | 19.5 |
| ratio to State | 47.1% | 0.90 | 1.15 | 1.02 | 1.03 |
| *HIGH SRI COUNTIES (N=21)^^* | | | | | |
| High SRI counties | 973,460 | 14.5 | 39.8 | 44.0 | 28.2 |
| ratio to State | 17.1% | 1.33 | 1.55 | 1.56 | 1.49 |
| ^Social Risk Index = 0.5*Poverty% + 0.25*HispBlack% + 0.25*NoCollege% | | | | | |
| ^^Aggregate statistics are population-weighted averages across all counties in an SRI cluster. | | | | | |
| Low SRI counties: Douglas*, Broomfield, Gilpin, Pitkin, Clear Creek, Ouray, San Miguel, Routt, Park, Teller, Jefferson*, San Juan, Gunnison, Elbert, Boulder*, Larimer*, Hinsdale, Washington, Summit, Mineral, Rio Blanco, Kiowa, Grand, Chaffee, Dolores, La Plata, Archuleta, Eagle, Cheyenne | | | | | |
| Medium SRI counties: El Paso*, Arapahoe*, Phillips, Sedgwick, Custer, Jackson, Mesa*, Baca, Montezuma, Weld*, Yuma, Garfield, Logan, Denver* | | | | | |
| High SRI counties: Lake, Kit Carson, Moffat, Montrose, Huerfano, Fremont, Delta, Adams*, Morgan, Prowers, Rio Grande, Lincoln, Pueblo*, Las Animas, Saguache, Otero, Alamosa, Conejos, Bent, Crowley, Costilla | | | | | |
| *County population 100,000+ | | | | | |

# Disparity ratios by SRI level (vs. Low SRI=1)

| Estimated disparity ratios (vs. Low SRI=1) for model start in 2000 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Colorado | Low SRI | Medium SRI | High SRI | | Low SRI | Medium SRI | High SRI |
| *Diet, Exercise, Smoking: from CO county data* | | | | *Chronic Conditions: from CO county data* | | | |
| Youth healthy fruit-veg | 1 | 0.95 | 0.87 | Youth obesity | 1 | 1.31 | 1.30 |
| Youth healthy beverage | 1 | 0.96 | 0.92 | Adult obesity | 1 | 1.14 | 1.47 |
| Youth healthy activity | 1 | 0.91 | 0.93 | Diagnosed diabetes | 1 | 1.30 | 1.90 |
| Adult healthy fruit-veg | 1 | 0.96 | 0.93 | Diagnosed high BP | 1 | 1.09 | 1.27 |
| Adult healthy beverage | 1 | 0.89 | 0.82 | Diagnosed high chol | 1 | 0.96 | 1.11 |
| Adult healthy activity | 1 | 0.88 | 0.85 | Post-CVD | 1 | 1.06 | 1.44 |
| Breastfeeding infants | 1 | 0.92 | 0.83 | *Chronic Conditions: from literature &/or calibration* | | | |
| Adult smoking | 1 | 1.38 | 1.51 | Diabetes screening | 1 | 0.90 | 0.85 |
| Ex-smoking | 1 | 0.93 | 0.96 | Diabetes management | 1 | 0.95 | 0.90 |
| *Smoking: from literature &/or calibration* | | | | High BP screening | 1 | 0.90 | 0.80 |
| Smoking initiation/relapse | 1 | 1.19 | 1.25 | High BP management | 1 | 0.95 | 0.90 |
| Recent ex-smoking | 1 | 1.05 | 1.10 | High chol screening | 1 | 0.85 | 0.75 |
| Longtime ex-smoking | 1 | 0.85 | 0.80 | High chol management | 1 | 0.95 | 0.90 |
| | | | | CV events | 1 | 1.07 | 1.57 |

Some assumed initial SRI ratios were adjusted to produce relatively flat simulated SRI ratio outputs from 2000 to 2020.

# Intervention testing

**Specify intervention effectiveness ($E_i$)**

- 17 intervention types **i**
- Assumed **$E_i$** at adoption peak and at final maintenance
- **$E_i$** may differ by social risk category to reflect barriers and targeting
- Uncertainty ranges for Monte Carlo sensitivity testing

**Dynamic CVD model**

- Simulate major risk factors and events/deaths
- Reproduce state-level time series data 2000-2018
- Project quarterly to 2050

**Intervention impact analysis**

- Deaths from CVD, diabetes, hypertension: “CVD-plus”
- Years of potential life lost
- Overall impacts and disparity ratios