Retrospective analysis of equity-based optimization for COVID-19 vaccine allocation.

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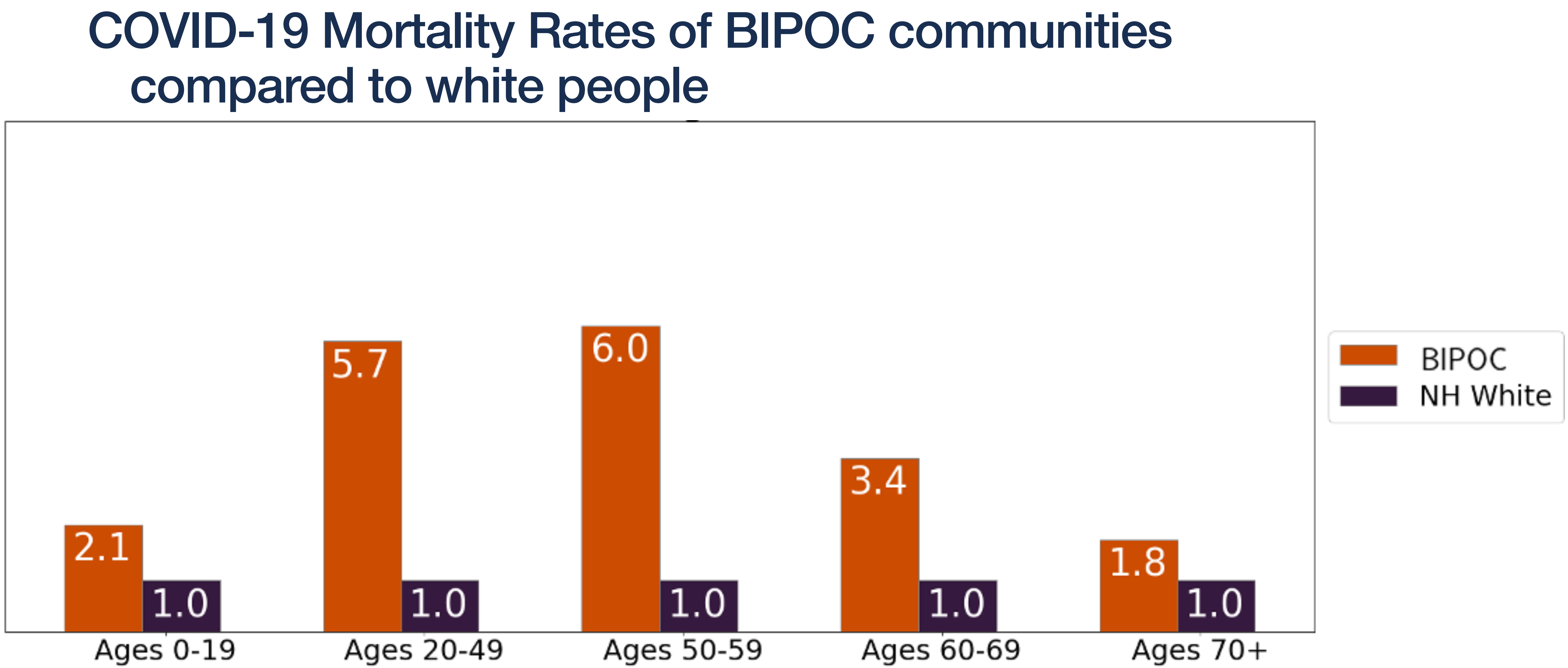
Situation in OR at the end of 2020:



BIPOC: Non-Hispanic Black, Hispanic, Non-Hispanic Asian and Non-Hispanic American Indian and Alaska Native)

Dilemma:

COVID-19 related mortality and hospitalization is extremely concentrated in the older population.

Age groups	0-19	20-50	50-60	60-70	>70
Hospitalization rates given symptoms	0.2	3	10.2	16.6	25.2
Mortality rates given hospitalized	8.3	3.1	10.7	16.6	23.2

BUT

Dilemma:

Younger people in marginalized populations are at increased risk of acquisition and have more comorbidities.

General Pop. Dist.	0-19	20-49	50-59	60-69	>70
White	15%	30%	10%	11%	11%
All Other Races (BIPOC)	7%	10%	2%	1%	1%
Age Total	22%	40%	12%	12%	12%

Dilemma:
How to use the available resources?

- Vaccinate the Older (mostly white) more accessible population who are most at **risk of severe disease/death**

  OR

- the younger marginalized populations that face the **most inequities and are at increased risk of acquisition**?

The New York Times

The Coronavirus Pandemic › | Map and Cases | Covid's Origins: What We Know | Pregnancy and Covid | Covid F.A.Q.

The Elderly vs. Essential Workers: Who Should Get the Coronavirus Vaccine First?

will soon decide which group to recommend next,
offs is growing heated. Ultimately,

VIEWPOINT

Opinion

Is It Lawful and Ethical to Prioritize Racial Minorities for COVID-19 Vaccines?

Home » News Center » The Push for Covid Vaccine Priority in Hard-Hit Black and Latino Communities

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The Push for Covid Vaccine Priority in Hard-Hit Black and Latino Communities

Posing the problem:

QUESTION: could we have administered the vaccines in a more equitable way? Use mathematical models and optimization to answer it!

Counterfactual scenario: January 2021

- Fixed amount of vaccine available (supply **is very** constrained).
- We want to minimize deaths/hospitalizations constrained to the vaccines we have.
- At the same time, we want to minimize the inequity observed and incurred when administering our strategy.

Important things to consider:

- Extremely difficult to take these decisions in the midst of a pandemic, there are intrinsic trade-offs that policy makers need to consider.
- Inequity is an extremely complex and multi-factorial problem, that can be emotionally charged.
- No optimization/mathematical model/vaccines alone will solve the centuries-long problem of inequity in the US.

AIM: to provide a quantitative framework to better understand inequity in public health interventions: both in resource allocation and in outcomes.

Think about the two extremes:

Minimize mortality only

- Expect: Give preference to the Older (mostly white) more accessible population who are **most at risk of severe disease/death**

OR

Minimize inequity only

- Expect: Give preference to the younger minority populations that face the **most inequities and are at increased risk of acquisition.**

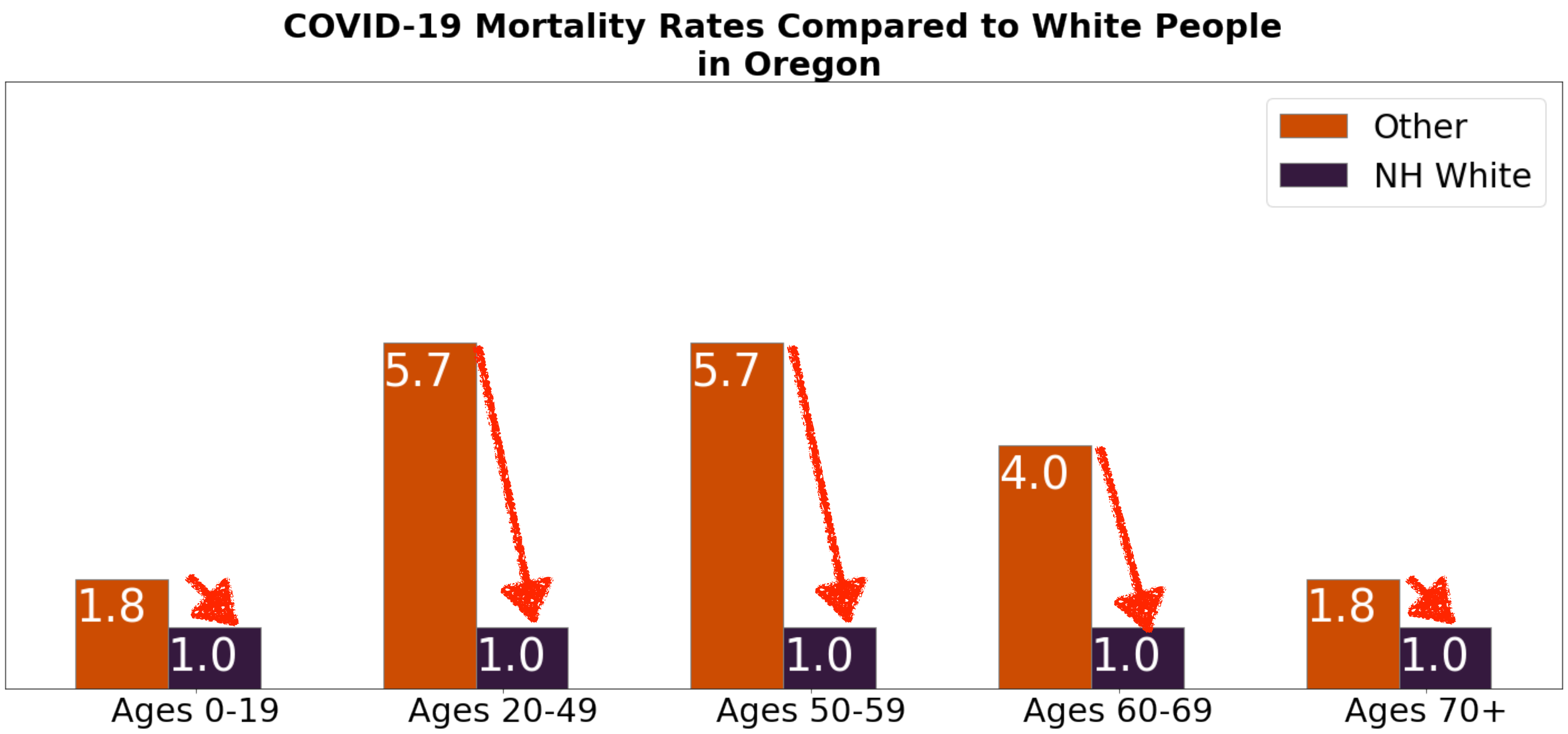
Minimize both at the same time. Can we find a happy medium?

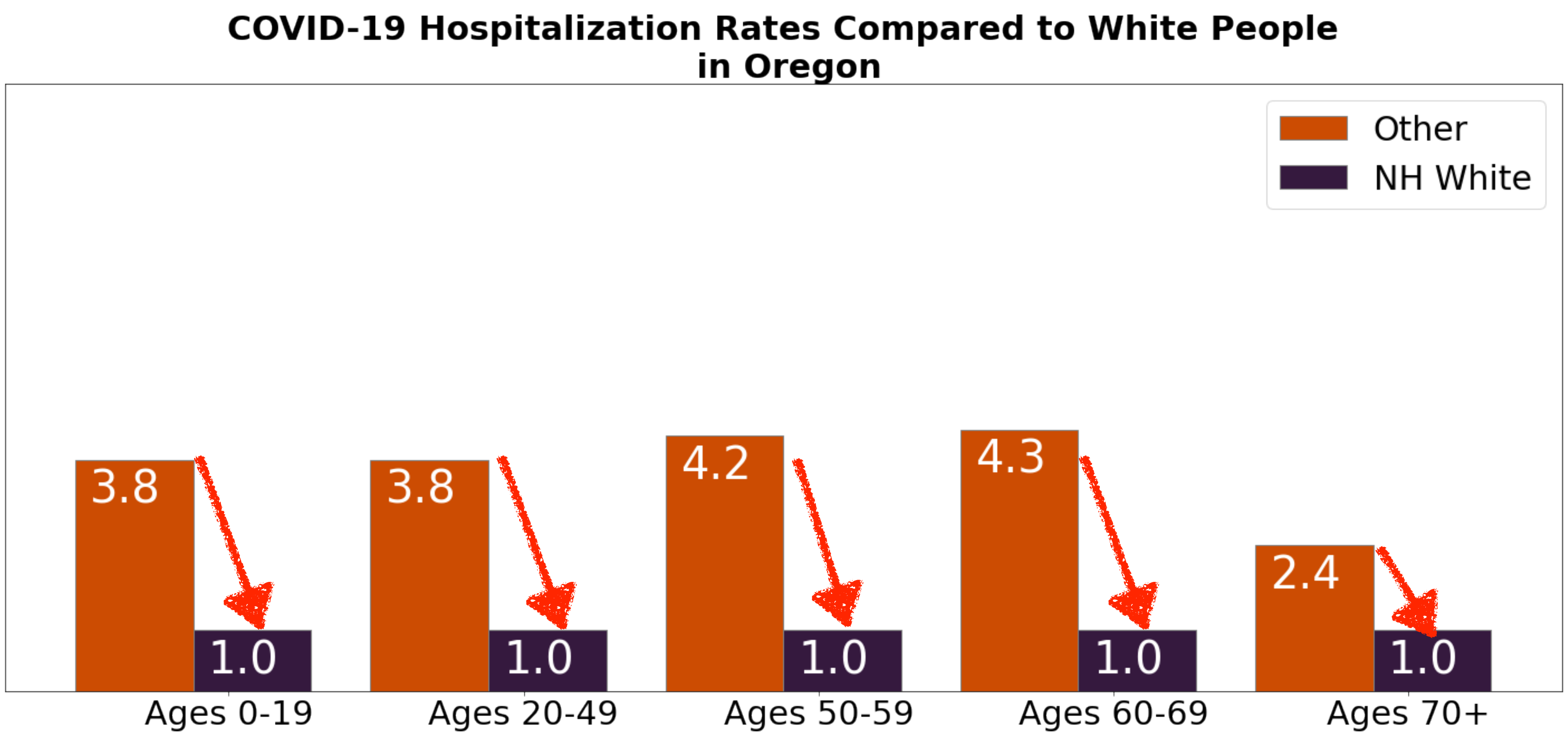
Methods

Question: How to quantify “equitable”?

How to translate “equitable” into a mathematical formula?

Want these bars to be equal:

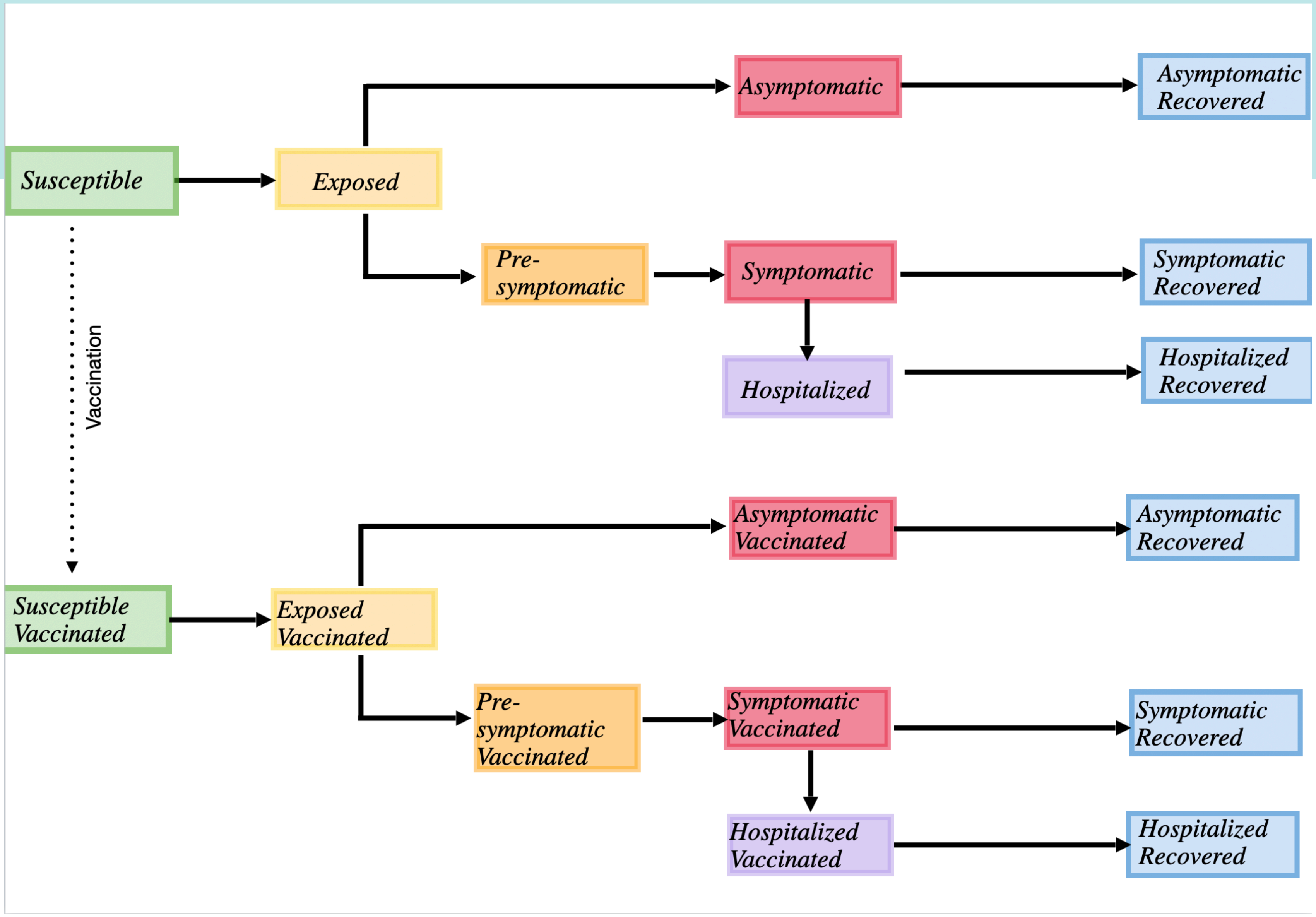




Inequity measures:

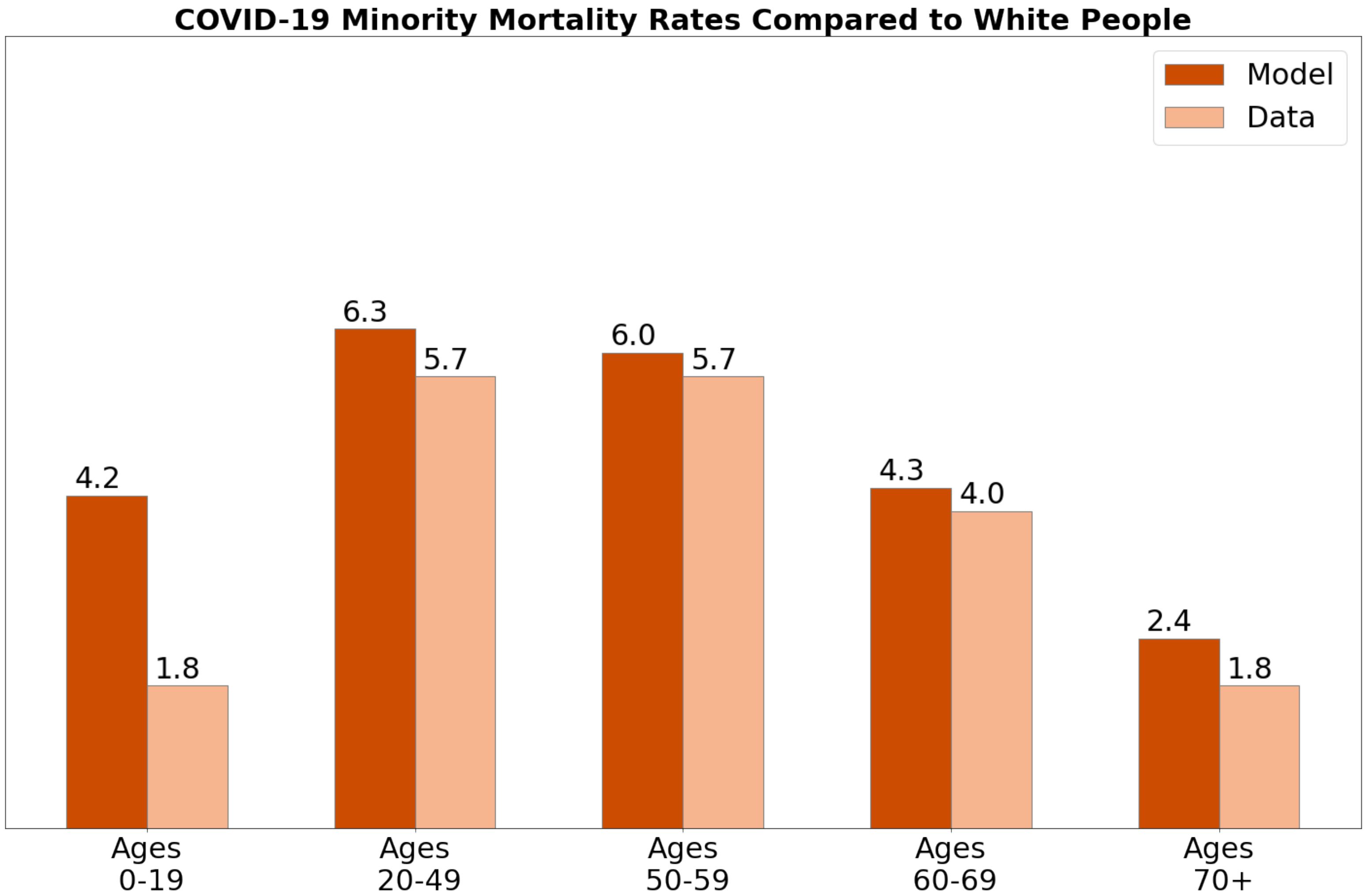
Name	Formula	Meaning
Relative disparity in mortality	$\sum_{a \in \text{ages}} \left\lvert \frac{m_{a,O}}{m_{a,W}} - 1 \right\rvert$	Inequity measure giving the sum of the distances of mortality rate ratios for each age group from one.
Absolute disparity in mortality	$\sum_{a \in \text{ages}} \lvert m_{a,O} - m_{a,W} \rvert$	Inequity measure giving the sum of the differences in mortality rates between racial groups for each age group.
Index of disparity (mortality)	$\sum_{a \in \text{ages}} \frac{1}{2} \cdot \frac{\sum_{R \in \text{races}} \lvert m_{a,R} - \overline{m}_a \rvert}{\overline{m}_a} \cdot 100$	Inequity measure giving the sum of the indices of disparity for mortality rates for each age group.
Absolute disparity in YLLs	$\sum_{a \in \text{ages}} \lvert YLL_{a,O} - YLL_{a,W} \rvert$	Inequity measure giving the sum of the differences in years of life lost between racial groups for each age group.
Index of disparity (YLLs)	$\sum_{a \in \text{ages}} \frac{1}{2} \cdot \frac{\sum_{R \in \text{races}} \lvert YLL_{a,R} - \overline{YLL}_a \rvert}{\overline{YLL}_a} \cdot 100$	Inequity measure giving the sum of the indices of disparity for YLLs for each age group.

Mathematical model



- 5 Age groups:
- (0-19, 20-49, 50-59, 60-69, 70+)
- Race/ethnicity
  White: Non-Hispanic white
  BIPOC: combined proportionally to the population in OR: Non-Hispanic Black, Hispanic, Non-Hispanic Asian and Non-Hispanic American Indian and Alaska Native)
- **Race stratified risk of acquisition** of SARS-CoV-2 infection.
- **Age and race stratified risk** of disease progression.
- **Age and race stratified** contacts.

Fit the model to OR to end of 2020:



Data: Total deaths: 1704

Deaths Per-Group	0-19	20-49	50-59	60-69	>70
White	0	17	49	173	1130
BIPOC	1	33	55	76	170

Model: Total deaths: 1704

Deaths Per-Group	0-19	20-49	50-59	60-69	>70
White	1	11	50	253	968
BIPOC	2	24	62	132	202

Optimization:

Minimize mortality (or YLLs) only:

$$\sum_{ages} Deaths$$

Minimize inequity only:

$$\sum_{ages} |(\frac{m_{a,O}}{m_{a,W}} - 1)|$$

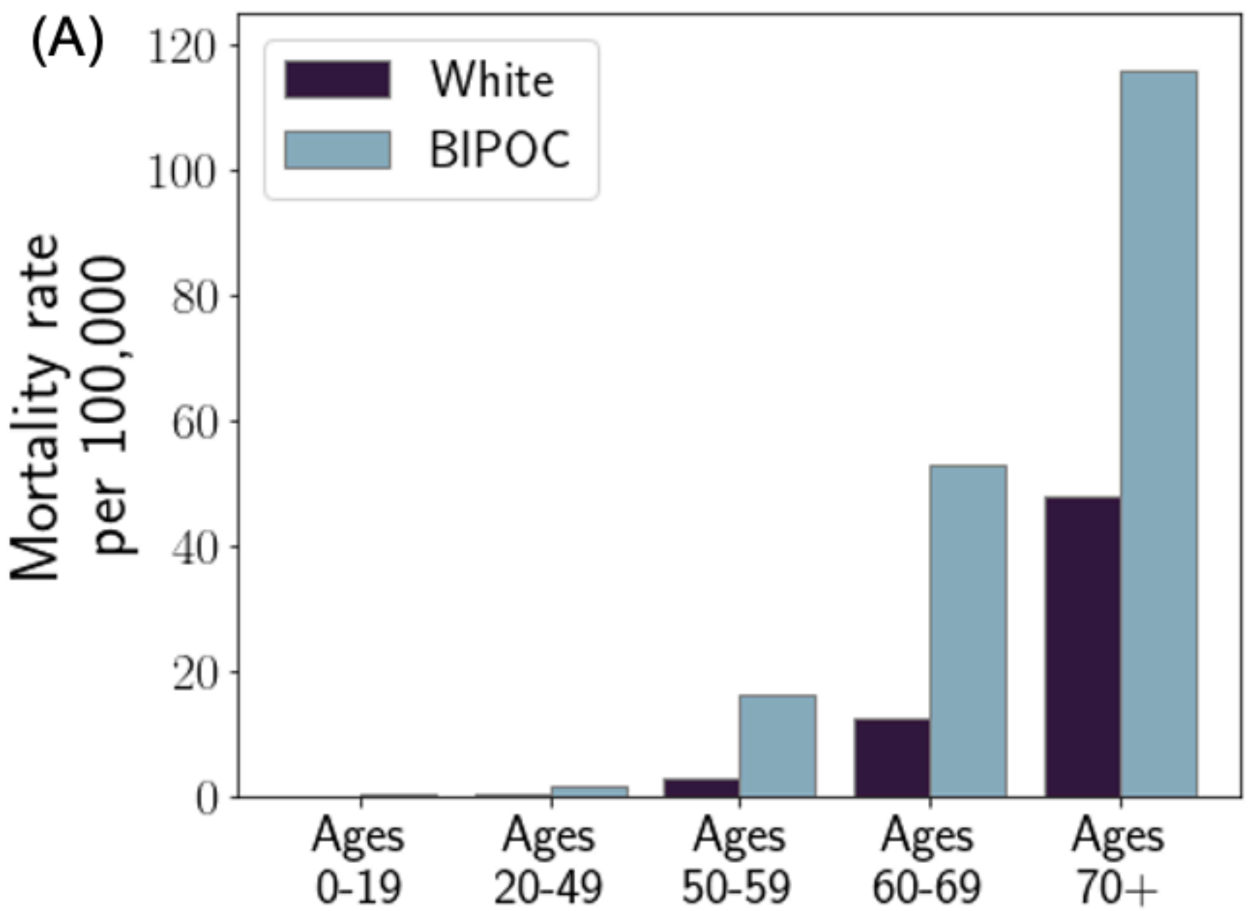
(Or any of the metrics given in the previous slide)

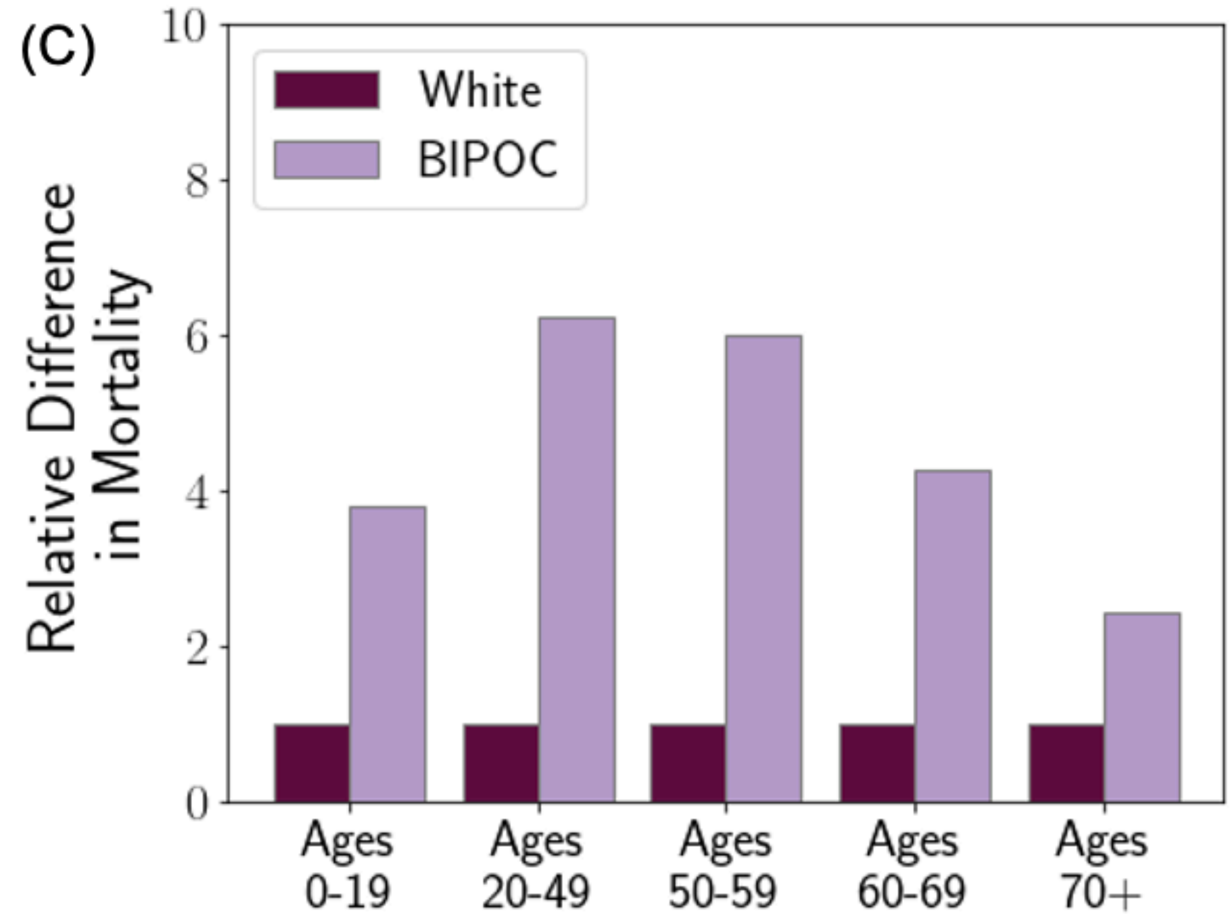
Minimize both:

$$\sum_{ages} Deaths + \sum_{ages} |(\frac{m_{a,O}}{m_{a,W}} - 1)|$$

Results

Counterfactual scenario: Baseline case, random vaccinations, 10% of the population vaccinated.





New Deaths: 390

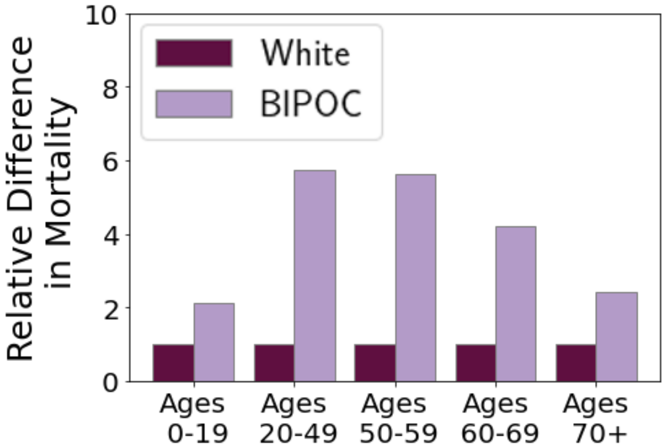
Deaths Per-Group	0-19	20-49	50-59	60-69	70+
White	0	3	12	58	220
BIPOC	1	6	14	30	46

Similar inequity profile to the one observed at the end of 2020.

Minimizing either deaths OR inequity

Enough vaccine to cover 10% of the pop.

Base case

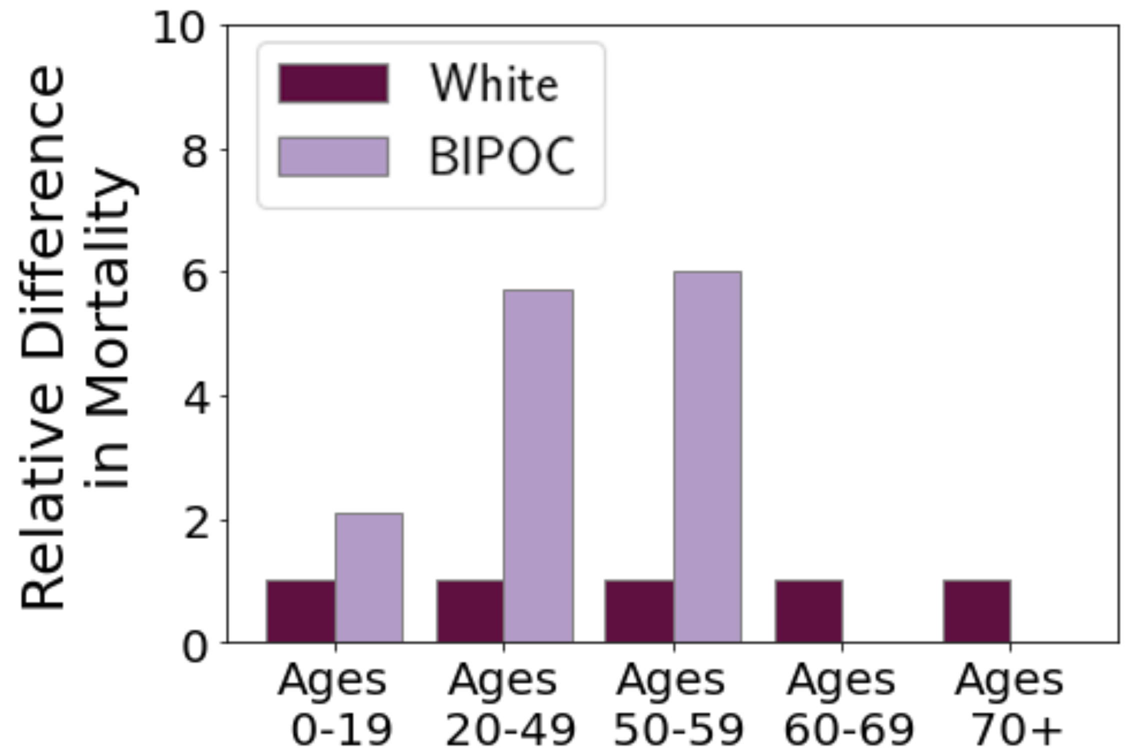


Minimizing only deaths:

61% more deaths averted compared to baseline.

- Minimizing mortality: less mortality in most groups, even in the marginalized ones, at the cost of more inequity, specially in young adults and those aged 50-59.

- Priority given to older adults, specially those in the marginalized groups.

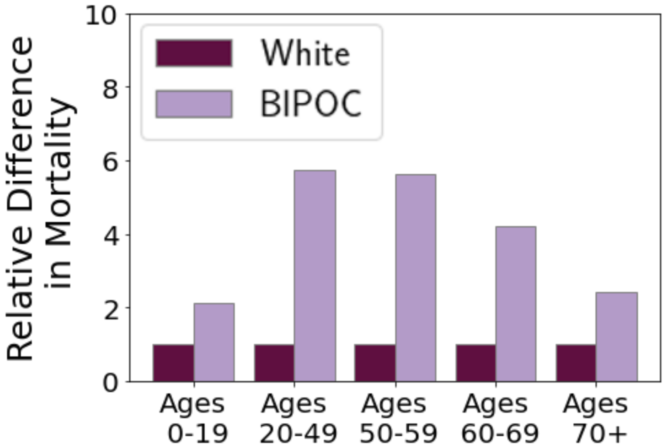


Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	3 (0%)	12 (0%)	58 (0%)	56 (75%)
All Other	1 (0%)	6 (0%)	15 (-7%)	0 (100%)	0 (100%)

Prop. Vaxed (%)	20-49	50-59	60-69	70+
White	0	0	0	70
BIPOC	0	0	100	100

Enough vaccine to cover 10% of the pop.

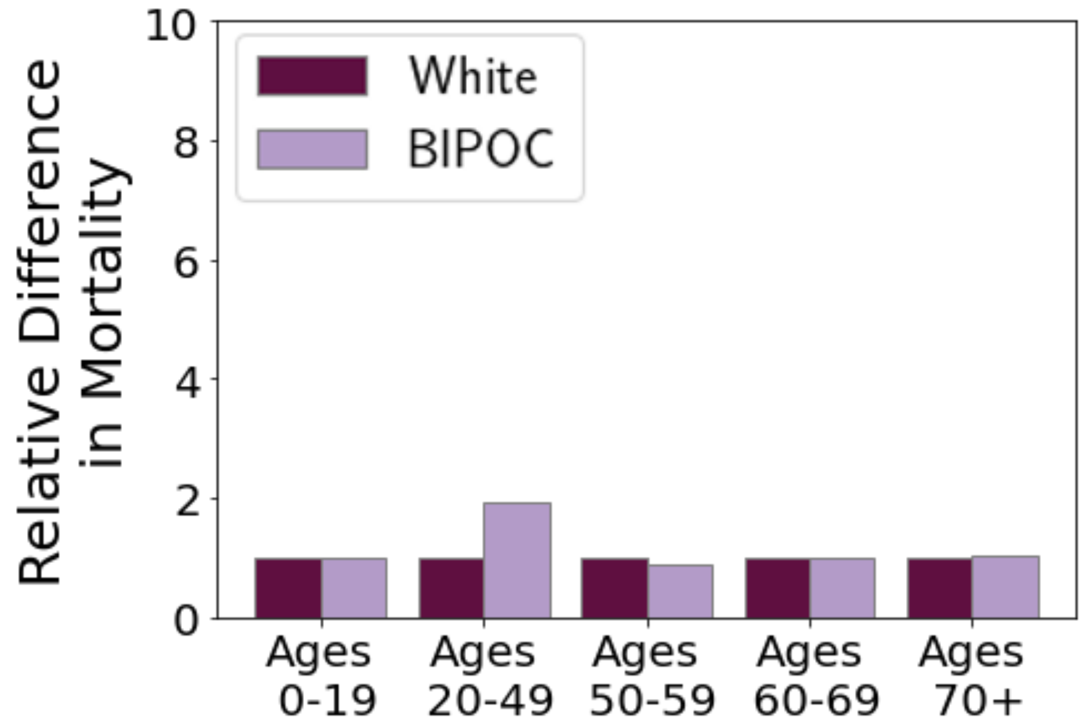
Base case



Minimizing only relative inequity:

18% more deaths averted compared to baseline

- Minimizing inequity: we achieve less inequity, at the cost of more older people dying.
- Priority to vaccinate younger adults in marginalized groups.



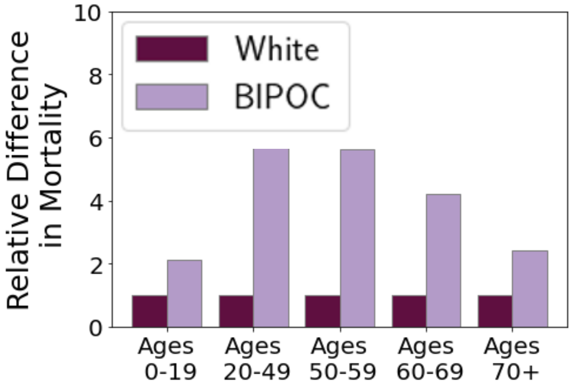
Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	3 (0%)	11 (8%)	57 (2%)	218 (1%)
All Other	0 (100%)	2 (67%)	2 (86%)	7 (77%)	19 (59%)

Prop. Vaxed (%)	20-49	50-59	60-69	70+
White	0	0	0	0
BIPOC	68	81	72	51

Minimizing deaths AND inequity

Enough vaccine to cover 10% of the pop.

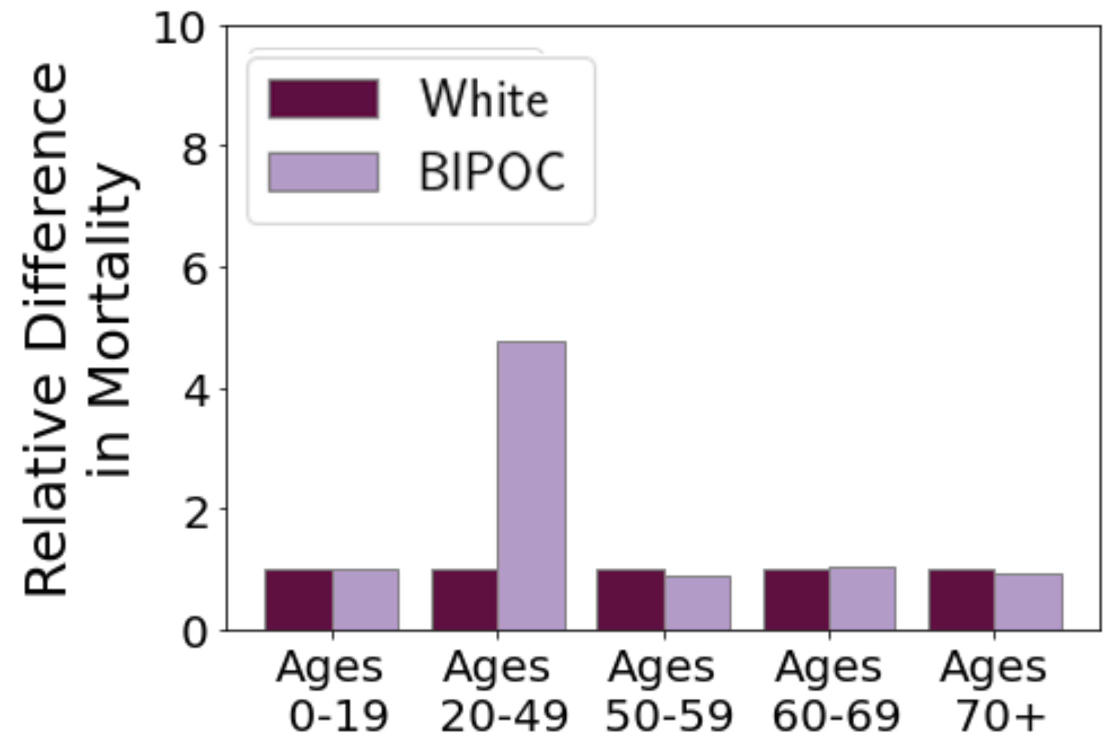
Base



Minimizing deaths and inequity: 57% more deaths averted

- Minimizing both: 4% less deaths averted than in the mortality only scenario.
- Significant gains in equity achieved.
- With low vaccine supply, minimizing both measures leads to a more balanced outcome. However, there is a trade-off between reducing overall mortality and reducing inequity.

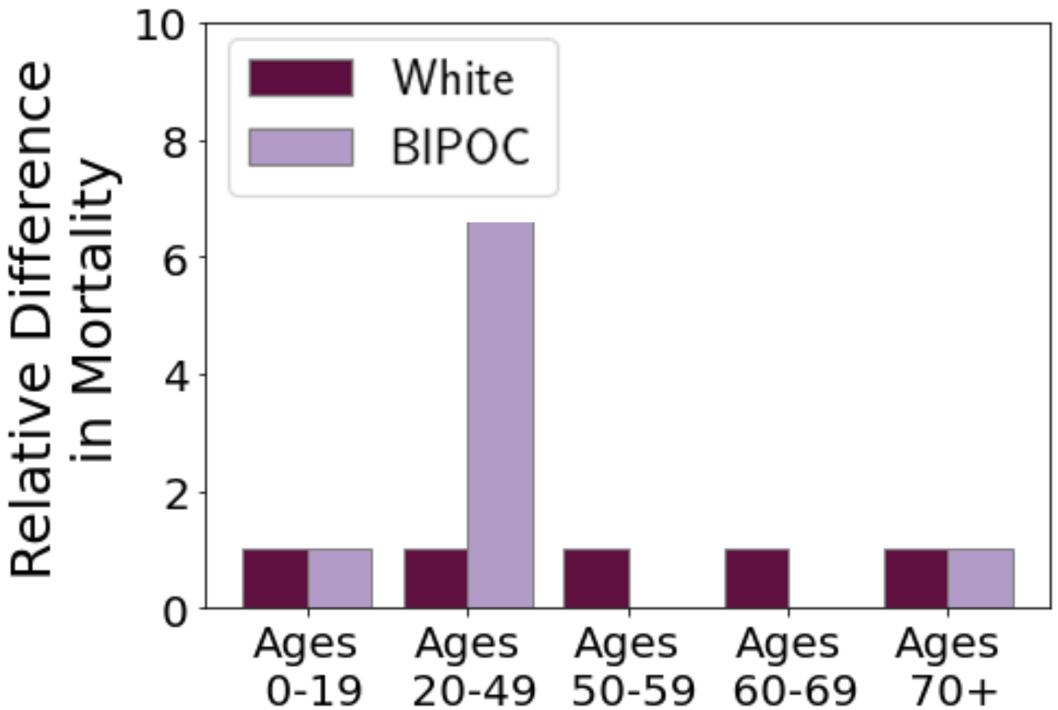
Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	3 (0%)	11 (8%)	55 (5%)	75 (66%)
All Other	0 (100%)	5 (17%)	2 (86%)	7 (77%)	6 (87%)



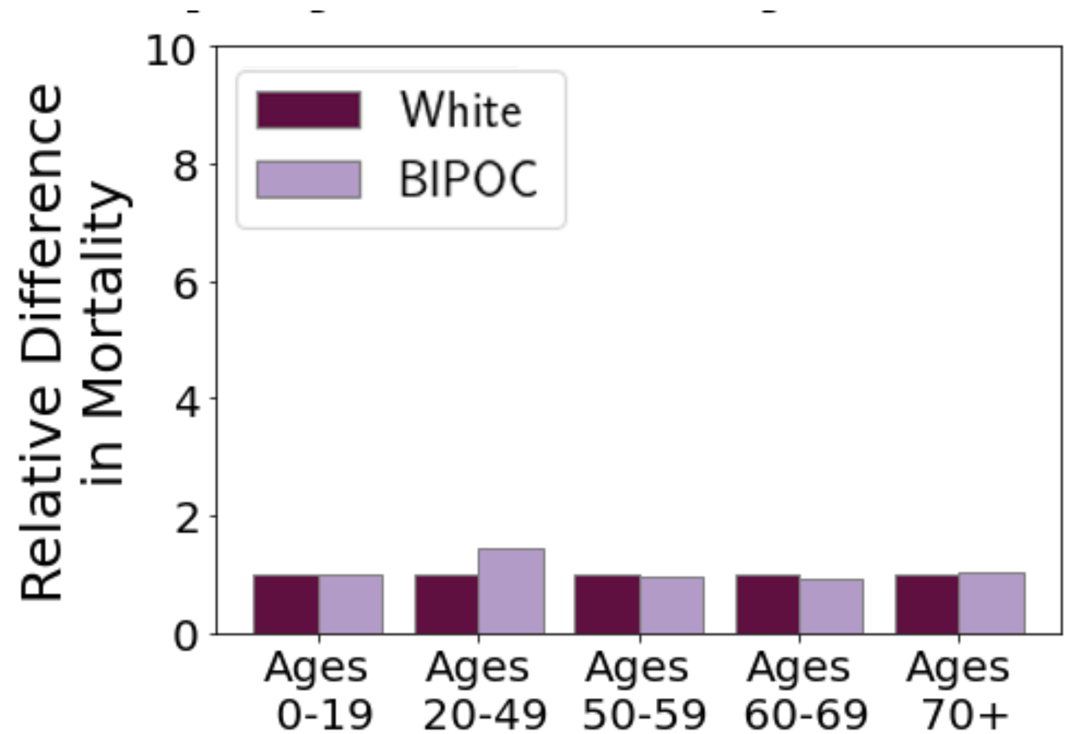
Prop. Vaxed (%)	20-49	50-59	60-69	70+
White	0	0	0	60
BIPOC	0	82	74	82

Enough vaccine to cover 20% of the pop.

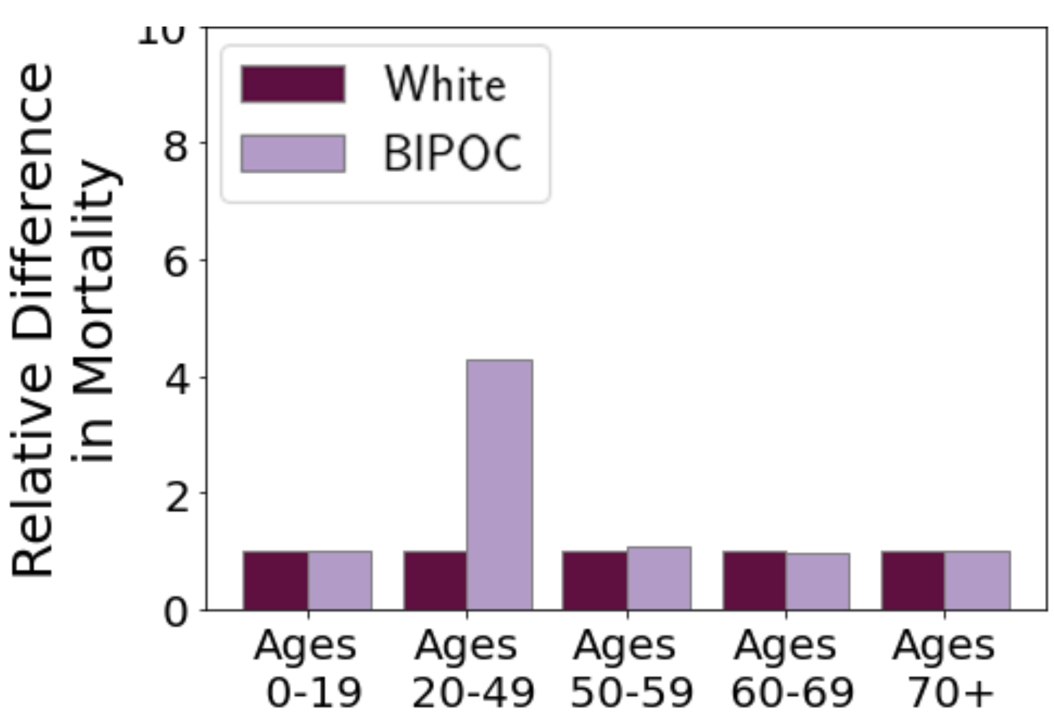
Minimizing deaths:
89% more deaths averted



Minimizing relative inequity:
50% more deaths averted

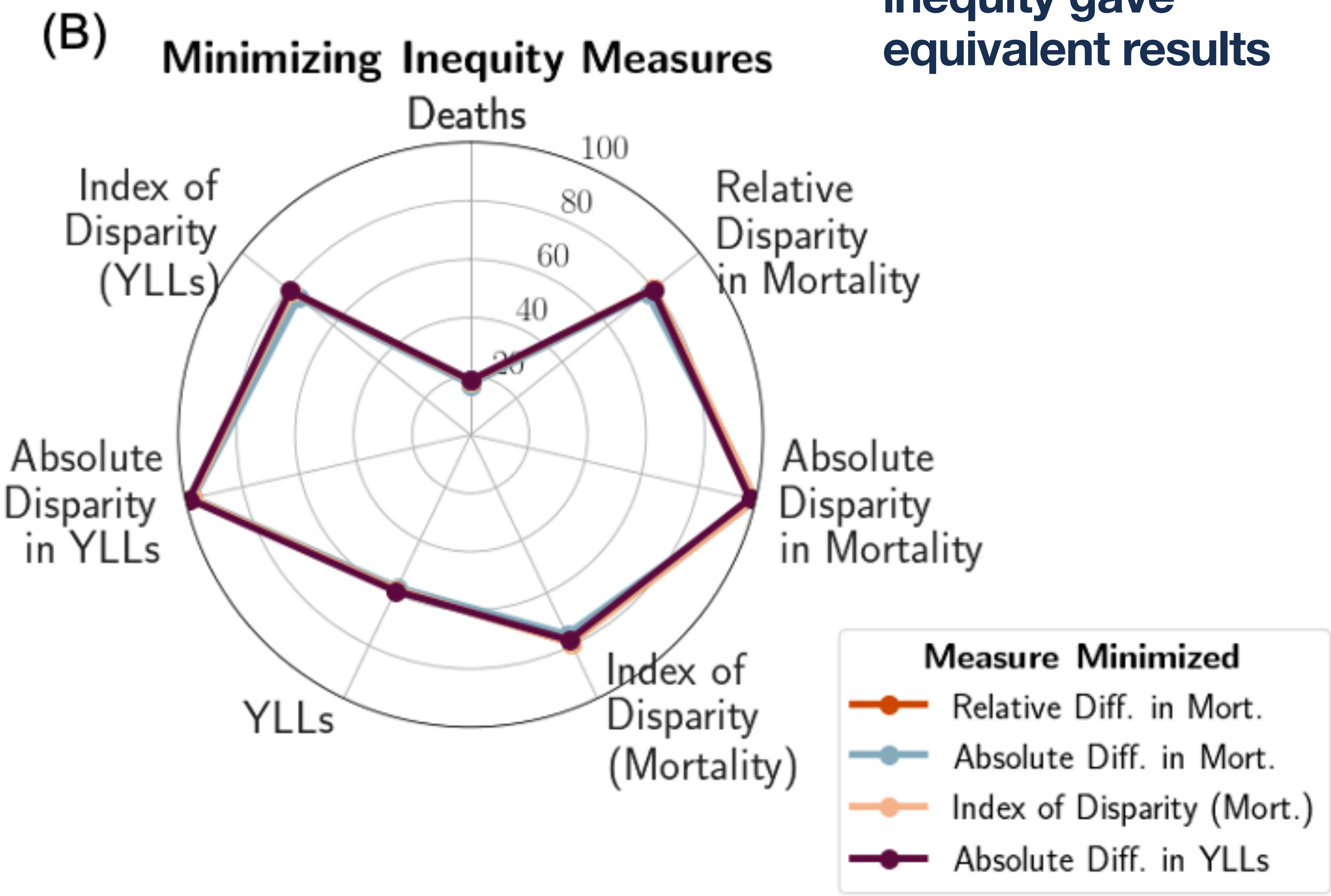


Minimizing deaths and inequity:
83% more deaths averted



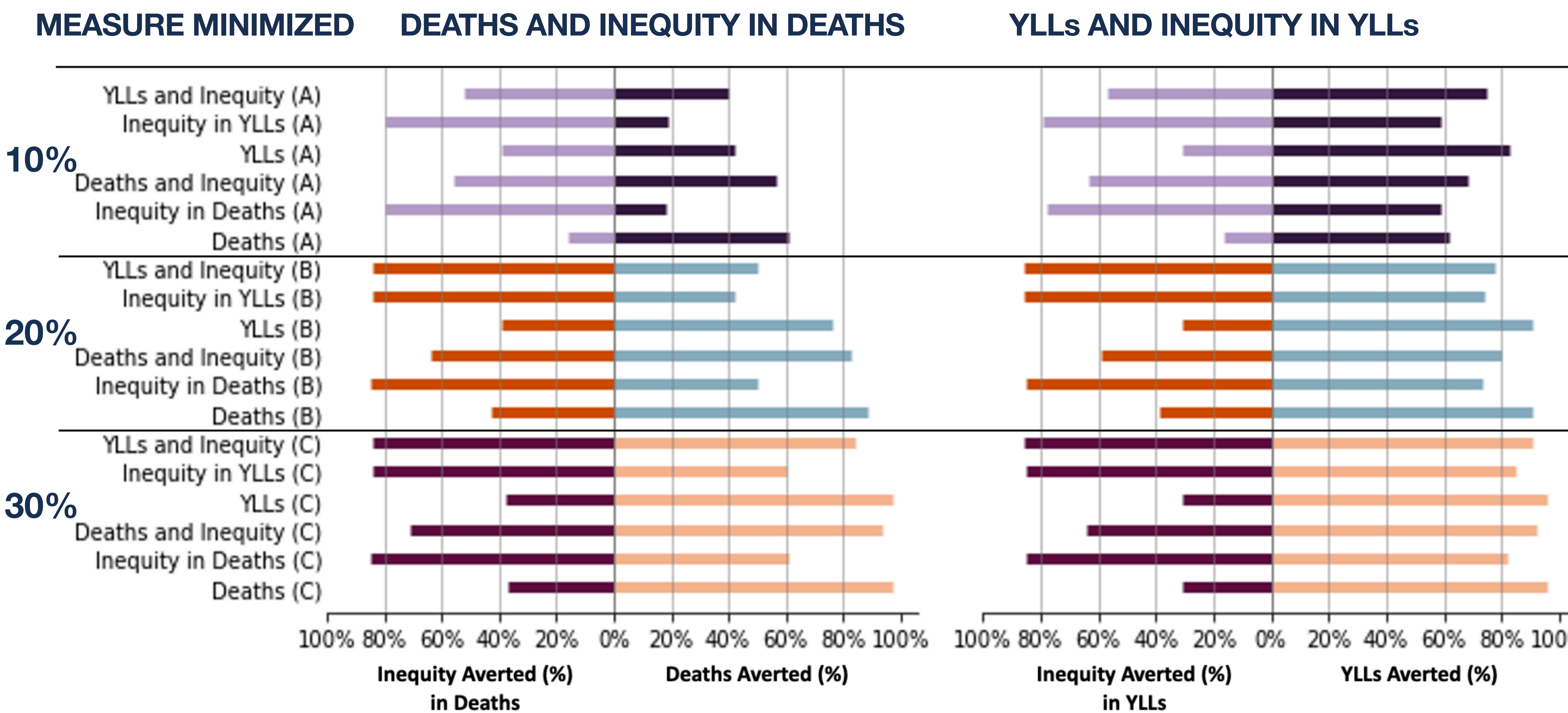
- At 20% coverage, the trade-off lessens: minimizing mortality in our model achieves great reduction in inequity.

Comparing different metrics of inequity:



- **All measures of inequity gave equivalent results**

Summary:



- At low coverage, minimizing a single measure (traditional measure or inequity) alone leads to big imbalance.
- As coverage increases, it is easier to minimize both measures simultaneously.

Conclusions

- With low vaccine supply, minimizing deaths was the optimal way of preventing overall deaths, and prevented more deaths in the marginalized communities, even if there was more inequity.
- With low vaccine supply, there is a *trade-off* between being more equitable and protecting overall mortality. This is true because COVID-19 related mortality is concentrated in the oldest populations. This would not be true for other diseases like HIV or Monkeypox.
- When minimizing both, we achieved more balanced allocations with higher equity and a small reduction in deaths averted.
- When vaccine supply is higher, it is possible to minimize mortality and inequity at the same time.
- Of all the metrics compared, a combination of deaths and relative inequity seems to be the best optimization metric to use.

Thanks!

Using the power of epidemiology
to improve the public's health.

Fred Hutch
Cancer Center

COVID-19
Prevention Network

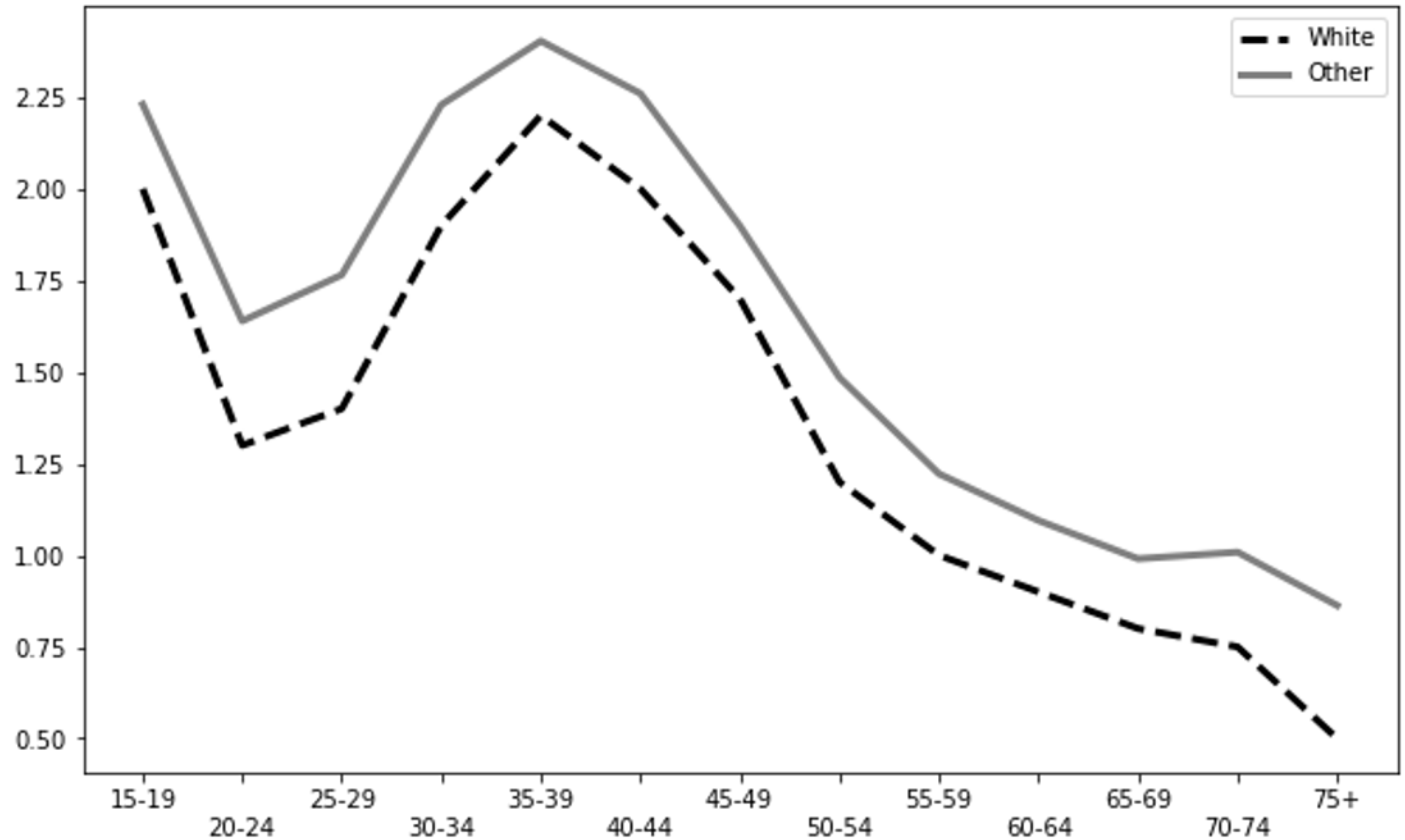
NSF

NIH
National Institute of
Allergy and
Infectious Diseases

Extra slides

Model assumptions (continued):

- Household contacts: assumed different racial groups have different numbers of contacts, taken from Dorélien et al.
- To determine the proportion of interracial households, census data is used.

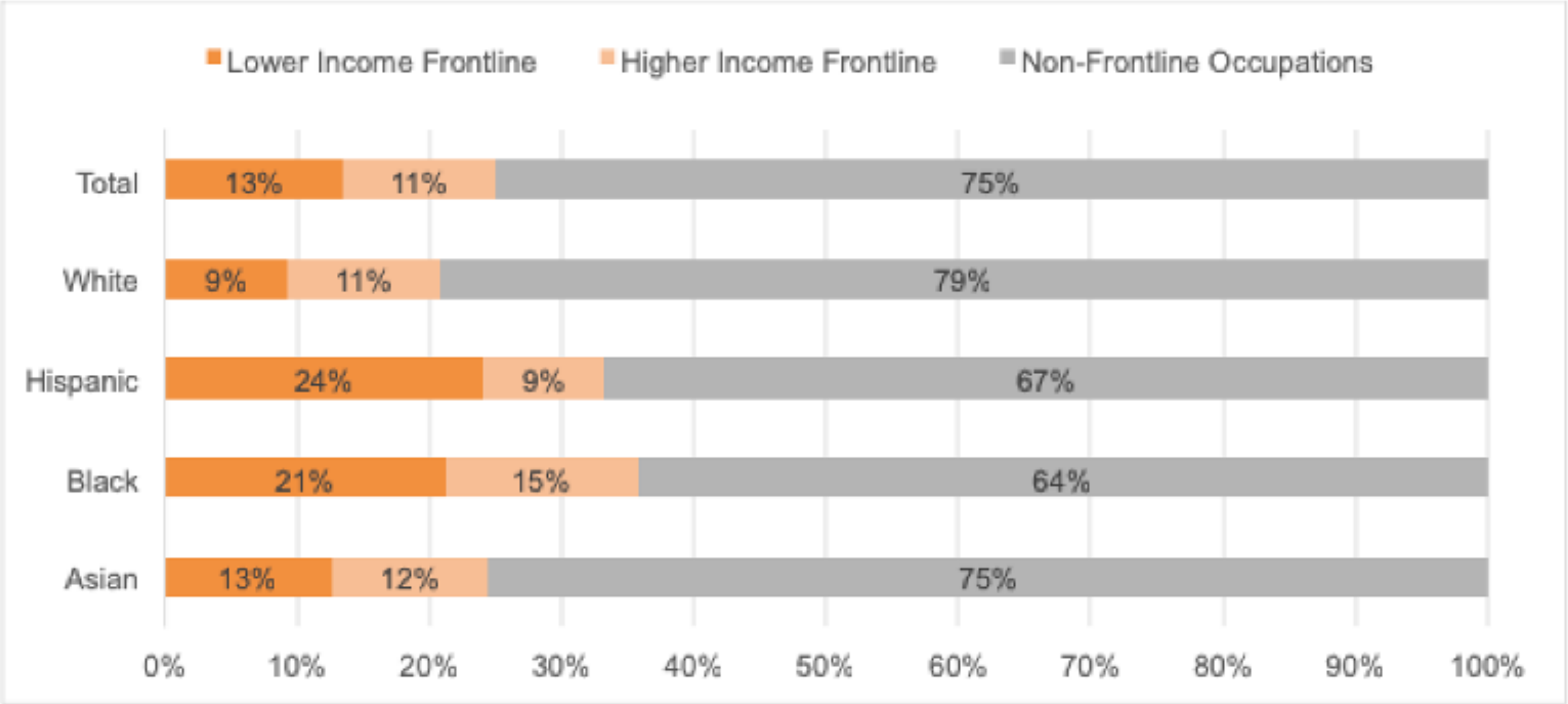


Model assumptions (continued):

- Work contacts:
  -Differences in work contacts for each racial/ethnic group were estimated from the 2018 American Community Survey (ACS) by IUSSP.

  -Non-frontline workers are assumed to have less contacts than frontline workers.

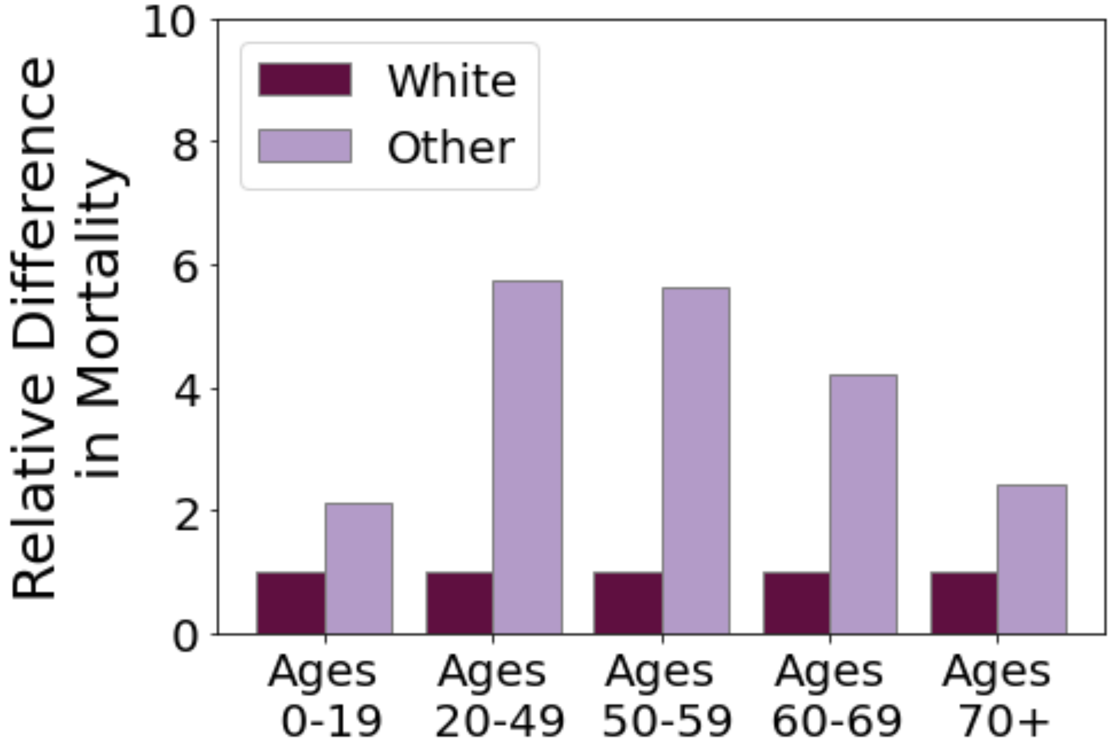
Figure 1. Workers by Race/Ethnicity and Frontline Status



Source: American Community Survey 2018, iPUMs

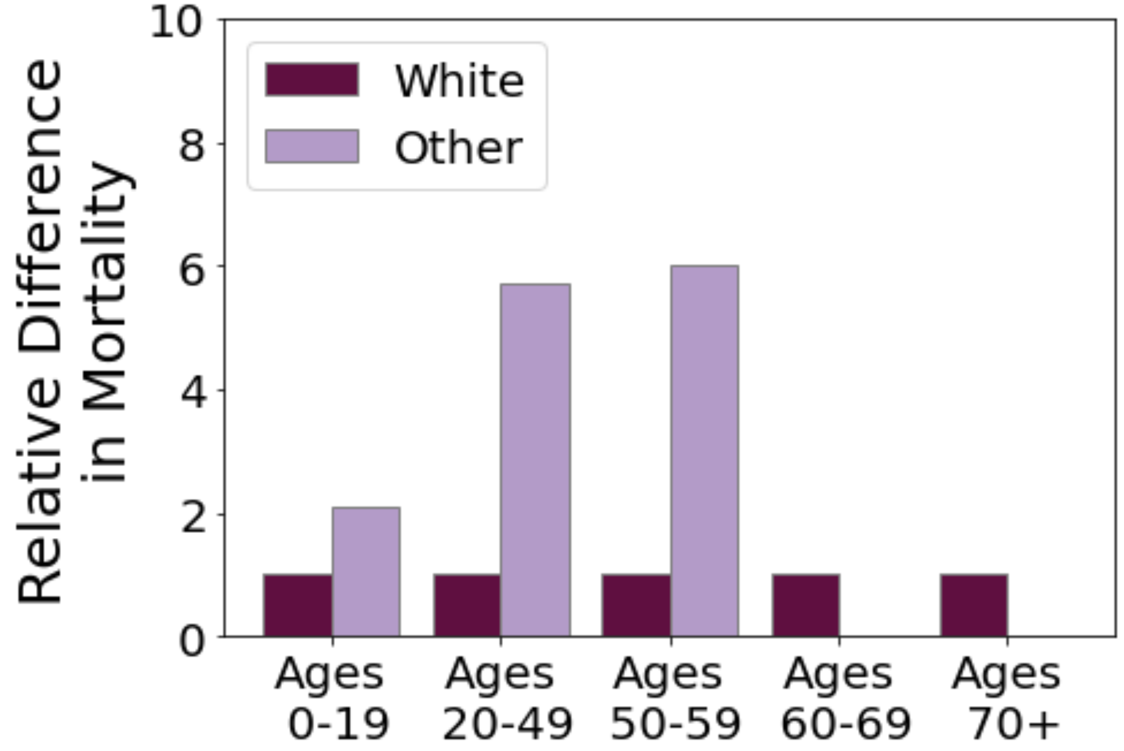
Enough vaccine to cover 10% of the pop.

Base case



Minimizing deaths:

61% more deaths averted



Prop. Vaxed (%)	20-49	50-59	60-69	70+
White	0	0	0	70
All Other	0	0	100	100

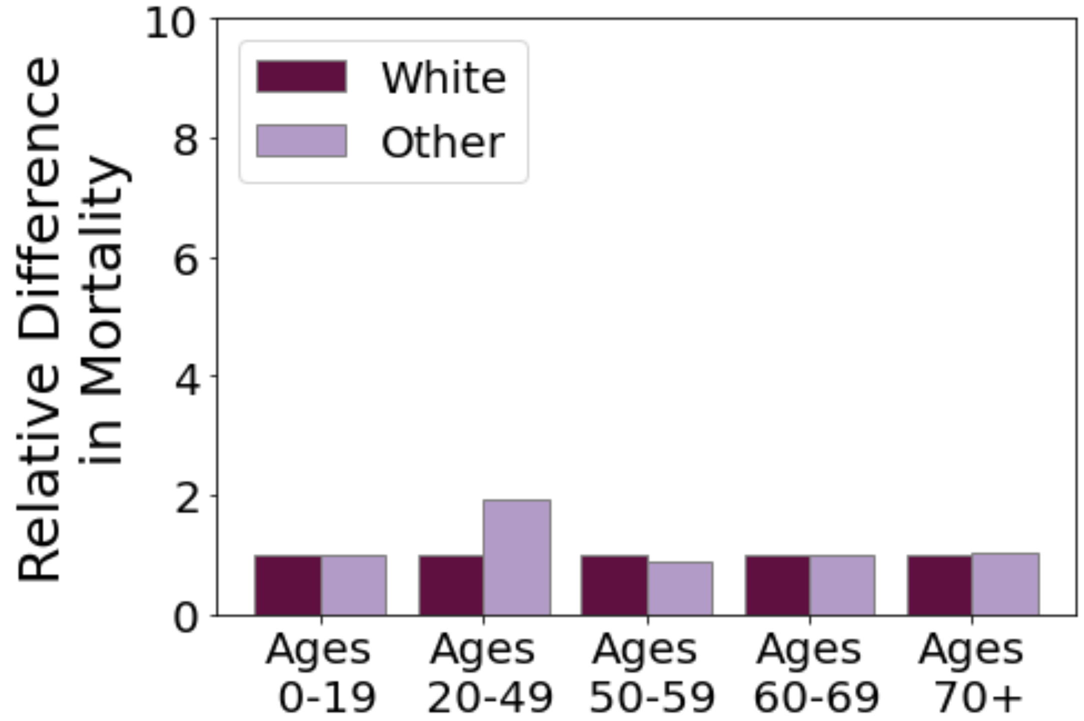
- Minimizing mortality: less mortality in most groups, even in the marginalized ones, at the cost of more inequity, specially in young adults and those aged 50-59.
- Priority given to older adults, specially those in the marginalized groups.

Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	3 (0%)	12 (0%)	58 (0%)	56 (75%)
All Other	1 (0%)	6 (0%)	15 (-7%)	0 (100%)	0 (100%)

Enough vaccine to cover 10% of the pop.

Minimizing relative inequity:
18% deaths averted

- Minimizing inequity: we achieve less inequity, at the cost of more older people dying.
- Priority to vaccinate younger adults in marginalized groups.



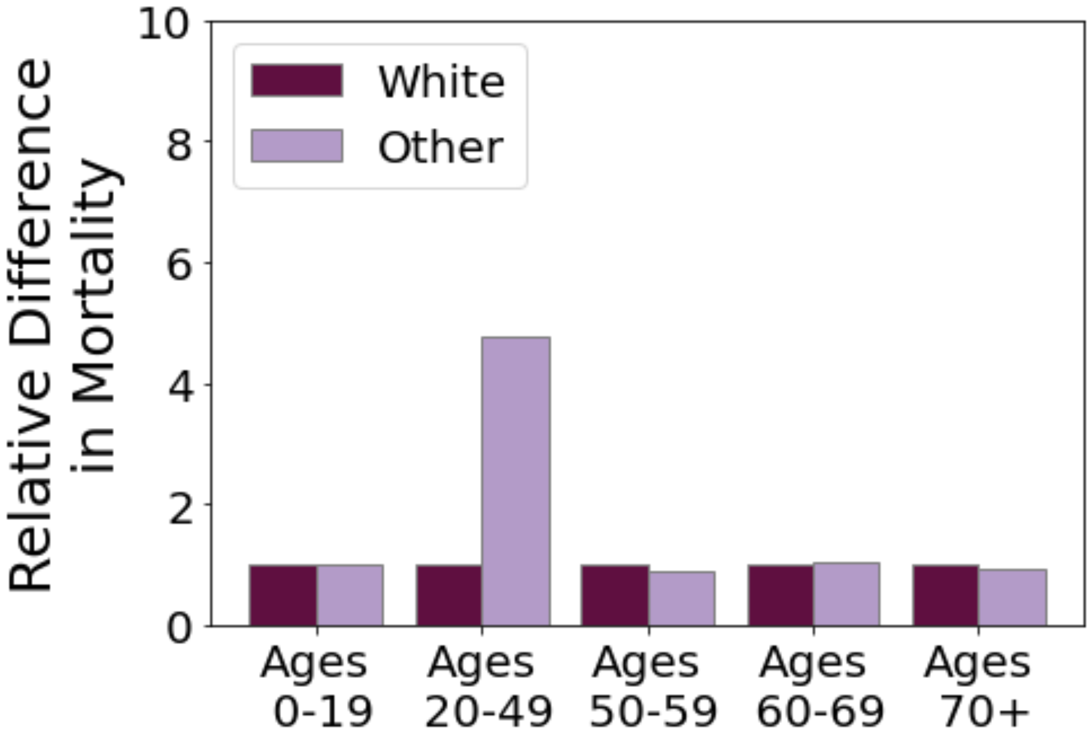
Prop. Vaxed (%)	20-49	50-59	60-69	70+
White	0	0	0	0
All Other	68	81	72	51

Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	3 (0%)	11 (8%)	57 (2%)	218 (1%)
All Other	0 (100%)	2 (67%)	2 (86%)	7 (77%)	19 (59%)

Enough vaccine to cover 10% of the pop.

Minimizing deaths and inequity:

57% deaths averted



Prop. Vaxed (%)	20-49	50-59	60-69	70+
White	0	0	0	60
All Other	0	82	74	82

Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	3 (0%)	11 (8%)	55 (5%)	75 (66%)
All Other	0 (100%)	5 (17%)	2 (86%)	7 (77%)	6 (87%)

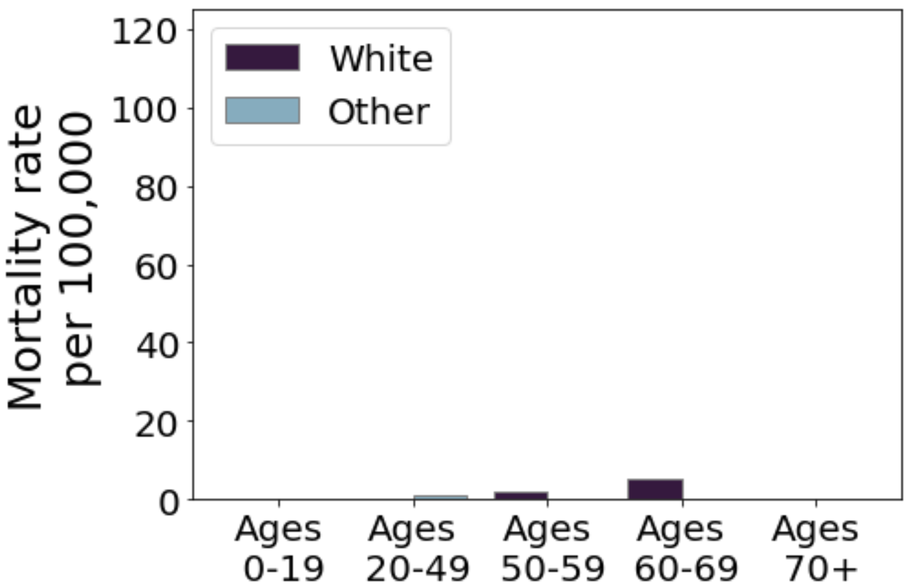
- Minimizing both: 4% less deaths averted than in the mortality only scenario.
- Significant gains in equity achieved.
- Is this acceptable?

With low vaccine supply, minimizing both measures leads to a more balanced outcome. However, there is a trade-off between reducing overall mortality and reducing inequity.

Enough vaccine to cover 20% of the pop.

Minimizing deaths:
89% deaths averted

Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	2 (33%)	9 (25%)	24 (59%)	0 (100%)
All Other	0 (100%)	5 (17%)	0 (100%)	0 (100%)	0 (100%)



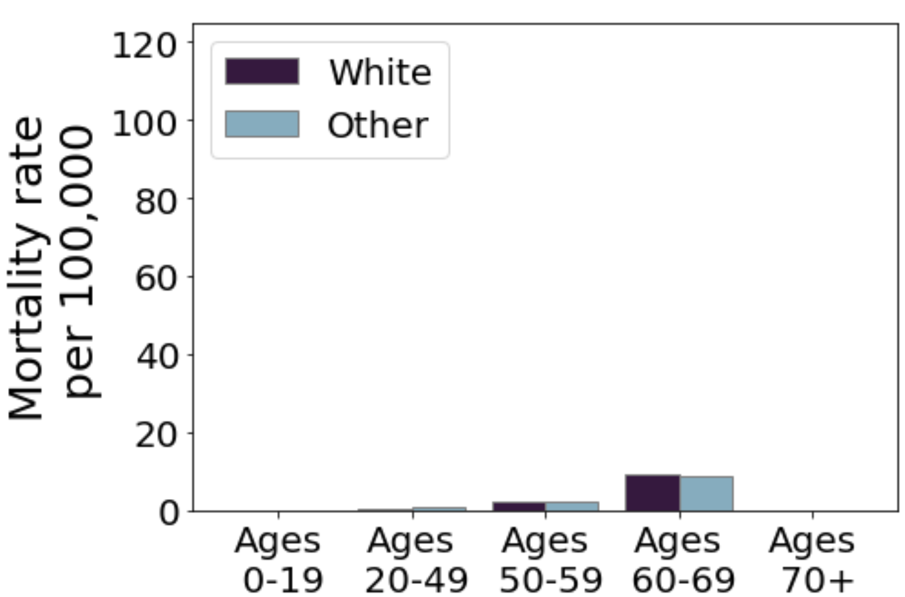
Minimizing relative inequity:
50% deaths averted

Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	2 (33%)	5 (58%)	44 (24%)	126 (43%)
All Other	0 (100%)	1 (83%)	1 (93%)	5 (83%)	11 (76%)

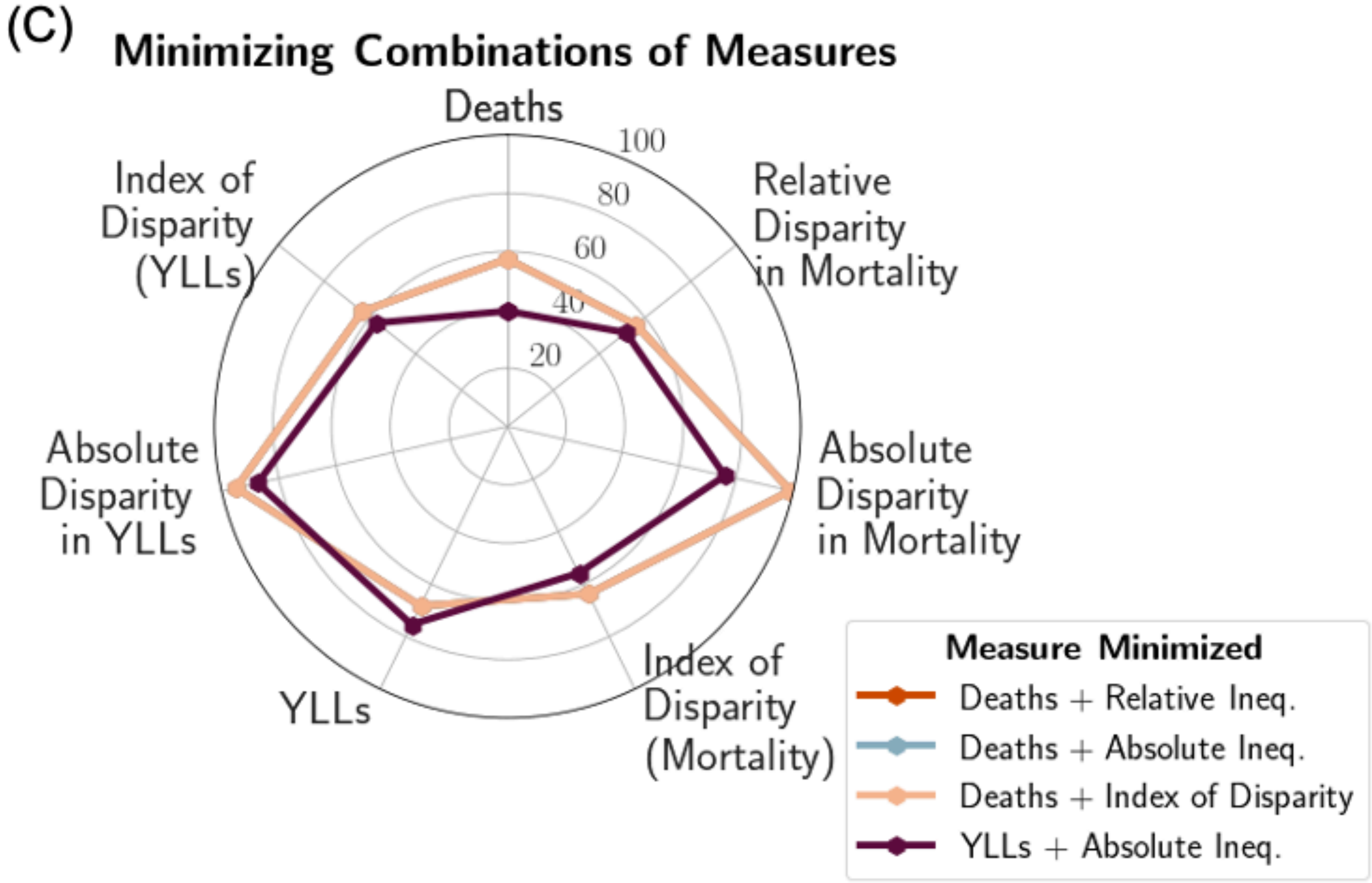
- At 20% coverage, the trade-off lessens: minimizing mortality in our model achieves great reduction in inequity.

Minimizing deaths and inequity:
83% deaths averted

Deaths (% Averted)	0-19	20-49	50-59	60-69	70+
White	0 (0%)	2 (33%)	9 (25%)	43 (26%)	0 (100%)
All Other	0 (100%)	3 (50%)	2 (86%)	5 (83%)	0 (100%)



Comparing Deaths vs YLLs:



- Any combination of Deaths + Measure of inequity led to similar results and was better than YLLs + Inequity.