

Metal mixtures in private well water are associated with preterm birth in North Carolina

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1. Introduction and Hypothesis

- In North Carolina (NC), the prevalence of preterm birth is 10.8%, compared to 10.1% nationwide. There is geographic variation in the prevalence across the state (**Fig. 1**) [1].
- Private well water in NC has been documented to contain high levels of toxic metals (**Table 1**) [2].
- Metal exposure via private well water, which is federally unregulated, may increase the risk of preterm birth [3].
- Municipal underbounding, the intentional gerrymandering of communities of color, leaves these peri-urban communities relying on private wells [4].
- Hypothesis:** (1) Exposure to metals (arsenic (iAs), manganese (Mn), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), and zinc (Zn)) and mixtures of metals via private well water increases the risk of preterm birth. (2) There exist differences in the metal mixture-preterm birth association by maternal race/ethnicity.

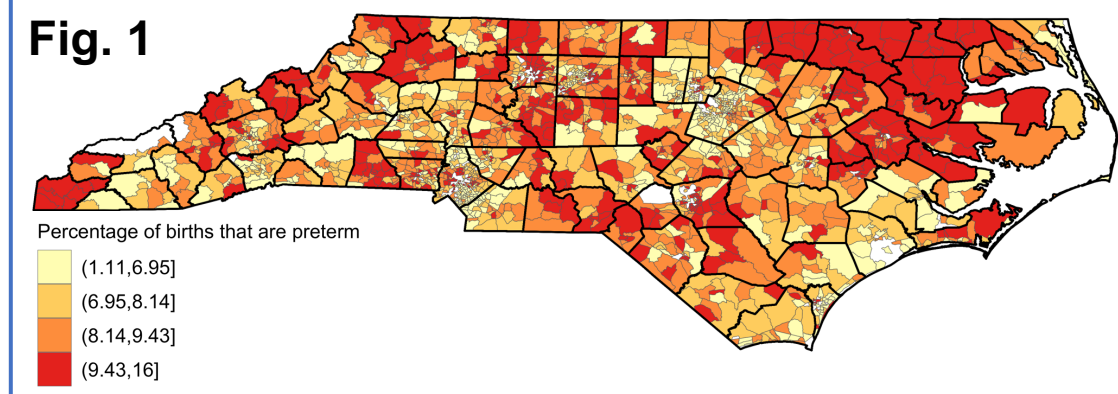


Table 1. iAs, Mn and Pb levels in NC private well water tests, 1998-2019

Metal (MCL)	Number of tests over EPA MCL	Maximum reported level
iAs (10 ppb)	2,502	806 ppb
Mn (300 ppb*)	5,405	46,300 ppb
Pb (15 ppb**)	3,076	105,440 ppb

*Mn Lifetime Health Advisory Limit
**Pb treatment technique action level

2. Methods

1: NCWELL database [2]	<ul style="list-style-type: none"> 117,960 well water test reports from 1998-2019 Metals included: iAs, Mn, Pb, Cd, Cr, Cu, Zn Multiple imputation with chained equations for values <limit of reporting
2. Birth certificate data	<ul style="list-style-type: none"> All non-anomalous singleton livebirths in NC from 2003-2015 (n=1,329,071) Geocoded by maternal residence at delivery Assigned the mean census tract-level concentration for each metal to each birth
3. Statistical analyses	<ul style="list-style-type: none"> Single metals: logistic regression Metal mixtures: partial effects quantile-based g-computation Adjusted for maternal smoking, maternal age, maternal race/ethnicity, maternal education, season of conception, tract-level poverty, tract-level nitrates and nitrites. Effect measure modification by maternal race/ethnicity

4. Conclusions

- Contamination of private wells with metals, namely Pb and Cd, contributes to preterm birth. This study:
 - extends the evidence connecting Pb and preterm birth to a specific exposure: federally unregulated private well water.
 - underscores environmental justice concerns in relation to well water-based toxic exposures among American Indian communities. This disparity is likely contributed to by historical patterns of forced removal from tribal lands and community exclusion from city services, ultimately leading to municipal underbounding and American Indian populations disproportionately relying on private well water for drinking and cooking.
 - highlights the **urgent need for awareness and action around metal contamination of private wells**, including greater access and affordability of testing and treatment.

3. Results

(A) Private well concentrations of Pb and Cd were associated with an increased risk of preterm birth (**Fig. 2**).

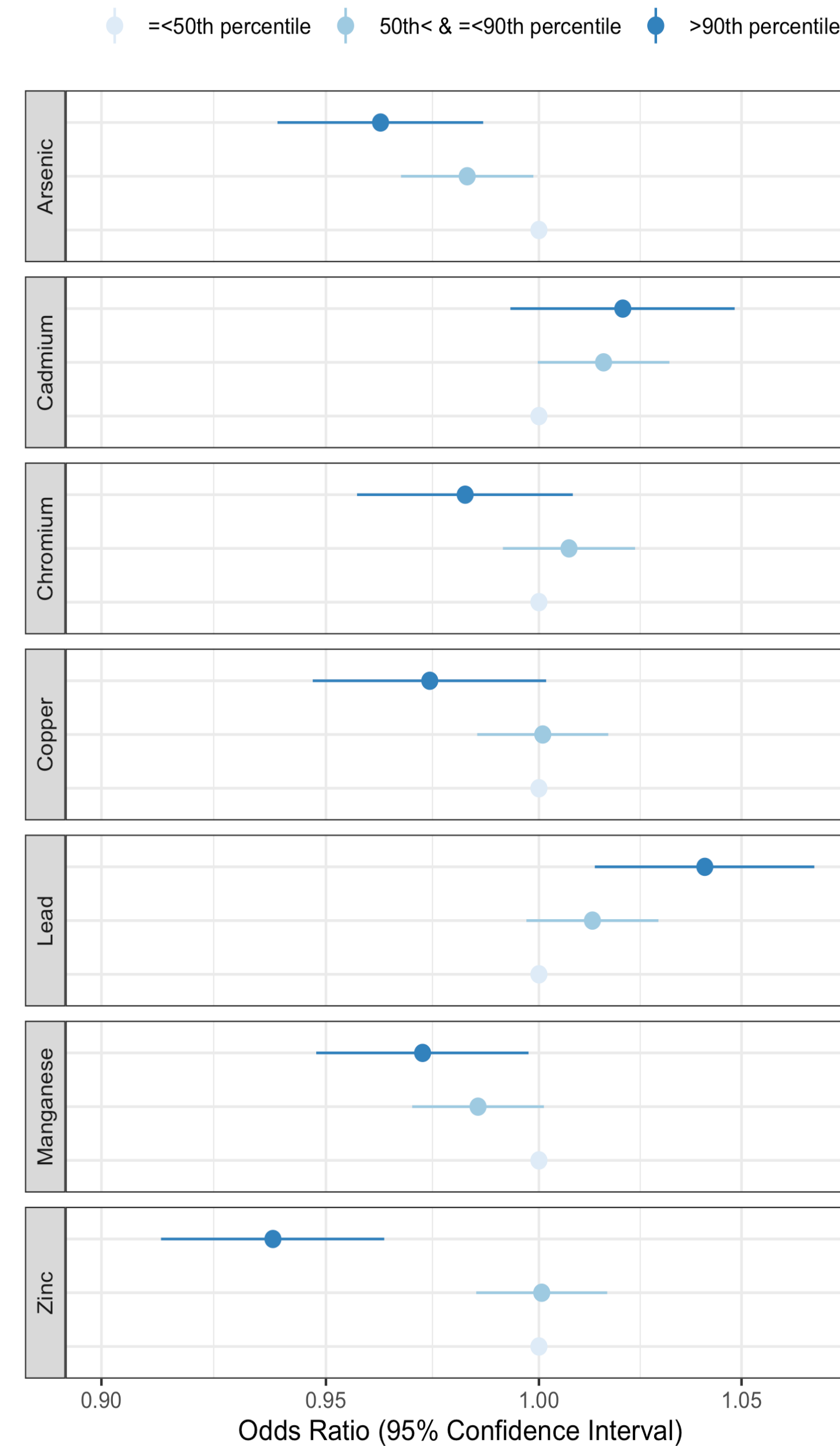


Fig. 2. Forest plot of odds ratios for preterm birth comparing mothers in tracts with varying concentrations of individual metal concentrations reported in private wells. Models were fit comparing mothers in tracts with low (mean tract-level metal concentration $\leq 50^{\text{th}}$ percentile of state-wide metal concentration), medium (mean tract-level metal concentration $> 50^{\text{th}}$ and $< 90^{\text{th}}$ percentile of state-wide metal concentration) and high (mean tract-level metal concentration $\geq 90^{\text{th}}$ percentile of state-wide metal concentration).

(B) A mixture of Cd, Cr and Pb increased the risk of preterm birth (**Fig. 3**).

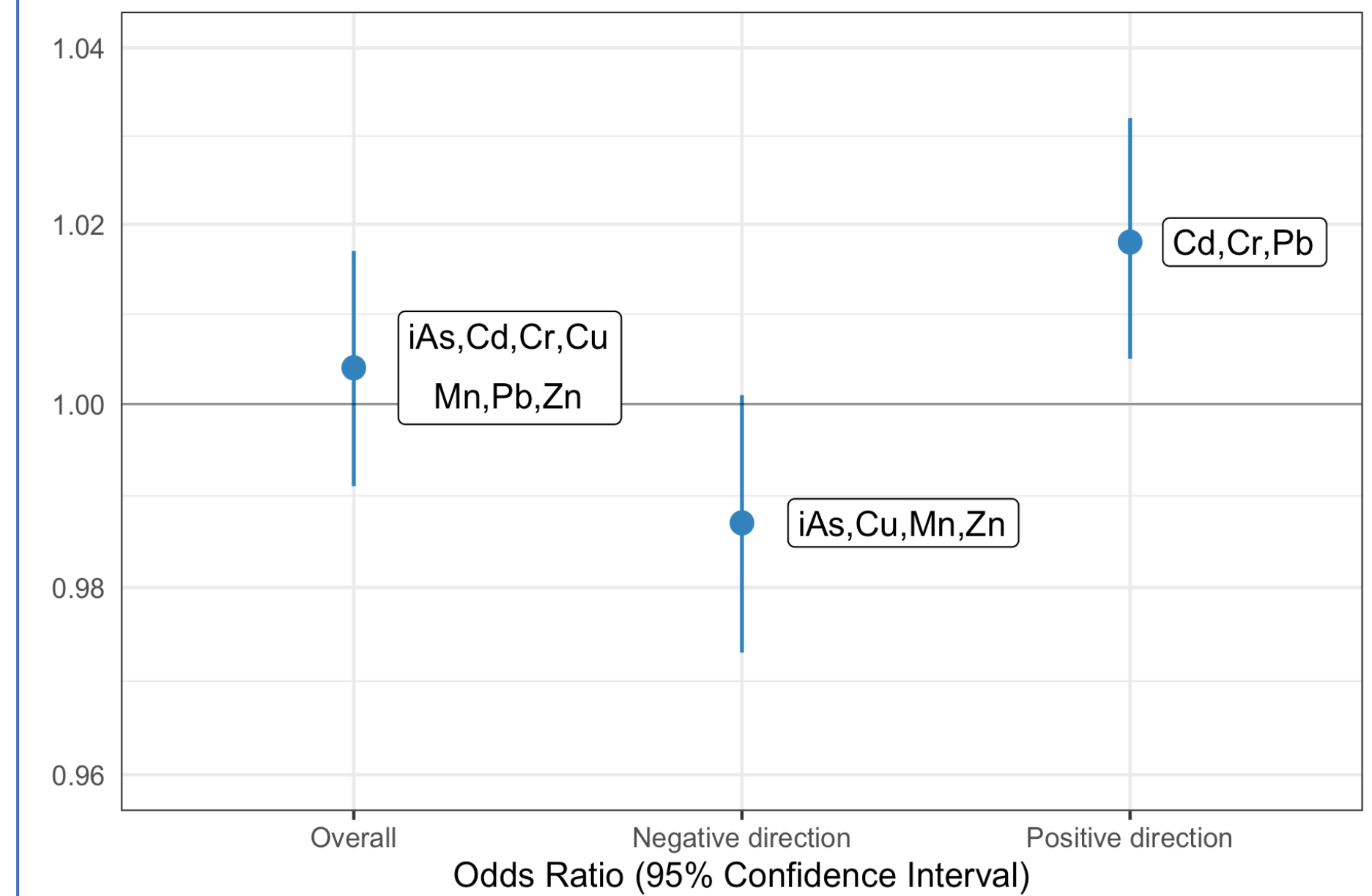


Fig. 3. Results from the partial effects quantile-based g-computations modeling. Forest plot of odds ratios for preterm birth associated with increasing all metal concentrations in private wells by one quartile (“Overall”), just the metals that had negative weights in the training set (“Negative direction”), and just the metals that had a positive weights in the training set (“Positive direction”).

(C). American Indian mothers had the most pronounced metal mixture effect, highlighting the impact of municipal underbounding and race-based segregation in relation to private well water-based exposure (**Fig. 4**).

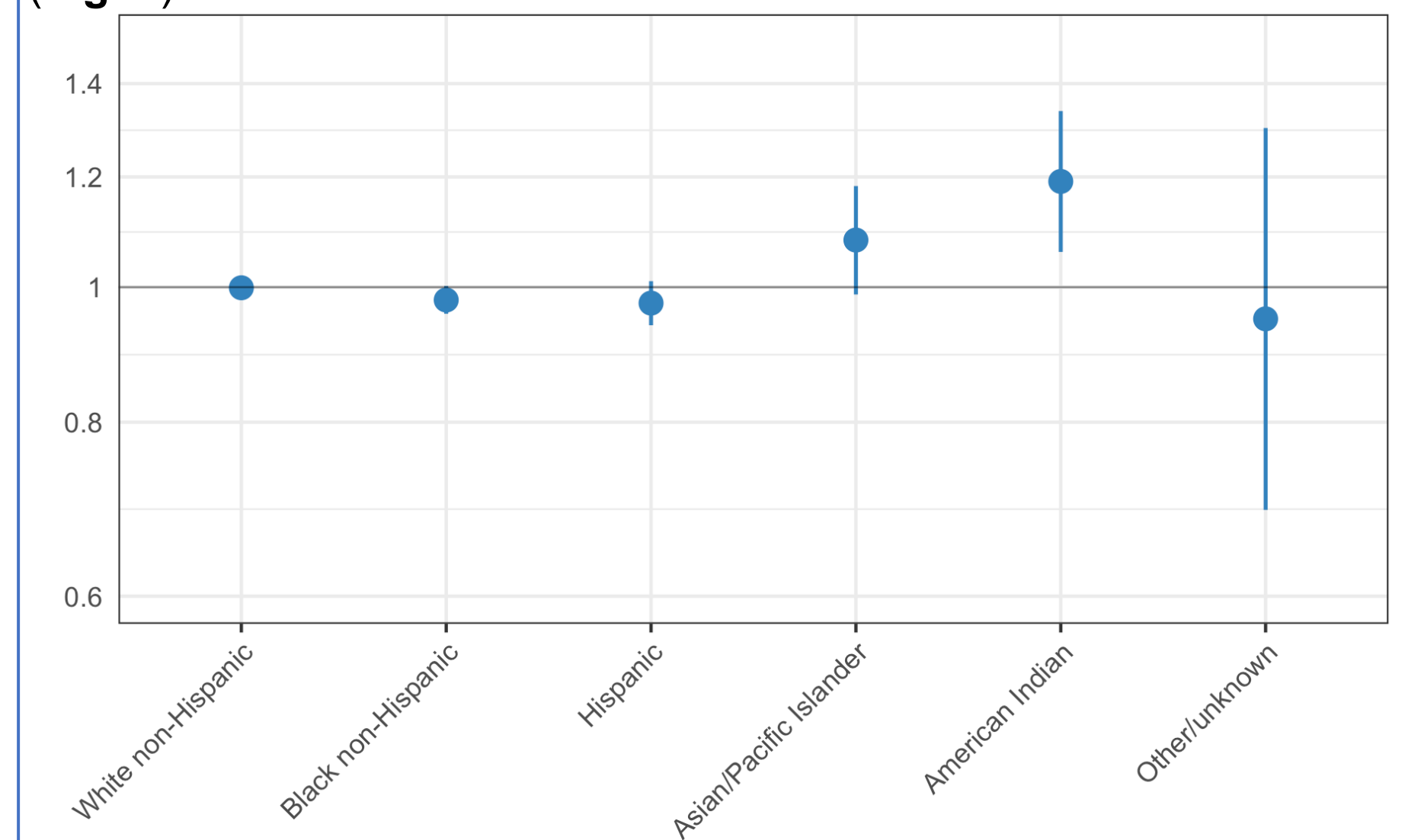


Fig. 4. Forest plot of odds ratios for preterm birth when simultaneously increasing the mean census tract concentration of all metals by one quartile, stratified by maternal race/ethnicity.

References

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