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US states that mandated COVID-19 vaccination see higher, not lower, takeup of COVID-19 boosters and flu vaccines

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**Main Text**

Rains & Richards (1), henceforth RR, reach two findings about US COVID-19 vaccination mandates. First, state mandates have no effect on COVID-19 vaccine takeup. Second, compared to states that banned COVID-19 vaccination requirements, states that imposed COVID-19 vaccination mandates exhibit lower adult and child uptake of flu vaccines, and lower uptake of COVID-19 boosters. RR interpret these differences causally.

I focus here on RR's second set of findings concerning COVID-19 booster and flu vaccine takeup, as these results arise from models exhibiting a key error: they include a bad control (2-4). Specifically, these models control for state COVID-19 vaccination rates. Figure 1 demonstrates why this is a bad control by showing causal pathways using a directed acyclic graph. A common factor (e.g., vaccine hesitancy) impacts all vaccination rates. Mandates may impact uptake of COVID-19 boosters or flu vaccines. If mandates also impact COVID-19 vaccination rates, then in models that control for COVID-19 vaccination rates, statistical associations between mandates and COVID-19 booster/flu vaccine uptake will reflect not just causal effects, but also *collider bias* (2-4). Though RR find that mandates have insignificant effects on COVID-19 vaccine uptake, they note that they lack enough data to detect small effects. Credible causal analyses with more data show that mandates had strong positive effects on COVID-19 vaccination rates in multiple countries, including the US (5-6). In any event, RR's statistically insignificant mandate effect estimates do not prove that mandates have *zero* effect on COVID-19 vaccination rates (7); this assumption is untestable.

The bad control problem is well-established but often ignored (8). Collider bias has impacted scientific conclusions in public health before, including those concerning COVID-19 risk factors (3-4). For instance, collider bias yielded the 'birth weight paradox', which incorrectly asserts that maternal smoking can be shown to reduce infant mortality after controlling for birth weight (2, 9). I use RR's data and code (10) to show in Table 1 that collider bias may induce similarly erroneous conclusions in RR's paper. When the bad control is removed from RR's baseline models (without interaction terms), mandates are no longer negatively associated with COVID-19 booster or flu vaccine takeup. In fact, these associations are significantly positive for both types of vaccine. The replication package for this analysis is publicly available at osf.io/mdfb4/.

Though average COVID-19 booster and flu vaccine uptake is higher in states that imposed mandates, this does not necessarily mean that mandates *caused* higher uptake. Both RR's estimates and mine simply reflect the differences in average (conditional) takeup between mandate states and states that banned vaccine requirements. These differences reflect many factors beyond mandates and should not be interpreted causally, even after controlling for COVID-19 vaccination rates. The key conclusion of this replication is that RR's findings on COVID-19 booster and flu vaccine uptake are not robust, as removing just one control variable can completely reverse these findings. This specific robustness issue is limited to RR's findings on COVID-19 booster and flu vaccine uptake, and does not concern their findings on COVID-19 vaccine uptake.

**Acknowledgments**

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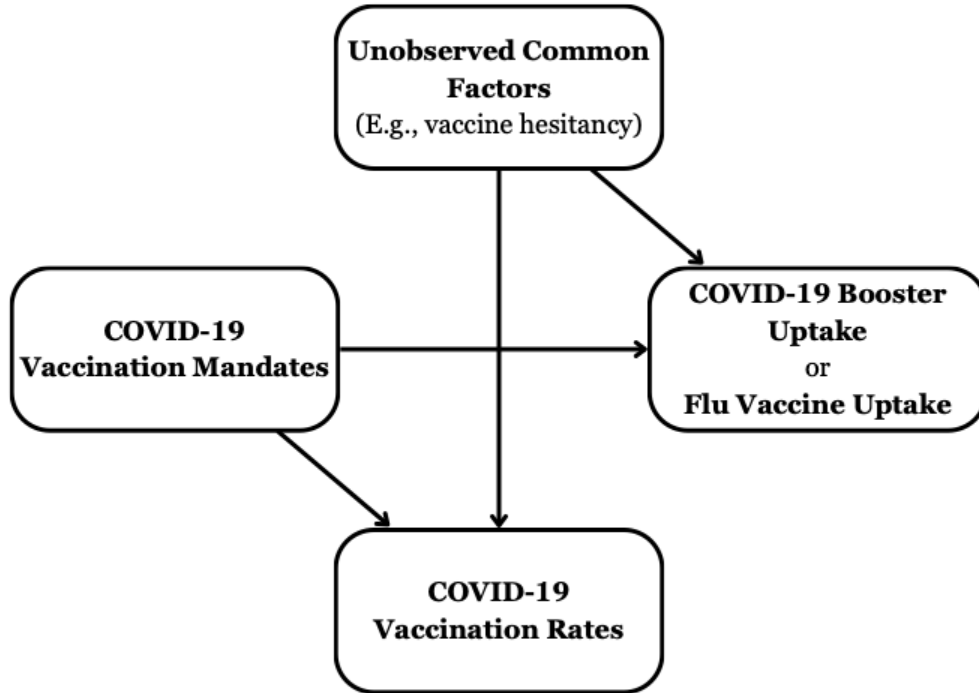
**Figures**



**Figure 1.** Directed acyclic graph showing the relationships between COVID-19 vaccination mandates, COVID-19 vaccination rates, COVID-19 booster/flu vaccine uptake, and unobserved factors such as vaccine hesitancy.

**Tables**

**Table 1. RR's COVID-19 booster/flu vaccine uptake models with and without the bad control**

|  | COVID-19 Booster Uptake | Adult Flu Vaccine Uptake | Child Flu Vaccine Uptake |
|---|---|---|---|
| **Panel A: Bad Control Included** |  |  |  |
| Mandate State | -0.072 | -0.119 | -0.179 |
|  | (0.027) | (0.021) | (0.028) |
| COVID-19 | 3.686 | 1.518 | 2.194 |
| Vaccination Rate | (0.056) | (0.07) | (0.029) |
| N | 1025 | 205 | 1025 |
| Conditional/marginal $R^2$ | 0.907/0.55 | 0.941/0.643 | 0.975/0.65 |
| **Panel B: Bad Control Removed** |  |  |  |
| Mandate State | 0.045 | 0.058 | 0.079 |
|  | (0.021) | (0.016) | (0.022) |
| N | 1025 | 205 | 1025 |
| Conditional/marginal $R^2$ | 0.298/0.034 | 0.512/0.155 | 0.597/0.151 |

*Note*: Standard errors are reported in parentheses.