



A quasi-experimental study of New York City's sodium warning regulation and hypertension prevalence, 2005–2020

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ABSTRACT

Objective: To quantify temporal trends in age-adjusted hypertension prevalence in New York City before and after implementation of a menu labeling regulation requiring sodium warning icons at chain restaurants.

Methods: Using data from the New York City Community Health Survey, segmented regression models assessed: (1) the average annual percent change (AAPC) of age-adjusted hypertension prevalence during the pre-regulation period (2005–2015), (2) the annual percent change (APC) from 2015 to 2016 (regulation onset association), (3) the AAPC of age-adjusted hypertension prevalence during the regulation period (2016–2020), and (4) the percentage-point difference between the AAPCs of the pre-regulation and regulation periods.

Results: We found a statistically significant average annual percent increase in the age-adjusted hypertension prevalence among the Hispanic population during the pre-regulation period (2005–2015 AAPC: 1.3 %, 95 % CI: 0.3 % to 2.3 %). The regulation's onset was significantly associated with a 4.2 % (95 % CI: 0.4 % to 8.0 %) increase in the age-adjusted hypertension prevalence among females from 2015 to 2016. During the regulation era, we observed statistically significant average annual percent decreases in age-adjusted hypertension prevalence among Black (2016–2020 AAPC: –1.9 %; 95 % CI: –2.5 % to –1.3 %) and female (2016–2020 AAPC: –3.5 %; 95 % CI: –5.0 % to –2.1 %) subgroups.

Conclusions: Findings suggest a potential positive impact of the sodium warning regulation on hypertension prevalence. The decreasing trends in hypertension prevalence among female and Black populations suggest that sodium reduction policies may have differential impacts across subgroups. These empirical insights underscore the importance of sustained sodium reduction policies.

1. Introduction

Excess sodium consumption is a significant public health concern, linked to increased risks of hypertension, obesity, heart disease, and stroke (Campbell et al., 2023). Beyond cardiovascular diseases, excess sodium consumption poses additional public health concerns as it is associated with increased risk of chronic kidney disease progression (Wang et al., 2022) and gastric cancer (Wu et al., 2021). Despite efforts to reduce sodium intake across the United States, average consumption

remains above recommended levels (Musicus et al., 2020). This persistent challenge highlights the need for effective policies and further research to address this issue.

In response to this health concern, on December 1, 2015, the New York City Department of Health and Mental Hygiene implemented a mandatory regulation requiring chain restaurants (establishments with 15 or more locations) to display a sodium warning icon directly next to menu items that contain 2300 mg or more of sodium per item or meal (including combination meals) (New York City Department of Health

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and Mental Hygiene, 2023). The regulation also required establishments to post a warning statement at the point where customers place orders, explaining that high-sodium items exceed the recommended daily limit and pose health risks (Anekwe et al., 2019; New York City Department of Health and Mental Hygiene, 2023; Prasad et al., 2020). This policy represents one of several recent municipal efforts to improve cardiometabolic health outcomes through dietary interventions (Adams, 2022; NYC Health Code Art. 81 §81.08, 2006).

The relevance of restaurant-focused sodium policies is underscored by changing dietary patterns, with the population in the United States population increasingly consuming food prepared outside the home (Nagao-Sato and Reicks, 2022). Chain restaurants, which the New York City regulation specifically targets, serve millions of meals daily and often provide menu items with sodium content far exceeding recommended daily limits (Sisti et al., 2023). While such policies show promise, there remain gaps in understanding their impact on population health outcomes, particularly age-adjusted hypertension prevalence.

Despite the growing body of evidence linking sodium consumption with elevated blood pressure over the past 50 years (Wang et al., 2022), the effectiveness of sodium reduction policies in reducing hypertension rates at the population level is not well established (Musicus et al., 2020). Recent evidence from a cluster-randomized trial in rural China demonstrated that sodium reduction interventions can significantly reduce the risk of stroke, major cardiovascular events, and mortality (Neal et al., 2021). Relatedly, an assessment of Chile’s Law of Food Labeling and Advertising, which includes mandatory warning labels for high-sodium products, showed a meaningful reduction in purchases of beverages high in sodium, sugar, calories, or saturated fat (Taillie et al., 2020). Nevertheless, hospitalizations for acute hypertension continue to rise, particularly among U.S. Medicare beneficiaries who identify as Black (Lu et al., 2021), underscoring the urgent need for effective population-level interventions.

While previous studies have evaluated the impact of menu labeling policies on consumer behavior and food industry reformulation (Bleich et al., 2017), few have examined the population-level health impacts of sodium warning policies (Alexander et al., 2021; Zhang et al., 2017). Studies of calorie labeling have shown mixed results on consumer purchasing behavior (Cantu-Jungles et al., 2017; Shangguan et al., 2019), and limited research has assessed whether sodium-specific warning labels translate to measurable health outcomes at the population level. Our study contributes to this knowledge gap by examining the relationship between New York City’s sodium warning regulation and age-adjusted hypertension prevalence among New York City adults. Using New York City Community Health Survey data from 2005 to 2020, we investigated whether there was a statistically significant decrease in age-adjusted hypertension prevalence after implementing the sodium warning regulation. Additionally, we analyzed whether the average annual percent change in age-adjusted hypertension prevalence differed between the years preceding and following the regulation’s implementation.

Importantly, our research is grounded in socioenvironmental theory and the concept of social determinants of health (N. Krieger, 2013). These frameworks recognize that health outcomes are shaped by the conditions in which people live, work, and play, which are, in turn, influenced by the distribution of resources and opportunities (N. Krieger, 2013). Social determinants of health often lead to disparate health outcomes across racial and ethnic groups, with minoritized communities frequently experiencing higher risks due to economic and social disparities (N. Krieger, 2013). Given these considerations, we hypothesized that the sodium warning regulation would be significantly associated with a reduction in age-adjusted hypertension prevalence among White individuals, who may experience greater benefits from such regulations due to differing access to resources and health promotion (N. Krieger, 2013). In contrast, we hypothesized that the regulation might not show significant associations with reductions among Black or Hispanic adults in New York City, who are more likely to be

impacted by broader social determinants of health that influence age-adjusted hypertension prevalence (Angell et al., 2014).

2. Materials and methods

2.1. Study design and setting

We analyzed data from the New York City Community Health Survey, which comprised 125 questions about various health-related topics (e.g., mental well-being, access to healthcare services, cardiovascular health) (New York City Department of Health and Mental Hygiene, 2024b). The New York City Community Health Survey is a cross-sectional survey conducted annually by the Bureau of Epidemiology Services at the New York City Department of Health and Mental Hygiene (New York City Department of Health and Mental Hygiene, 2024b). The New York City Community Health Survey includes around ~7000 to ~10,000 randomly chosen adults aged 18 and above—depending on the year—from Manhattan, Brooklyn, Queens, Bronx, and Staten Island. The sampling frame comprised telephone numbers sourced from a commercial vendor and was used in participant selection, with one adult randomly chosen from each household for interview participation. Since 2002, the New York City Community Health Survey has sampled adults reachable by landline phones. Starting in 2009, adults who were accessible by cellphone were also included. The survey was developed in English but translated into Spanish, Russian, Chinese, Bengali, and Haitian Creole. The Bureau of Epidemiology Services prepared the data for this analysis in March 2024. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines. This study used de-identified and publicly accessible data on the New York City Community Health Survey website (New York City Department of Health and Mental Hygiene, 2024b); therefore, the New York University Institutional Review Board considered this secondary data analysis exempt.

2.2. Analytic sample

Table 1 presents the unweighted analytic sample derivation by year. Participants with missing hypertension data ($n = 483$ total across all years, 0.3 % of total unweighted sample) were excluded from analysis, resulting in a final unweighted analytic sample of 147,475 adults across the 16-year study period.

Table 1
Unweighted analytic sample derivation by year, New York City Community Health Survey, 2005–2020.

Year	Hypertension (unweighted count)			Unweighted analytic sample
	Yes	No	Missing	
2005	3213	6673	30	9886
2006	3072	6572	39	9644
2007	3167	6329	24	9496
2008	2657	4867	30	7524
2009	3547	6366	21	9913
2010	3044	5594	27	8638
2011	3171	5586	35	8757
2012	3058	5712	27	8770
2013	2841	5831	26	8672
2014	2806	5726	30	8532
2015	3485	6644	43	10,129
2016	3519	6445	36	9964
2017	3483	6488	34	9971
2018	3552	6493	31	10,045
2019	2857	5920	26	8777
2020	2596	6161	24	8757
Total	50,068	97,407	483	147,475

2.3. Outcome variable

Hypertension prevalence was assessed using one item: “Have you ever been told by a doctor, nurse, or other health professional that you have hypertension, also called high blood pressure?” We analyzed hypertension prevalence data from 2005 to 2020. Hypertension prevalence estimates were weighted to generalize to the New York City adult population and age-adjusted to the US population in 2000. The unit of analysis was at the population-level.

2.4. Covariates

Race/ethnicity was assessed using question asking participants “Which one or more of the following would you use to describe yourself?” Response options included: (1) White, (2) Black or Black American, (3) Asian, (4) Middle Eastern or North African, (5) Native Hawaiian or Other Pacific Islander, (6) American Indian, Native, First Nations, Indigenous Peoples of the Americas, or Alaska Native, (7) Something else (with specification), and (8) Hispanic/Latino. For analysis, participants were categorized into five groups: non-Hispanic White (including Middle Eastern or North African), non-Hispanic Black, Hispanic, non-Hispanic Asian/Pacific Islander (combining Asian, Native Hawaiian or Other Pacific Islander categories), and non-Hispanic Other (combining American Indian, Native, First Nations, Indigenous Peoples of the Americas, Alaska Native, and “Something else” responses). Participants who selected Hispanic/Latino were classified as Hispanic regardless of other race selections. Sex assigned at birth was assessed by asking “What was your sex assigned at birth? Male or female?”

2.5. Statistical analysis

We employed interrupted time series analysis using segmented regression to assess: the average annual percent change (AAPC) of age-adjusted hypertension prevalence during the pre-regulation period (2005–2015), the annual percent change (APC) from 2015 to 2016 (regulation onset association), the AAPC of age-adjusted hypertension prevalence during the regulation period (2016–2020), and the percentage-point difference between the AAPCs of the pre-regulation and regulation periods. This method was appropriate since we constructed a quasi-experimental design to estimate a policy’s association with population-level outcome changes in a non-randomized setting (Lopez Bernal et al., 2017). An additional advantage of this technique is its robustness against internal validity threats (Lopez Bernal et al., 2017). We fit single-group segmented regression models for the overall sample, by racial/ethnic groups (non-Hispanic White, non-Hispanic Black, Hispanic, non-Hispanic Asian/Pacific Islander, and non-Hispanic Other), and by sex (male and female). This analysis used population-level aggregated data (age-adjusted hypertension prevalence rates by year and demographic group) rather than individual-level data, so individual covariates were not included in the models. R version 4.3.0 was used to perform all statistical analyses (R Core Team, R Foundation for Statistical Computing).

3. Results

3.1. Trends of pre-regulation era (2005–2015)

Figs. 1 displays the observed temporal trends in age-adjusted hypertension prevalence among New York City adults for the overall population and by race/ethnicity from 2005 to 2020. Fig. 2 presents these trends by sex over the same period. We found a statistically significant average annual percent increase in the age-adjusted hypertension prevalence among the Hispanic population (AAPC: 1.3 %, 95 % CI: 0.3 % to 2.3 %) between 2005 and 2015 (Table 2). During the pre-regulation era, the AAPCs for the other subpopulations ranged from –0.9 % to 1.2 % and were not statistically significant (Table 2).

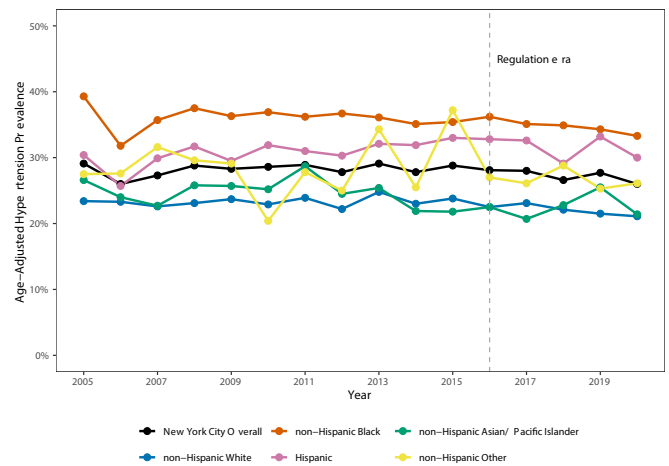


Fig. 1. Observed trends in age-adjusted hypertension prevalence in the overall study population and by race/ethnicity, New York City, 2005 to 2020.

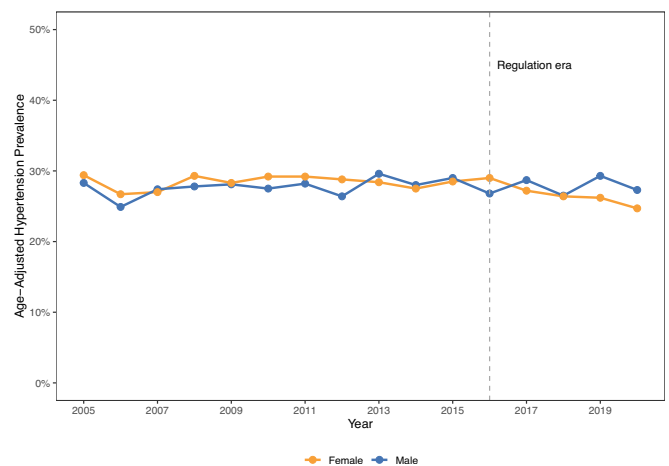


Fig. 2. Observed trends in age-adjusted hypertension prevalence by sex, New York City, 2005 to 2020.

3.2. Immediate association with the regulation onset (2015–2016)

The regulation’s onset was significantly associated with a 4.2 % (95 % CI: 0.4 % to 8.0 %) increase in the age-adjusted hypertension prevalence among females from 2015 to 2016 (Table 2). Over the same period, there was a 2.8 % (95 % CI: –0.9 % to 6.6 %) increase among the non-Hispanic Black subgroup and a 1.2 % (95 % CI: –3.8 % to 6.5 %) increase among the Hispanic subgroup, but these APCs were not statistically significant (Table 2). The three largest decreases from 2015 to 2016 were observed in individuals categorized as non-Hispanic Other (APC: –9.8 %; 95 % CI: –26.0 % to 9.9 %), non-Hispanic Asian/Pacific Islander (APC: –7.9 %; 95 % CI: –19.3 % to 5.1 %), and males (APC: –4.9 %; 95 % CI: –11.5 % to 2.1 %) but were not statistically significant. The APCs for the overall New York City population (2015–2016 APC = 0.0 %; 95 % CI: –3.2 % to 3.3 %) and the non-Hispanic White population (2015–2016 APC = –0.8 %; 95 % CI: –6.0 % to 4.7 %) were also not statistically significant.

3.3. Trends during the regulation era (2016–2020)

Notable in Table 2 are the statistically significant average annual percent decreases in the age-adjusted hypertension prevalence among the non-Hispanic Black (2016–2020 AAPC: –1.9 %; 95 % CI: –2.5 % to –1.3 %) and female (2016–2020 AAPC: –3.5 %; 95 % CI: –5.0 % to

Table 2

Age-adjusted hypertension prevalence among adults in New York City, New York City Community Health Survey, 2005 to 2020. Average annual percent changes and annual percent changes with 95 % CIs were generated from a segmented regression model. We applied the following transformation to convert coefficients into percent changes: $[exp(\beta) - 1] \times 100$.

	2005–2015		2015–2016		2016–2020		AAPC Percentage-point difference	95 % CI
	AAPC (%)	95 % CI	APC (%)	95 % CI	AAPC (%)	95 % CI		
Overall	0.3	(−0.4, 1.0)	0.0	(−3.2, 3.3)	−1.6	(−3.3, 0.1)	−2.0	(−3.1, −0.8)
Race/ethnicity								
non-Hispanic White	0.2	(−0.2, 0.7)	−0.8	(−6.0, 4.7)	−2.0	(−4.1, 0.2)	−2.2	(−3.2, −1.2)
non-Hispanic Black	−0.2	(−1.3, 1.0)	2.8	(−0.9, 6.6)	−1.9	(−2.5, −1.3)	−1.7	(−2.9, −0.5)
Hispanic	1.3	(0.3, 2.3)	1.2	(−3.8, 6.5)	−1.6	(−4.3, 1.2)	−2.9	(−4.7, −1.0)
non-Hispanic Asian/Pacific Islander	−0.9	(−2.2, 0.4)	−7.9	(−19.3, 5.1)	−1.2	(−7.1, 10.2)	2.0	(−2.2, 6.6)
non-Hispanic Other	1.2	(−1.5, 3.9)	−9.8	(−26.0, 9.9)	−1.0	(−2.6, 0.6)	−2.2	(−4.9, 0.7)
Sex								
Male	0.6	(−0.2, 1.5)	−4.9	(−11.5, 2.1)	0.6	(−3.2, 4.5)	−0.1	(−2.1, 2.0)
Female	0.1	(−0.6, 0.7)	4.2	(0.4, 8.0)	−3.5	(−5.0, −2.1)	−3.6	(−4.6, −2.7)

AAPC = Average Annual Percent Change; APC = Annual Percent Change.

−2.1 %) subgroups during the regulation era. Conversely, the overall New York City population observed a non-significant decrease (AAPC 2016–2020: −1.6 %; 95 % CI: −3.3 % to 0.1 %) in age-adjusted hypertension prevalence during the regulation era. Similarly, non-significant decreases were observed among the non-Hispanic White (AAPC: −2.0 %; 95 % CI: −4.1 % to 0.2 %), Hispanic (AAPC: −1.6 %; 95 % CI: −4.3 % to 1.2 %), non-Hispanic Asian/Pacific Islander (AAPC: −1.2 %; 95 % CI: −7.1 % to 10.2 %), and non-Hispanic Other (AAPC: −1.0 %; 95 % CI: −2.6 % to 0.6 %) racial/ethnic subgroups. Additionally, a non-significant annual change was observed among males (AAPC 2016–2020: 0.6 %; 95 % CI: −3.2 % to 4.5 %) during the regulation era.

4. Discussion

We analyzed data from the New York City Community Health Survey to investigate temporal trends in age-adjusted hypertension prevalence among New York City adults before and after the implementation of New York City’s sodium warning regulation. Our findings suggest a potential positive impact of the sodium warning regulation on hypertension prevalence, particularly among specific demographic groups. We observed statistically significant decreasing trends in age-adjusted hypertension prevalence among Black adults and females during the regulation period, suggesting meaningful population-level health improvements following policy implementation.

Our findings contribute to a growing body of international evidence on sodium warning policies and their population health impacts (Santos et al., 2021; Taillie et al., 2020). For instance, implementing Chile’s Law of Food Labeling and Advertising was associated with significant reductions in purchases of beverages high in sodium, sugar, calories, or saturated fat (Taillie et al., 2020). The Chile study also demonstrated that the policy’s association was moderated by household socioeconomic status, which aligns with our finding of differential associations of sodium warning regulation across different sociodemographic groups (Taillie et al., 2020). Our finding of improvements in hypertension prevalence among Black adults and females suggests that sodium warning policies may help address health inequities and disparities.

The observed trends can be understood through multiple pathways. The initial nonsignificant increases in hypertension prevalence immediately following the regulation’s implementation likely reflect the time needed for policy awareness to spread and for behavioral changes to manifest in measurable health outcomes (J. W. Krieger et al., 2013; Macdiarmid et al., 2011). The subsequent decreasing trends during the regulation period suggest both direct consumer behavioral changes and potential industry reformulation effects (Kerins et al., 2018; VanEpps et al., 2016). The declines during the sodium regulation era could be explained by sodium content reductions in restaurant meals, suggesting the health benefits result not just from sodium warning labels, but also from actual reformulation of menu items (Kerins et al., 2018; VanEpps

et al., 2016).

These findings should be interpreted within the context of existing health disparities in New York City (Angell et al., 2014). Hispanic and non-Hispanic Black adults in New York City consume 300 to 400 more daily milligrams of salt than their non-Hispanic White counterparts, which may contribute to higher baseline rates of hypertension in these populations (Angell et al., 2014). The statistically significant decreasing trend among Black adults during the regulation period is particularly noteworthy given these baseline disparities and suggests that sodium warning policies may help reduce health inequities over time. The sex differences we observed may reflect differential restaurant dining patterns, sodium awareness, and biological responses to sodium reduction (Azizi et al., 2023; Cifková and Strilchuk, 2022). Research suggests that females are more likely to notice and respond to nutrition labeling (Campos et al., 2011; Christoph et al., 2016; Stran and Knol, 2013), which could explain the more pronounced associations we observed in this population.

Our findings complement evidence from other NY restaurant regulations that have demonstrated measurable population health benefits (Restrepo and Rieger, 2016). Research on NY’s trans fat ban showed reductions in cardiovascular disease hospitalizations and mortality (Restrepo and Rieger, 2016). While our study focused on hypertension prevalence trends, the pattern of initial implementation followed by longer-term health improvements mirrors the trans fat policy experience and suggests that sodium warning regulations may similarly reduce hypertension-related hospitalizations and mortality.

Despite these important findings, several limitations warrant consideration. The current investigation used population-level age-adjusted hypertension prevalence rates and did not account for other important risk factors such as changes in body mass index distribution over the study period, which may influence hypertension trends independent of the sodium warning regulation. We were unable to conduct trend analyses specifically among individuals who regularly dine at chain restaurants, which is important because New York City’s sodium warning regulation applied specifically to these establishments. Many racially minoritized populations in New York City are concentrated in areas serviced by both chain and non-chain restaurants, potentially diluting the observable policy effects (New York City Department of Health and Mental Hygiene, 2024a). Additionally, our analysis relied on self-reported hypertension data, which may be subject to recall and social desirability biases.

The analysis period beginning in 2005 provided insufficient data points to formally evaluate the impact of earlier New York City dietary policies, such as the 2008 trans fat ban (Restrepo and Rieger, 2016), using interrupted time series methods. Future research with more extended time series data could employ multiple interrupted time series analyses to examine the effects of sequential municipal dietary interventions and their potential cumulative effects on population health

outcomes, including hospitalization rates for hypertension-related conditions (e.g., hypertensive crises, heart failure exacerbations, and cardiovascular events attributable to uncontrolled blood pressure). This single-city analysis also lacks a comparative control population. Future investigations should employ difference-in-differences approaches using comparable hypertension data from similar large metropolitan areas to strengthen the ability to isolate policy-specific effects from broader temporal trends. Additionally, research examining the mechanisms through which sodium warning policies influence health outcomes—including changes in consumer behavior, industry reformulation, and healthcare utilization—would provide valuable insights for optimizing policy design and implementation.

Our analysis encompassed data through 2020 for several methodologically sound reasons. The regulation was implemented in December 2015, providing five full years of post-implementation data (2016–2020) to detect population-level health changes. The 2020 endpoint represented the most recent year available for the New York City Community Health Survey. Moreover, using this endpoint avoids potential confounding effects from the COVID-19 pandemic, which altered dining behaviors, restaurant operations, and health survey methodologies in ways that could obscure the regulation's impact. The 16-year analysis period (2005–2020) establishes crucial baseline evidence of the regulation's effectiveness under normal operating conditions. This foundational understanding is essential for informing future policy decisions and provides a critical reference point for subsequent research examining post-pandemic trends.

5. Conclusion

In summary, our findings provide important evidence that restaurant-focused sodium warning policies may contribute to population-level improvements in hypertension prevalence. The statistically significant decreasing trends among Black adults and females during the regulation period suggest meaningful health benefits, particularly among populations that have historically faced health disparities (N. Krieger, 2013). These results support the continued implementation and expansion of sodium reduction policies while emphasizing the need for sustained monitoring to ensure equitable benefits across all population groups. As cities and nations worldwide consider strategies to address the persistent challenge of excess sodium consumption, New York City's experience provides valuable evidence that targeted regulatory approaches may contribute to measurable improvements in cardiovascular health outcomes at the population level.

CRedit authorship contribution statement

Nathaniel J. Maxey: Writing – original draft, Methodology, Investigation, Conceptualization. **José A. Pagán:** Writing – review & editing, Investigation, Conceptualization. **Brennan Rhodes-Bratton:** Writing – review & editing, Investigation, Conceptualization. **Anjali Phalke:** Writing – review & editing, Investigation, Conceptualization. **Marina Mautner Wizentier:** Writing – review & editing, Investigation, Conceptualization. **Kimberly A. Kaphingst:** Writing – review & editing, Investigation, Conceptualization. **Melody S. Goodman:** Writing – review & editing, Investigation, Conceptualization. **Jemar R. Bather:** Writing – review & editing, Software, Methodology, Formal analysis, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial

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Data availability

Data will be made available on request.

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