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INCLUSIVITY IN PEOPLE, METHODS, AND OUTCOMES

RESEARCH ARTICLE

The Role of Individual-Level Factors in Rural Mortality Disparities

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Introduction: The role of individual risk factors in the rural–urban mortality disparity is poorly understood. The purpose of this study was to explore the role of individual-level demographics and health behaviors on the association between rural residence and the risk of mortality.

Methods: Cancer Prevention Study-II participants provided updated addresses throughout the study period. Rural–Urban Commuting Area codes were assigned to participants' geocoded addresses as a time-varying exposure. Cox proportional hazards regression was used to estimate hazard ratios and 95% CIs for mortality associated with Rural–Urban Commuting Area groups.

Results: After adjustment for age and sex, residents of rural areas/small towns had a small but statistically significant elevated risk of all-cause mortality compared with metropolitan residents (hazard ratio=1.04; 95% CI=1.01, 1.06). Adjustment for additional covariates attenuated the association entirely (hazard ratio=0.99; 95% CI=0.97, 1.01). Individually, adjustment for education (hazard ratio=0.99; 95% CI=0.97, 1.01), alcohol use (hazard ratio=1.01; 95% CI=0.99, 1.04), and moderate-to-vigorous intensity aerobic physical activity (hazard ratio=1.00; 95% CI=0.97, 1.02) eliminated the elevated risk.

Conclusions: The elevated risk of death for rural compared with that for metropolitan residents appeared to be largely explained by individual-level demographics and health behaviors. If replicated in other subpopulations, these results suggest that modifiable factors may play an important role in reducing the rural mortality disparity.

INTRODUCTION

Over the last 4 decades, age-specific mortality has been steadily improving for many demographic subgroups in the U.S.[1,2] Conversely, the gap in early mortality rates among those living in rural versus urban areas has grown since 1990.[3] Studies using surveillance data show that rural residents experience approximately 135−170 excess deaths per 100,000 residents compared with urban residents.[4−7] Given that approximately 19% of U.

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S. adults live in rural areas, understanding this disparity is imperative.[8]

Reasons for the rural mortality disparity in the U.S. are poorly understood but are likely multifaceted. Socioeconomic status may partially explain the disparity because residents of rural areas generally have lower educational attainment than urban residents.[9] In addition, race/ethnicity may compound the rural disparity in mortality because Black residents of rural areas have poorer mortality outcomes than White rural residents.[10,11] It is also possible that rural–urban differences in modifiable health behaviors, such as smoking, physical activity, and alcohol consumption, may contribute to the disparity. Adults living in rural areas have a higher prevalence of drinking[12] and tobacco use[13,14] and a lower prevalence of meeting physical activity guidelines than adults in metropolitan areas.[15]

Nevertheless, the potential role of modifiable risk factors is poorly understood, likely because many studies of rural health are surveillance studies, which lack individual-level data. To address this limitation, we used detailed individual-level data from a large cohort study to explore the role of individual-level demographics (race, educational attainment, marital status, living arrangement), health history (previous comorbidities), and health behaviors (smoking, physical activity, alcohol use, chewing tobacco use, and BMI) on the association between rural residence and mortality risk.

METHODS

Study Population

The Cancer Prevention Study-II Nutrition Cohort (CPS-IINC) is a longitudinal study of cancer incidence and mortality initiated by the American Cancer Society.[16] CPS-IINC was established in 1992 and included >184,000 participants from 21 U.S. states. Beginning in 1997, CPS-IINC participants were mailed biennial surveys to update their health history and health behavior information. Cancer Prevention Study-II is approved by the Emory University IRB.

Measures

To assess urban/rural residence, Rural–Urban Commuting Area (RUCA) codes and census tract–level codes that integrate measures of population density, urbanization, and daily commuting to identify urban cores and adjacent territories were used to define urban/rural residence. Participants provided a current address in 1997 and subsequently thereafter through mailed biennial surveys. The 10 primary RUCA codes were assigned to participants' geocoded addresses as a time-varying exposure (with 1990 RUCA codes assigned to 1997−1999 addresses, 2000 codes assigned to 2000−2009 addresses, and 2010 codes assigned to addresses after 2009 to account for area reclassification over time).[9,17] If an updated address was unable to be linked to a RUCA code, the previous RUCA code was carried forward. Most (83.4%) participants did not change RUCA codes during the study period. All primary RUCA codes were collapsed into the 3 RUCA groups for analyses: (1) metropolitan (Codes 1−3), (2) micropolitan (Codes 4−6), and (3) rural areas and small towns combined (Codes 7−10).[9]

For outcomes, the primary outcome was all-cause mortality (with cardiovascular, cancer, and respiratory mortality analyses included in the appendix only) ascertained through the biennial linkage of the cohort with the National Death Index.[18] Causes of death were classified with ICD-9 codes for deaths occurring from 1992 to 1998, and ICD-10 codes for additional deaths occurring through the end of follow-up (December 2016).

Statistical Analysis

Cox proportional hazards regression was used to estimate hazard ratios (HR) and 95% CIs for all-cause mortality associated with RUCA group in models: (1) adjusted for age and sex; (2) further adjusted for individual potential confounders selected a priori; and (3) adjusted for all potential confounders, including race/ethnicity, highest educational attainment, marital status, living arrangement, comorbidity score, aspirin use, occupational dirtiness index, pesticide exposure, average particulate matter exposure, moderate–vigorous intensity aerobic physical activity (MVPA), BMI, smoking duration and cigarettes/day for current smokers, years since quitting for former smokers, chewing tobacco, and alcohol use (covariates are described in Appendix Table 1, available online).

Modification by sex, education (a proxy for SES), race, and MVPA was explored, and a sensitivity analysis, excluding participants with a history of cancer (n=24,698), cardiovascular disease/stroke (n=23,488), or emphysema/chronic bronchitis (n=6,840) at baseline, was conducted.

All the 160,296 participants who returned the 1997 survey were eligible for inclusion. Participants were excluded if their address could not be geocoded for the entire follow-up period (i.e., match score <60 for all years, n=2,269; excluded versus included participants did not differ in race or education). The remaining 158,027 participants, among whom 76,887 died between 1997 and 2016, were included in analyses.

RESULTS

Participants were 53.8% women and 97.5% White with a mean age of 68 (SD=6.3) years (Table 1). More than 10% of participants (n=16,861) lived in a rural area/small town. Rural residents were more likely to report high school as their highest educational attainment, be overweight/obese, and be physically inactive than residents of metropolitan and micropolitan areas. Residents of metropolitan areas had a higher average particulate matter with a diameter <2.5 μm exposure and were more likely to be former smokers than residents of rural and micropolitan areas.

The risk of all-cause mortality was similar among metropolitan and micropolitan residents (Table 2). After adjustment for age and sex, residents of rural areas had a small but statistically significant elevated risk of all-cause mortality compared with metropolitan residents

Table 1. Participant Characteristics by Rural-Urban Commuting Area (RUCA) Group, 1997

Characteristics	Metropolitan (*n*=126,570)	Micropolitan (*n*=14,596)	Rural/small town (*n*=16,861)
Age at baseline (years), mean (SD)	68 (6.24)	68.1 (6.29)	68.1 (6.3)
Sex, *n* (%)			
Female	68,334 (54.0)	7,750 (53.1)	8,916 (52.9)
Male	58,236 (46.0)	6,846 (46.9)	7,945 (47.1)
Race, *n* (%)			
White	122,968 (97.2)	14,373 (98.5)	16,662 (98.8)
Black	1,806 (1.4)	123 (0.8)	105 (0.6)
Other	1,796 (1.4)	100 (0.7)	94 (0.6)
Education, *n* (%)			
<HS	6,578 (5.2)	1,320 (9.0)	1,956 (11.6)
HS grad	29,923 (23.6)	4,522 (31.0)	6,096 (36.2)
Some college	36,886 (29.1)	4,104 (28.1)	4,441 (26.3)
College grad	27,203 (21.5)	2,415 (16.5)	2,346 (13.9)
Grad school	25,117 (19.8)	2,153 (14.8)	1,915 (11.4)
Unknown	863 (0.7)	82 (0.6)	107 (0.6)
Marital status, *n* (%)			
Single	1,862 (1.5)	158 (1.1)	152 (0.9)
Married	93,811 (74.1)	10,747 (73.6)	12,495 (74.1)
Other	30,897 (24.4)	3,691 (25.3)	4,214 (25)
Alcohol use, *n* (%)			
None	49,382 (39)	6,679 (45.8)	8,123 (48.2)
<1/day	45,396 (35.9)	4,426 (30.3)	4,903 (29.1)
1/day	12,009 (9.5)	1,068 (7.3)	1,167 (6.9)
≥2/day	4,892 (3.9)	472 (3.2)	519 (3.1)
Missing	14,891 (11.8)	1,951 (13.4)	2,149 (12.7)
Living arrangement, *n* (%)			
Alone	13,855 (10.9)	1,564 (10.7)	1,788 (10.6)
With spouse/family	83,412 (65.9)	9,409 (64.5)	10,829 (64.2)
Assisted living	243 (0.2)	29 (0.2)	39 (0.2)
Other/missing	29,060 (23)	3,594 (24.6)	4,205 (24.9)
Body mass index (kg/m^2), *n* (%)			
18.5 to <25	50,314 (39.8)	5,124 (35.1)	5,662 (33.6)
25 to <30	45,621 (36.0)	5,583 (38.3)	6,498 (38.5)
≥30	18,396 (14.5)	2,462 (16.9)	2,922 (17.3)
Missing	12,239 (9.7)	1,427 (9.8)	1,779 (10.6)
Comorbidity score, *n* (%)			
None	42,438 (33.5)	4,906 (33.6)	5,730 (34.0)
1	40,424 (31.9)	4,638 (31.8)	5,241 (31.1)
≥2	43,708 (34.5)	5,052 (34.6)	5,890 (34.9)
Aspirin use, *n* (%)			
No regular use	74,176 (58.6)	8,159 (55.9)	9,334 (55.4)
0 to <15 pills/month	12,046 (9.5)	1,347 (9.2)	1,567 (9.3)
15 to <30 pills/month	5,681 (4.5)	607 (4.2)	678 (4)
≥30 pills/month	14,509 (11.5)	1,741 (11.9)	2,121 (12.6)
Missing	20,158 (15.9)	2,742 (18.8)	3,161 (18.7)
$PM_{2.5}$ (quartiles), *n* (%)			
Q1	30,127 (23.8)	5,437 (37.2)	8,373 (49.7)
Q2	32,647 (25.8)	3,976 (27.2)	4,082 (24.2)
Q3	31,672 (25.0)	3,216 (22.0)	2,636 (15.6)
Q4	30,748 (24.3)	1,869 (12.8)	1,674 (9.9)
Missing	1,376 (1.1)	98 (0.7)	96 (0.6)

(*continued on next page*)

Table 1. Participant Characteristics by Rural-Urban Commuting Area (RUCA) Group, 1997 (*continued*)

Characteristics	Metropolitan (*n*=126,570)	Micropolitan (*n*=14,596)	Rural/small town (*n*=16,861)
MVPA (MET hours/week), *n* (%)			
None	10,423 (8.2)	1,538 (10.5)	1,977 (11.7)
>0 to <7.5	42,039 (33.2)	5,261 (36.0)	6,009 (35.6)
7.5 to <15	31,406 (24.8)	3,465 (23.7)	4,142 (24.6)
15 to <22.5	18,402 (14.5)	1,892 (13.0)	1,994 (11.8)
≥22.5	15,823 (12.5)	1,312 (9.0)	1,295 (7.7)
Missing	8,477 (6.7)	1,128 (7.7)	1,444 (8.6)
Years since quitting smoking, *n* (%)			
Never smoker	55,909 (44.2)	6,884 (47.2)	8,055 (47.8)
≥30	24,596 (19.4)	2,475 (17.0)	2,813 (16.7)
20 to <30	14,853 (11.7)	1,539 (10.5)	1,734 (10.3)
10 to <20	13,031 (10.3)	1,463 (10.0)	1,621 (9.6)
<10	9,769 (7.7)	1,188 (8.1)	1,317 (7.8)
Current smoker	7,046 (5.6)	882 (6.0)	1,079 (6.4)
Missing	1,366 (1.1)	165 (1.1)	242 (1.4)
Cigarettes/day, *n* (%)			
Never smoker	55,909 (44.2)	6,884 (47.2)	8,055 (47.8)
Former smoker	63,548 (50.2)	6,816 (46.7)	7,708 (45.7)
<20	3,871 (3.1)	461 (3.2)	579 (3.4)
20	1,449 (1.1)	195 (1.3)	252 (1.5)
>20	1,513 (1.2)	193 (1.3)	221 (1.3)
Missing	280 (0.2)	47 (0.3)	46 (0.3)
Years smoked, *n* (%)			
Never	55,909 (44.2)	6,884 (47.2)	8,055 (47.8)
Former	63,548 (50.2)	6,816 (46.7)	7,708 (45.7)
<40	1,768 (1.4)	223 (1.5)	292 (1.7)
40 to <50	3,085 (2.4)	377 (2.6)	451 (2.7)
≥50	2,124 (1.7)	273 (1.9)	320 (1.9)
Missing	136 (0.1)	23 (0.2)	35 (0.2)

Grad, graduate; HS, high school; MVPA, moderate-to-vigorous intensity aerobic physical activity; $PM_{2.5}$ = particulate matter with diameter <2.5 μm; RUCA, Rural–Urban Commuting Area.

(HR=1.04; 95% CI=1.01, 1.06). Adjustment for additional covariates attenuated the association entirely (HR=0.99; 95% CI=0.97, 1.01). Individually, adjustment for education (HR=0.99; 95% CI=0.97, 1.01), alcohol use (HR=1.01; 95% CI=0.99, 1.04), and MVPA (HR=1.00; 95% CI=0.97, 1.02) independently eliminated the elevated risk for all-cause mortality for rural residents (Table 2) (relationships with specific causes of death are shown in Appendix Table 2, available online).

Results were largely similar when stratified by sex, race, MVPA, and baseline comorbidity status (Tables 3 and 4). Among participants with higher education, rural residence was associated with an elevated risk of mortality; among those with less formal education, rural residence was associated with a lower risk of mortality (p-interaction=0.007).

DISCUSSION

In this study, there was a small but statistically significant elevated risk of death in rural compared with that among metropolitan residents. However, this elevated risk was eliminated after accounting for education, MVPA, and alcohol use. These findings suggest that individual characteristics, including modifiable behaviors, may at least partially explain the rural–urban mortality disparity.

The 4% rural–urban mortality disparity seen in the age-/sex-adjusted model in this study was smaller than the disparity reported in other studies.[4–6] This may be because the nature and magnitude of the rural mortality disparity vary across the U.S. In fact, certain rural areas have recently seen a decline in mortality rates, whereas

Table 2. Association Between Rural–Urban Commuting Area Group and All-Cause Mortality

Model covariates	Metropolitan (*n* = 126,570)	Micropolitan (*n* = 14,596)	Rural/small town (*n* = 16,861)
N deaths	60,517	7,514	8,856
Sex and age adjusted	1.00 (ref)	1.02 (0.99−1.04)	**1.04 (1.01−1.06)**
Demographics			
+ Education	1.00 (ref)	0.99 (0.96−1.01)	*0.99 (0.97−1.01)*
+ Race	1.00 (ref)	1.02 (0.99−1.04)	1.04 (1.01−1.06)
+ Marital status	1.00 (ref)	1.02 (0.99−1.04)	1.04 (1.01−1.06)
+ Living arrangement	1.00 (ref)	1.01 (0.99−1.04)	1.03 (1.01−1.06)
Modifiable behaviors			
+ BMI	1.00 (ref)	1.01 (0.99−1.03)	1.03 (1.00−1.05)
+ Alcohol use	1.00 (ref)	1.00 (0.98−1.02)	*1.01 (0.99−1.04)*
+ Cigarettes per day	1.00 (ref)	1.02 (1.00−1.05)	1.04 (1.02−1.07)
+ Smoking duration	1.00 (ref)	1.02 (1.00−1.05)	1.04 (1.02−1.07)
+ Time since quitting smoking	1.00 (ref)	1.02 (0.99−1.04)	1.04 (1.02−1.06)
+ Chewing tobacco	1.00 (ref)	1.01 (0.99−1.04)	1.03 (1.01−1.06)
+ Physical activity	1.00 (ref)	0.99 (0.97−1.02)	*1.00 (0.97−1.02)*
Health history			
+ Comorbidity score	1.00 (ref)	1.02 (1.00−1.05)	1.04 (1.02−1.06)
+ Aspirin use	1.00 (ref)	1.01 (0.99−1.04)	1.03 (1.00−1.05)
Environment			
+ $PM_{2.5}$	1.00 (ref)	1.02 (1.00−1.05)	1.04 (1.02−1.07)
+ Occupational dirtiness	1.00 (ref)	1.01 (0.99−1.04)	1.02 (1.00−1.05)
+ Pesticide exposure	1.00 (ref)	1.01 (0.99−1.04)	1.03 (1.01−1.05)
Multivariable adjusted[a]	1.00 (ref)	0.98 (0.96−1.01)	0.99 (0.97−1.01)

Note: Hazard ratios in *italics* indicate individual covariates that attenuated the elevated age- and sex-adjusted mortality risk for rural/small town residents to null.
[a]All-cause multivariable-adjusted model included age, sex, education, race, marital status, living arrangement, BMI, alcohol use, smoking (cigarettes/day, years since quit, duration), chewing tobacco, physical activity, comorbidity score, aspirin use, $PM_{2.5}$ exposure, occupational dirtiness index, and pesticide exposure.
$PM_{2.5}$, particulate matter with diameter <2.5 microns.

others have experienced an increase.[11] For example, relative to high SES and White rural residents, Black and/or lower SES rural residents have higher mortality rates.[10,11] CPS-IINC had a small percentage of both non-White racial/ethnic groups and low SES participants (although education was used as a proxy), so this study must be replicated in other subpopulations.

Previous studies suggest that population-level poverty[6] and lack of a college education[4] partially explain the mortality disparity between urban and rural residents, but studies exploring the potential role of individual-level modifiable behaviors are lacking. The attenuation of the rural mortality risk by MVPA and alcohol in this study suggests that these modifiable behaviors may be contributing to the larger problem. This finding justifies exploring opportunities for behavioral interventions in rural areas. The attenuation of risk with adjustment for education was confirmed in this study. Interestingly, among the highly educated, rural residence was associated with higher mortality; conversely, among those with less formal education, rural residence appeared to be protective. This could be because higher costs of living in urban (than in rural) areas exacerbate the mortality risk associated with lower levels of formal education (and perhaps a lower income). Research incorporating both individual-level and population-level data would likely provide further insight into this disparity.

Limitations

A strength of this study is the availability of individual-level data, although lack of income and residential history information before adulthood is a limitation. This study also consists exclusively of an older population and has a small number of non-White racial/ethnic groups and smokers, which may limit generalizability to other rural populations. The study population was also restricted to 21 states at baseline, which could be a limitation; however, as participants moved throughout follow-up, this study ended up including participants living

Table 3. Association Between Rural–Urban Commuting Area Group and All-Cause Mortality by Sex, Educational Attainment, Race, and Physical Activity

	Metropolitan	**Micropolitan**	**Rural/small town**	**Metropolitan**	**Micropolitan**	**Rural/small town**				
	Men				**Women**					***p*-interaction**
N deaths	33,813	4,289	5,039	26,704	3,225	3,817				
Age-adjusted HR	1.00 (ref)	**1.03 (1.00−1.06)**	**1.04 (1.01−1.08)**	1.00 (ref)	1.00 (0.96−1.04)	1.03 (0.99−1.06)				0.48
Multivariable adjusted[a]	1.00 (ref)	*0.98 (0.94−1.01)*	*0.97 (0.94−1.00)*	1.00 (ref)	0.99 (0.95−1.03)	1.01 (0.97−1.05)				0.31
	HS graduate or less			**Some college or more**						
N deaths	18,577	3,152	4,426	41,492	4,316	4,362				
Sex and age adjusted	1.00 (ref)	0.97 (0.93−1.00)	0.96 (0.93−0.99)	1.00 (ref)	1.01 (0.98−1.05)	**1.03 (1.00−1.06)**				**0.007**
Multivariable adjusted[a]	1.00 (ref)	0.97 (0.93−1.00)	0.97 (0.94−1.01)	1.00 (ref)	0.99 (0.96−1.03)	*1.00 (0.97−1.03)*				0.32
	Non-Hispanic/Latino White			**All other racial/ethnic groups**						
N deaths	58,900	7,390	8,752	1,436	104	77				
Sex and age adjusted	1.00 (ref)	1.01 (0.99−1.04)	**1.04 (1.01−1.06)**	1.00 (ref)	1.18 (0.96−1.45)	1.02 (0.79−1.30)				0.33
Multivariable adjusted[a]	1.00 (ref)	0.98 (0.96−1.01)	*0.99 (0.97−1.02)*	1.00 (ref)	1.14 (0.92−1.40)	0.87 (0.68−1.12)	**Metropolitan**	**Micropolitan**	**Rural/small town**	0.21
	Physically active (≥7.5 MET-hours/week)			**Physically active (>0 to <7.5)**			**Physically inactive (0)**			
N deaths	28,429	3,084	3,388	20,765	2,721	3,226	6,565	1,043	1,322	
Sex and age adjusted	1.00 (ref)	1.00 (0.97−1.04)	1.01 (0.98−1.05)	1.00 (ref)	0.99 (0.95−1.03)	1.00 (0.96−1.04)	1.00 (ref)	1.00 (0.94−1.07)	0.95 (0.90−1.01)	0.48
Multivariable adjusted[a]	1.00 (ref)	0.98 (0.94−1.02)	0.98 (0.94−1.01)	1.00 (ref)	0.98 (0.94−1.03)	1.00 (0.96−1.04)	1.00 (ref)	1.00 (0.94−1.08)	0.98 (0.92−1.04)	0.92

[a]Multivariable-adjusted models included age, sex, race, education, marital status, living arrangement, BMI, alcohol use, smoking (cigarettes/day, years since quit, duration), chewing tobacco, physical activity, comorbidity score, aspirin use, $PM_{2.5}$ exposure, occupational dirtiness index, and pesticide exposure. Hazard ratios in *italics* indicate that adjustment for individual-level covariates attenuated the elevated mortality risk to null.

$PM_{2.5}$, particulate matter with diameter <2.5 μm.

Table 4. Sensitivity Analysis of Association between Rural-Urban Commuting Area Group and Mortality Excluding those with Comorbidities at Baseline

	Metropolitan	Micropolitan	Rural/small town
All-cause mortality			
N deaths	35,779	4,368	5,175
Sex and age adjusted HR	1.00 (ref)	1.00 (0.97, 1.03)	**1.04 (1.01, 1.07)**
Multivariable adjusted HR[a]	1.00 (ref)	0.96 (0.93, 1.00)	*0.99 (0.96, 1.02)*

[a]Multivariable adjusted models included: age, sex, race, education, marital status, living arrangement, BMI, alcohol use, smoking (cig/day, years since quit, duration), chewing tobacco, physical activity, comorbidity score, aspirin use, $PM_{2.5}$ exposure, occupational dirtiness index, and pesticide exposure. Hazard ratios in *italics* indicate that adjustment for individual-level covariates attenuated the elevated mortality risk to null.
HR, hazard ratio; $PM_{2.5}$, particulate matter with diameter <2.5 μm.

in all the 50 states. The complexity of the impact of race alone and in combination with SES warrants further assessment of generalizability. Another strength of this study is the use of time-varying RUCA codes (updated as participants moved or as communities changed), which are finer in spatial resolution (census tract level) than several other common metrics.[19] These results are robust because a sensitivity analysis excluding those with a history of chronic disease at baseline produced similar point estimates.

CONCLUSIONS

In this study, the elevated risk of death for rural compared with that for metropolitan residents appeared to be largely explained by individual-level demographics and health behaviors. These results suggest that modifiable factors, such as MVPA and alcohol consumption, may play an important role in reducing the rural mortality disparity. Although replication in other subpopulations is necessary, these results underscore the need for regulatory efforts to provide safe opportunities for physical activity and guidance on alcohol consumption to reduce health disparities in rural populations.

CREDIT AUTHOR STATEMENT

Erika Rees-Punia: Conceptualization; Methodology; Writing — original draft. Emily Deubler: Formal analysis, Writing - review and editing. Alpa V. Patel: Writing — review and editing. W. Ryan Diver: Methodology; Writing — review and editing. James Hodge: Writing - review and editing. Farhad Islami: Writing - review and editing. Minjee Lee: Writing - review and editing. Marjorie L. McCullough: Writing - review and editing. Lauren R. Teras: Methodology; Writing - review and editing.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.focus.2022.100013.

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