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From convergence to divergence: Lifespan variation in US states, 1959–2017

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ABSTRACT

Background: Large disparities in life expectancy exist across US states and the gaps have been widening in recent decades. Less is known about the lifespan variability – a measure that can provide important insights into mortality inequalities both between and within states.
Method: Using yearly lifetables from the United States Mortality Database, we explore geographic and temporal patterns in lifespan variation (unconditional and conditional on survival to age 10, 35 and 65) across US states between 1959 and 2017. We also examine the contribution of state differences in life expectancy to overall lifespan variation using standard decomposition techniques.
Results: Despite overall convergence in lifespan variation across states over the last six decades, in more recent years there has been notable divergence. Gender-specific analyses show that lifespan variation was generally greater among males than among females; but this pattern reverses for mortality past age 65. Much of the state disparities in lifespan variation, unconditional and conditional on survival to age 10 and 35, were due to mortality differences under the age 65. Decomposition analysis shows that while within-state variability remains the primary driver of overall lifespan variation, the contribution of cross-state differences in life expectancy is growing.
Conclusions: Variation in longevity is greater within US States than between them, yet cross-states disparities in mortality are increasing. This likely reflects the long-term consequences of rising social, economic, and political stratification for health inequalities both within and across states.

1. Introduction

The considerable disparities in population health across US states are the subject of a growing body of research (Farina et al., 2021; Fenelon, 2013; Montez et al., 2016, 2017; Montez & Farina, 2021; Subramanian et al., 2001). Much of this research examines differences in life expectancy across populations, yet this measure of *average* lifespan leaves hidden substantial *variation* in the length of life both between and within state contexts. Lifespan variability reflects inter-individual differences in life chances, and considering differences in lifespan variability across socio-demographic and geographically defined populations provides important insights into spatially-patterned social and economic stratification with serious implications for health and longevity (Chetty et al., 2016; Firebaugh et al., 2014). Lifespan variability is thus an important indicator of inequality that can underscore the long-term consequences of policy differences and inform more targeted interventions (Edwards, 2013; van Raalte et al., 2018). In this study, we examine patterns in lifespan variation in US states over the last six decades, considering the differential impacts of places on the distribution of longevity for men and women, across the life course, and over time.

Historically, life expectancy and lifespan variation have had a strong negative linear relationship at the population level (Aburto et al., 2020; Németh, 2017). However, difference in lifespan variation captures a unique dimension of mortality inequalities. At the population level, lifespan variation measures dispersion in the age distribution of death, a function of differential mortality risks within the population. A greater lifespan variation implies greater heterogeneity in underlying population health. At the individual level, it means that members in the population with a greater lifespan variation are subject to greater uncertainty in achieving the average lifespan (i.e., life expectancy) of

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the population. Empirical studies have demonstrated the value of monitoring lifespan variation in addition to life expectancy. First, global studies show that countries with similar life expectancies can have substantially different lifespan variations (Smits & Monden, 2009), reflecting the fact that the same average can emerge from narrow or wide-spread age distribution of deaths (Aburto et al., 2020). Second, life expectancy and lifespan variation respond differently to changes in age distribution of deaths. Life expectancy increases with reduction in mortality at all ages; however, in the context of improving mortality, lifespan variation decreases only when more deaths are averted below a population-specific age threshold (van Raalte & Caswell, 2013; Zhang & Vaupel, 2009). Third, the changing patterns of life expectancy and lifespan variation may differ across population groups. van Raalte et al. (2018) showed that life expectancy improved unambiguously among Finnish females of all income, education, and occupation classes between 1971 and 2017. However, lifespan variation among these social groups had diverged: more advantaged groups enjoyed a reduction in lifespan variation over time while lifespan variation in disadvantaged groups increased. Divergent trends in lifespan variation have also been observed across different age groups (Engelman et al., 2010; Myers & Manton, 1984). While lifespan variability conditional on survival to younger ages decreased among Swedish females between 1990 and 2010, lifespan variation among survivors to older ages increased (Engelman et al., 2014). These findings suggest that examining lifespan variations may reveal systematic inequalities in health and mortality that are usually masked by focusing on life expectancy measures alone.

Past research on geographic disparities in lifespan variation has mainly focused on cross-country comparisons (Aburto & van Raalte, 2018; Edwards & Tuljapurkar, 2005; Gillespie et al., 2014; Neumayer & Plumper, 2016; Peltzman, 2009; Permanyer & Scholl, 2019; Smits & Monden, 2009; Tuljapurkar, 2010). Decomposition results from these studies show that approximately 10–30% of the inter-individual lifespan variation is contributed by cross-country differences (Clark & Snawder, 2020; Edwards, 2011; Pradhan et al., 2003; Smits & Monden, 2009). Factors including maternal mortality, fertility, economic development, HIV prevalence, and access to improved water sources (Clark & Snawder, 2020), income inequality (Shkolnikov et al., 2011), and income redistribution (difference in income inequality before and after taxes and transfers) (Neumayer & Plumper, 2016) have been associated with disparities in lifespan variation across countries.

The geographies of lifespan variation within the US have received little scholarly attention. At the national level, the US has made substantial progress in reducing lifespan variations over the study period: unconditional lifespan variation among the total population decreased from 385.40 (19.6 years) in 1959 to 284.90 (16.88 years) in 2017. Yet, most of the improvement was achieved during the first four decades and unconditional lifespan variations showed an uptick in more recent years (for national trends in lifespan variation conditional on survival to different ages and among male and female sub-populations, see appendix Fig. A1. Calculations were based on the United States Mortality Database). Geographic disparities in mortality and their determinants suggest that some places may have experienced bigger upticks more than others. Indeed, past research has documented substantial geographic disparities in adult (Christopoulos & Eleftheriou, 2020; Cullen et al., 2012; Krieger et al., 2008; Shiels et al., 2017; Woolf & Schoomaker, 2019) and infant (Krieger et al., 2008; Rossen et al., 2016) mortality within the US. When different ages groups are compared, spatial disparities in mortality is greatest in early to mid-adulthood (Vierboom et al., 2019). There has also been geographic divergence in mortality over time: coastal states experienced mortality improvements comparable to other high-income countries while states in the South, and more recently the Mountain and Great Plain regions, have been lagging behind (Elo et al., 2019; Fenelon, 2013; Fenelon & Witko, 2021; Vierboom et al., 2019). Given lifespan variation responds differently to changes in mortality at different ages, geographic and temporal patterns of lifespan variation may not perfectly map onto those of other mortality measures such as life expectancy (Aburto & van Raalte, 2018). However, no study has comprehensively explored the extent to which lifespan variation differs across US states, both in the general population and its subgroups, and how state lifespan variations have changed over time. Examining this often-overlooked dimension of lifespan measure across US states may reveal another layer of health and mortality inequality across peoples and places.

In this paper, we examine the long-term trends in US state level lifespan variation, either unconditional or conditional on survival to different ages, in the total population and stratified by gender. Specifically, we address the following questions:

1) To what extent does lifespan variation differ among US states?
2) How has state lifespan variation changed over the last six decades? Are US states becoming more or less similar in lifespan variability over time?
3) How much of total lifespan variation is attributable to differences in average lifespan between-states? Has this contribution changed over time?

2. Data and methods

2.1. Data

We used the United States mortality database for all 50 states for our analyses (United States Mortality DataBase, 2019). This database provides complete lifetables with single-year age groups running up to 110+ years old for individual states for each year between 1959 and 2017. It also includes lifetables for male and female separately, allowing us to examine sex-specific trends in state lifespan variation as well as contributions of cross-state differences to overall lifespan variation. We excluded DC[1] from our analyses because the population's mortality profile may be much more sensitive to sudden changes in local conditions than other states due to its very small geographic area.

2.2. Methods

2.2.1. Measuring lifespan variation

We measure lifespan variation as the variance (V) in life table age at death. Several indices have been proposed to measure lifespan variation, including life disparity, Gini coefficient, Theil's index, variance, standard deviation, mean logarithmic deviation and interquartile range (van Raalte & Caswell, 2013). Due to their additively decomposable property, both Theil's index and variance can be decomposed into within-group and between-group components. They have previously been used to examine the contribution of cross-country difference to the global trends in lifespan inequalities (Permanyer & Scholl, 2019) as well as the extent to which educational inequalities contribute to overall lifespan variation in the US (van Raalte et al., 2012). We prefer variance of age at death as the measure of lifespan variation because it is a measure of absolute inequality (i.e., its value is insensitive to the additive changes to each individual's lifespan) and relatively easier to interpret. The square root of its value (i.e., standard deviation) can be easily calculated and expressed in years. The calculation of variance is formally expressed as Eq (1):

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[1] By comparing the distributions of age at death among all states and DC during our study period, we found that DC experienced a drastic increase in male mortality between age 10 and 40 during the 1980–1990 period. This resulted in a drastic decline in its life expectancy and increase in lifespan variation. Because our focus is on the long-term trends in state differences in lifespan variation, including DC in our analyses would obscure our findings as any place with sudden changes in age patterns of mortality would have an oversized influence on our decomposition results.

$$V(\alpha)=\frac{1}{l_\alpha}\sum_{x=\alpha}^{110+}\left[d_x(x-M_\alpha)^2\right] \tag{1}$$

where *a* is the youngest age taken from the life table. For unconditional lifespan variation, *a* is equal to 0. l_a is the radix of the population survived to age *a* (initial population size if *a*=0). M_α is the mean age at death after age α: for deaths at all ages, M_α is equal to life expectancy at birth, *e*(0); for deaths after age α, M_α is equal to $e(\alpha)+\alpha$. d_x and *x* are respectively the life table number of deaths and the average age at death in the age interval *x* to *x+1*.

2.2.2. *Decomposition of overall lifespan variation*

We adopt the standard decomposition method for examining the contribution of group differences to overall lifespan variation (Permanyer & Scholl, 2019; van Raalte et al., 2012). The total variation (V_T) can be broken down into the between-group variation (V_{BG}) and within-group variation (V_{WG}), formally expressed as Eq (2). In our analysis of lifespan variation, V_{BG} captures the differences in average lifespan *between* US states while V_{WG} captures the lifespan inequalities observed *within* states. The contribution of state differences in average lifespan to total lifespan variation can then be calculated as the share of V_{BG} within V_T.

$$V_T = V_{BG} + V_{WG} \tag{2}$$

The calculation of V_{BG} and V_{WG} are expressed in Eq (3) and (4), respectively, where *n* is the number of states, w_a^i is the share of individuals who survived to age α in state *i* among individuals who survived to age α in all states, ${M_\alpha}^i$ is the average age at death of individuals who survived to age α in state *i* (for conditional lifespan variations, e_α equals the remaining life expectancy at age α in the lifetables plus α). ${M_\alpha}^t$ is the average age at death of individuals in all states who survived to age α, which is the weighted average of ${M_\alpha}^i$. And lastly, V_a^i is the variance of age at death of individuals in state *i* who survived to age α. The calculation of V_{BG} rests on the assumption that the age of death of all individuals in state *i* equals the mean age at death in the corresponding state, thus eliminating within-state variability.

$$V_{BG}(\alpha)=\sum_{i=1}^{n}\left[w_a^i\left({M_\alpha}^i - {M_\alpha}^t\right)^2\right] \tag{3}$$

$$V_{WG}(\alpha)=\sum_{i=1}^{n}\left[w_a^i V_a^i\right] \tag{4}$$

To explore the extent to which state differences in life expectancy contribute to the overall lifespan variation may differ between subpopulations, we calculate the ratio of V_{BG} and V_T for the unconditional and conditional (on survival to age 10, 35, 65, respectively) lifespan variations for males, females, and both. We chose age cutoffs based on the following rationales: age 10 eliminates the impact of childhood mortality on measures of lifespan variation; 35 is the age after which the risk of mortality begins to rise exponentially through adulthood (Engelman et al., 2017); age 65 captures variability in mortality at older ages.

3. Results

3.1. *Current patterns in state lifespan variations*

We first present US state lifespan variations in 2017 in Fig. 1. For ease of interpretation, we also present the standard deviation of age at death expressed in years along with lifespan variation. We notice remarkable geographic disparities in V(0, 10, 35). States with the greatest V(0)s among the total population were West Virginia (337.2, 18.4 years), Alaska (336.3, 18.3 years), New Mexico (333.6, 18.3 years) while the lowest states were Minnesota (245.0, 15.7 years), Washington (245.2, 15.7 years), California (249.1, 15.8 years) (for states with the highest and lowest Vs between 1959 and 2017, see Fig. A2). States with the greatest lifespan variations appear to cluster in the South and Appalachia regions (Alaska also stands out in some cases). However,

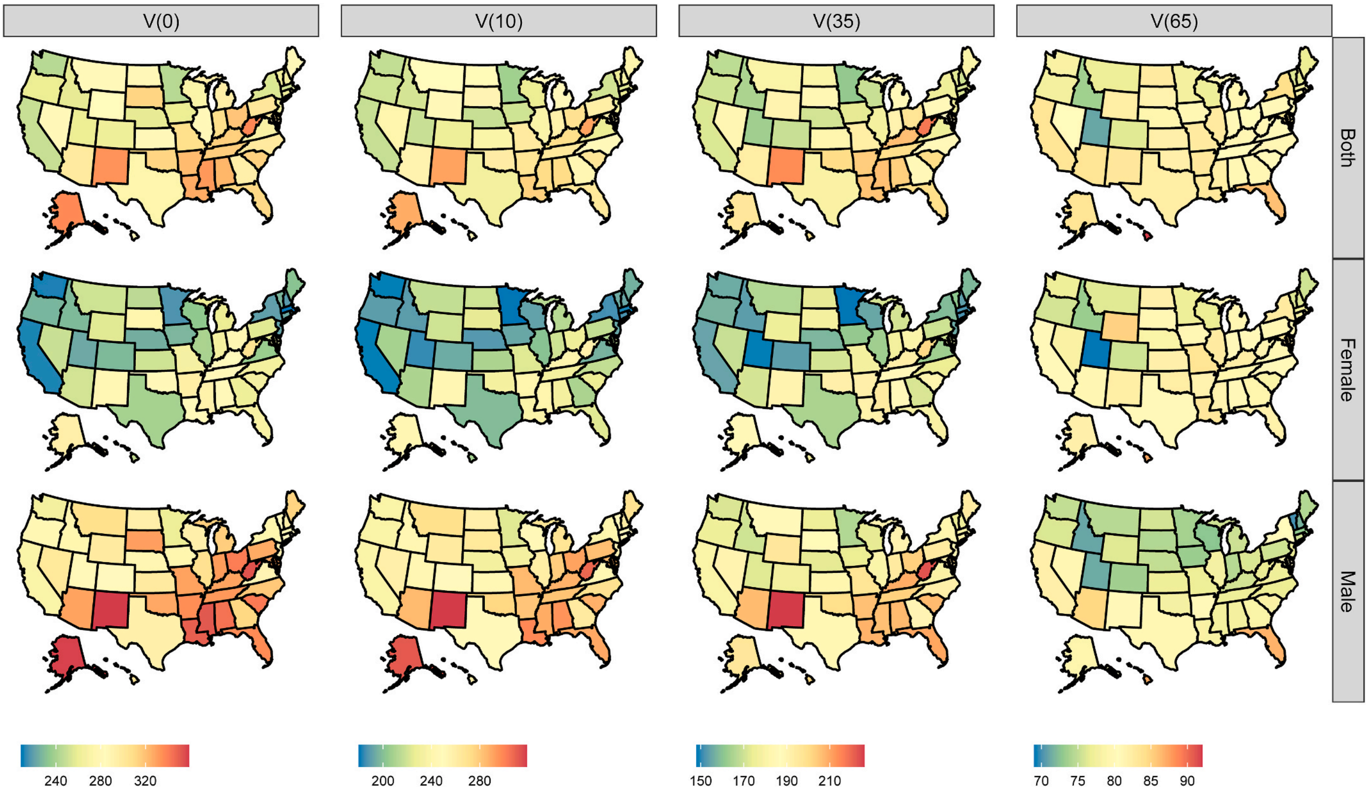

Fig. 1. Unconditional and conditional lifespan variation in US states in 2017.

geographic disparities in V(65) were much less pronounced (the gap in V(65) across US states in 2017 was only 23.0, compared to 150.1 in V(0)), implying that much of the geographic disparities observed in V(0, 10, 35) were due to mortality differences under age 65. For V(0, 10, 35), lifespan variation among males was greater than that among females in every state (13.8–34.8% greater for V(0), 16.9–37.7% greater for V(10), 1.1–22.7% greater for V(35)). Yet, the majority of states had greater V(65)s among females, although the gaps were small. We also observe that states with higher lifespan variations among males also tend to have higher lifespan variations among females. The correlation between males and females is 0.93, 0.90, 0.88 and 0.61 for V(0), V(10), V(35) and V(65), respectively.

3.2. *Temporal trends in US state lifespan variations*

We used standard convergence plots to illustrate whether state Vs had become more (dis)similar over the entire period. Fig. 2 plots state Vs in 1959 against the changes in state Vs between 1959 and 2017. As indicated by the downward slopes, there was a universal convergence in state Vs: states with greater Vs in 1959 also had greater decrease or smaller increase in V over time. State V(0, 10)s among males and females converged at a very similar pace. State V(10)s showed weaker convergence than V(0)s. As we look at lifespan variations among survivors to more advanced ages, differences in the degree of convergence between males and females become more pronounced. US states appear to have greater convergence among females than males in both V(35) and V(65).

Fig. 3 shows the convergence and/or divergence in state Vs during 6 period segments (1959–1970, 1970–1980, 1980–1990, 1990–2000, 2000–2010, 2010–2017). For the total population, there was a strong convergence in state V(0) in 1959–1970 and 1970–1980. State V(0) continued to converge in the following three decades but in a much slower pace. In 2010–2017, V(0) increased in most states and state V(0)s showed a divergence trend. Gender-specific trends showed that the divergence in state V(0) during 2010–2017 in the total population was mainly driven by the divergence among females, as state V(0)s among males continued to converge in the years. For V(10) and V(35) in the total population, however, states started to diverge during 2000–2010, earlier than for V(0). This divergence was also mainly attributed to the divergence among females. We observe continued convergence in state V(65) during the last two periods among males, females and combined. What these period trends revealed is that the unambiguous convergence in state Vs between 1959 and 2017 was mainly achieved during the latter part of the twentieth century. The convergence, most notably in V(0, 10, 35), slowed and eventually reversed between 2000 and 2017. Moreover, the divergence in state V(0, 10, 35) occurred earlier in females than in males.

To illustrate how lifespan variations have changed in each state over time, we plotted the difference in state Vs between the 3-year average around each decennial year (year 2016 for the last period) and the 3-year average between 1959 and 1961 among the total population, as presented in Fig. 4. 3-year averages were used to reduce the influence of single-year idiosyncratic values. This set of maps contrast the increase and decline in lifespan variations compared to the levels in 1959–1961. For V(0), almost all states had persistent decline over the entire study period. V(0) decreased the most in Arizona (−163.2, −4.2 years),

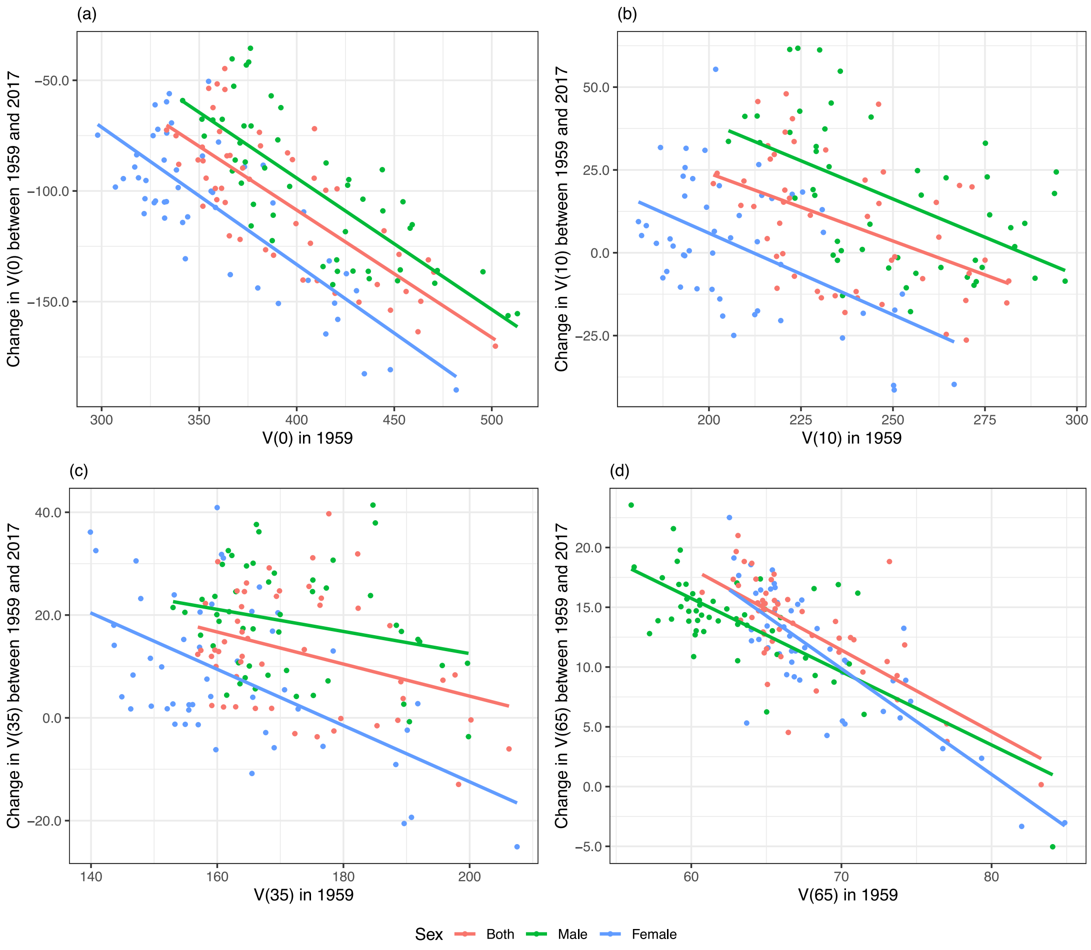

Fig. 2. Convergence in state lifespan variation between 1959 and 2017.

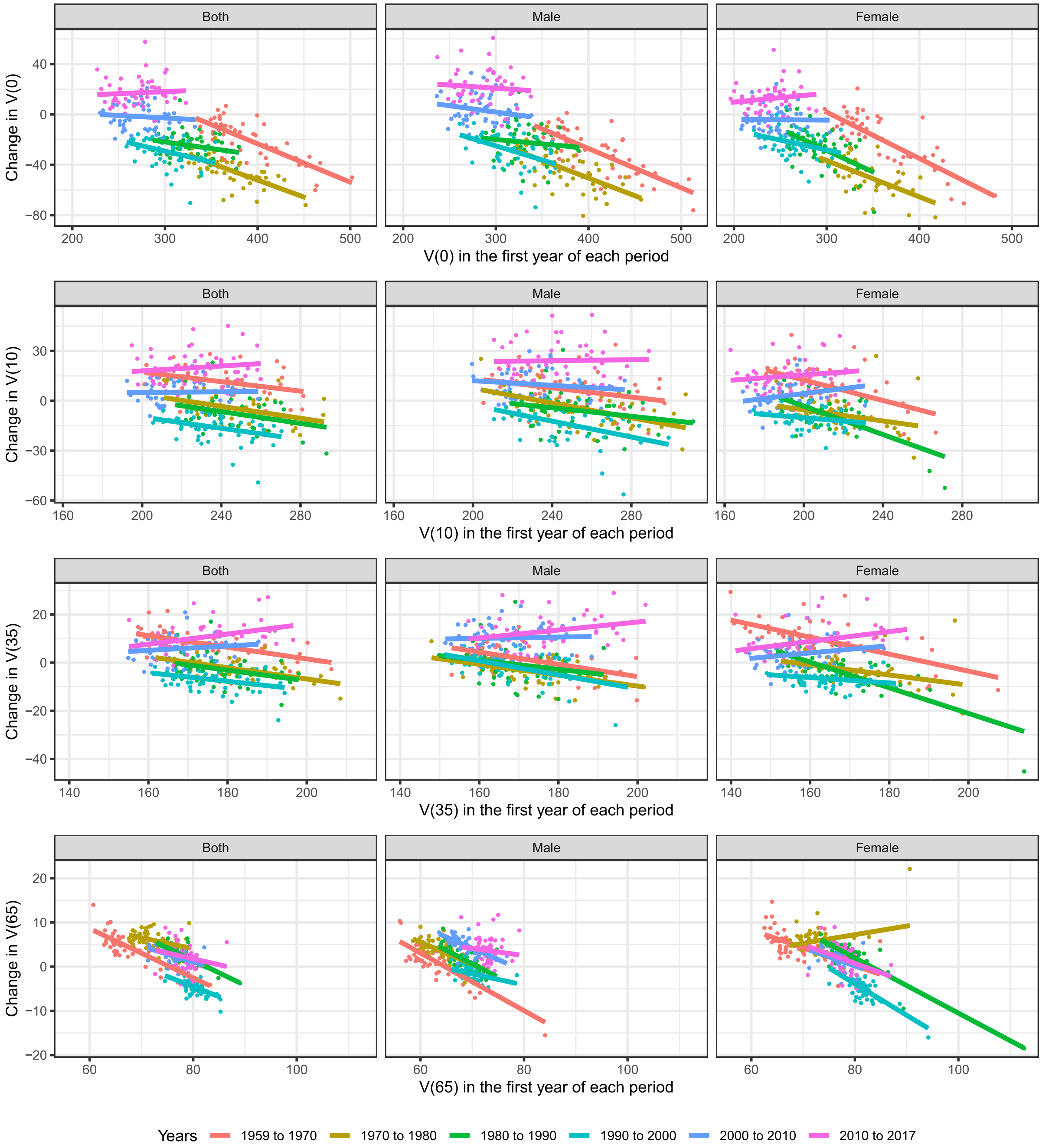

Fig. 3. Period convergence/divergence in state lifespan variations during 1959 and 2017.

Mississippi (−164.8, −4.1 years), Alaska (−152.4, −3.8 years) and the least in Ohio (−47.9, −1.3 years), Pennsylvania (−56.2, −1.6 years) and Delaware (−58.4, −1.6 years). However, the declines in V(0) seem to have stalled after 1999–2001. In contrast, V(65) increased in every state over the decades, with the greatest increase in North Dakota (20.3, 1.2 years), New York (19.7, 1.2 years) and Hawaii (18.7, 1.0 years) and the least in Utah (5.8, 0.3 years), Mississippi (6.0, 0.3 years) and Alaska (6.0, 0.3 years). There are periods when V(65) fell below the levels in 1959–1961 in some states, particularly Alaska, Florida, Mississippi and New Mexico.

The trajectories of state V(10) and V(35) were diverse. State V(10) rose in most states during the first decade. V(10) in many states started to fall after that period and by 1999–2001 most states had V(10) lower than that in 1959–1961. What is concerning, however, is that V(10) in a large number of states, particularly in the South and Appalachia, showed a reversal from reduction to expansion. By 2015–2017, V(10) had risen well above their levels in 1959–1961 in many states, with most notable increases in West Virginia (40.7, 1.3 years), Ohio (40.6, 1.3 years) and Pennsylvania (38.3, 1.3 years). For those states where V(10) in 2015–2017 maintained below the levels in 1959–1961, the differences also diminished compared to those in 1999–2001. Gender-specific patterns (see Fig. A3) show that the reversal was generally more prominent among males; however, females in Montana, Wyoming, Nebraska and the Dakotas appeared to have had greater increases in V(10) compared to males. We also observe similar patterns for state V(35): for males and females combined, lifespan variations in most states in 2015–2017 were similar to or well above their initial levels. In almost all states, male V(35)s in 2015–2017 were greater than the 1959–1961 levels, but in some state, most notably South Carolina, Georgia, and Nevada, female V(35)s had dropped below the levels in 1959–1961.

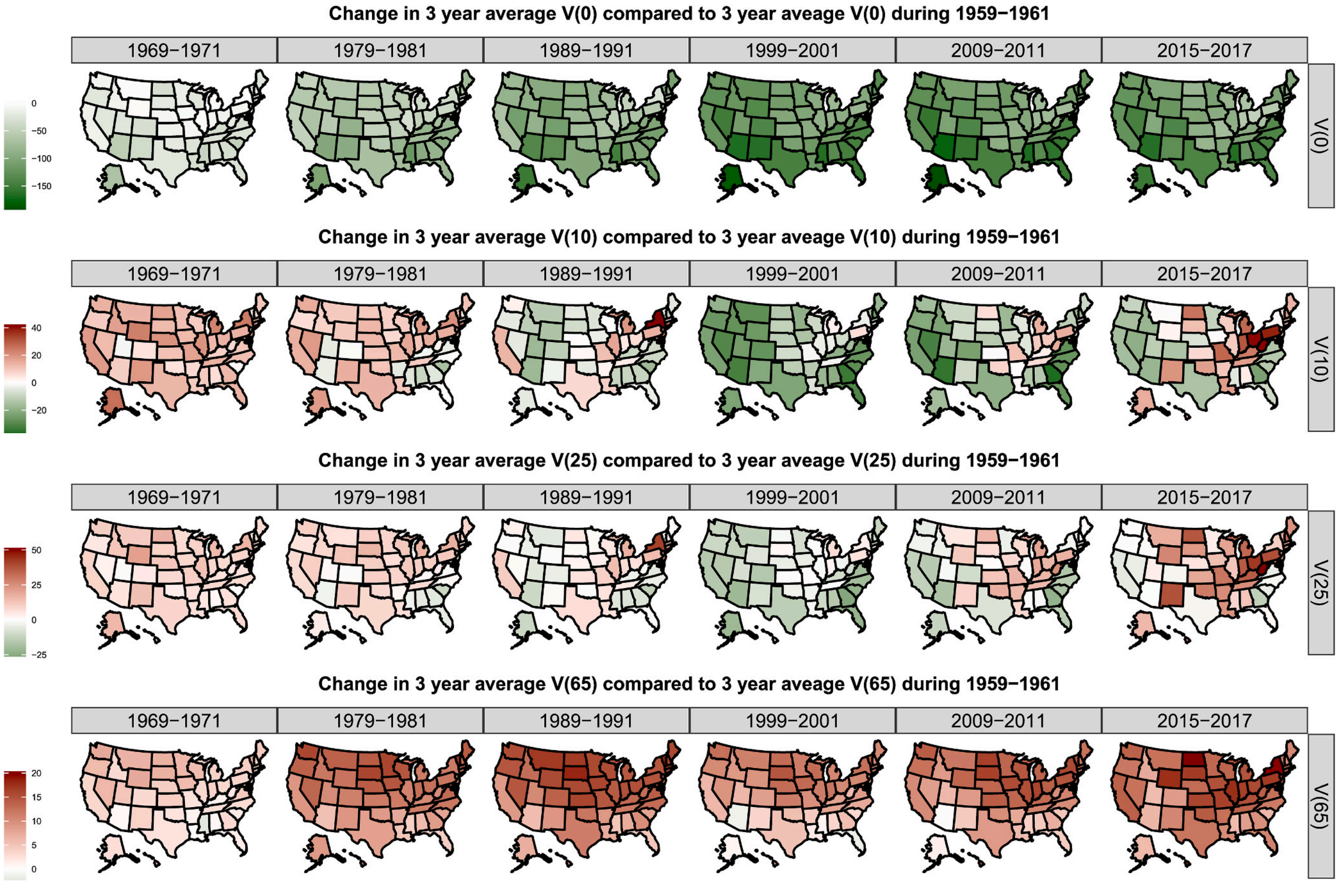

Fig. 4. Changes in state lifespan variation over time. Color and shading indicate differences in the direction and magnitude of changes. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

3.3. Decomposing overall lifespan variation

Table 1 shows changes in the contribution of the between-state differences in life expectancy to the overall lifespan variation in male, female and combined in select years. Overall, the between-state component contributes a very small proportion of the overall lifespan variations. Less than 1.5% of the overall lifespan variation can be attributed to the state differences in life expectancy over the entire period. However, despite the small contribution of the between-state component to the overall lifespan variation, we observe a persistent increase in its share since the mid-1980s (see Fig. A4). By 2017, the proportion of the between-state component of lifespan variation had doubled for male, female and combined. Temporal patterns show that for the total population, the proportion of the between-state component in the overall lifespan variation increased slightly between 1959 and 1970, and then fell back to the initial level by early 1980s. However, the proportion has been increasing persistently since the early 1980s, a trend unprecedented in previous decades and showing no signs of slowing. Although males and females showed similar overall temporal trends, it appears that the contribution of between-state differences in life expectancy to the overall lifespan variations, especially V(0), V(10) and V(35), is more pronounced among males than for females.

The share of the between-state component in the overall lifespan variation has been increasing, but how have the between-state and within-state components themselves changed over time? Fig. 5 shows that proportional changes in the within-state component of the overall lifespan variation for V(0) and V(65) mimic the average trajectories of state Vs. For V(0), the within-state component has declined over the study period, despite a stagnation in more recent decades. In contrast, the within-state component of V(65) had increased. The declining within-state component of V(0) and increasing component of V(65) demonstrate the divergence in lifespan variations between the young and the old (Engelman et al., 2010, 2014; Myers & Manton, 1984). One of the consequences of increased survivorship is that older adults now have a much greater variability in mortality risk compared to persons who survived to older ages in earlier decades, a process of “delayed selection” (Engelman et al., 2010). For V(10) and V(35), however, the within-state components had insignificant change relative to their levels in 1959 over the decades. States had diverse changes in V(10) and V(35) over time as illustrated in Fig. 4, but collectively the within-state lifespan variations conditional on survival to age 10 and 35 remained at levels similar to those in 1959. More striking in our findings is that the between-state component of lifespan variations had experienced greater relative changes over time compared to the level in 1959: an initial increase followed by a decline until it reached its lowest level in the mid-1980s and then a persistent increase until 2017. This trend is observed for both the unconditional and conditional lifespan variation among males, females and combined.

4. Discussion

Disparities in lifespan variations have been examined along the lines of various social markers such as race, income, occupation and education (Brown et al., 2012; Firebaugh et al., 2014; Permanyer et al., 2018; Sasson, 2016; Van raalte et al., 2011; van Raalte et al., 2018) as well as area-based deprivation (Seaman, Riffe, & Caswell, 2019; Seaman, Riffe, Leyland, et al., 2019). These studies showed that individuals in more disadvantaged social groups tend to have higher lifespan variations compared to their counterparts. Over time, they also tend to experience increasing lifespan variations as opposed to a reduction among

Table 1

Decomposition of overall lifespan variation. The between-state component represents the contribution of cross-state differences in life expectancy.

	1959	1980	2000	2017
(a) Both				
V(0)				
Between-state	1.50	1.46	2.06	3.03
Within-state	392.90	327.19	272.91	288.35
Share due to between-state (%)	0.38%	0.44%	0.75%	1.04%
V(10)				
Between-state	0.97	1.22	1.81	2.74
Within-state	236.70	243.83	220.65	245.73
Share due to between-state (%)	0.41%	0.50%	0.81%	1.10%
V(35)				
Between-state	0.82	0.99	1.41	2.23
Within-state	172.41	178.38	168.62	185.25
Share due to between-state (%)	0.48%	0.55%	0.83%	1.19%
V(65)				
Between-state	0.28	0.33	0.51	0.75
Within-state	67.21	77.92	75.80	80.53
Share due to between-state (%)	0.41%	0.42%	0.67%	0.92%
(b) Male				
V(0)				
Between-state	1.78	2.00	2.61	3.47
Within-state	408.64	334.36	284.44	309.32
Share due to between-state (%)	0.43%	0.59%	0.91%	1.11%
V(10)				
Between-state	1.20	1.73	2.30	3.14
Within-state	249.11	250.91	231.79	265.79
Share due to between-state (%)	0.48%	0.68%	0.98%	1.17%
V(35)				
Between-state	0.96	1.36	1.73	2.45
Within-state	171.60	169.42	166.88	190.24
Share due to between-state (%)	0.56%	0.80%	1.02%	1.27%
V(65)				
Between-state	0.33	0.42	0.55	0.71
Within-state	62.77	67.61	68.19	76.79
Share due to between-state (%)	0.53%	0.62%	0.80%	0.92%
(c) Female				
V(0)				
Between-state	1.47	1.13	1.63	2.64
Within-state	359.34	291.42	242.97	251.33
Share due to between-state (%)	0.41%	0.39%	0.67%	1.04%
V(10)				
Between-state	1.00	0.94	1.44	2.38
Within-state	208.47	209.86	191.94	210.24
Share due to between-state (%)	0.48%	0.45%	0.74%	1.12%
V(35)				
Between-state	0.96	0.87	1.19	2.02
Within-state	161.64	168.33	157.48	170.18
Share due to between-state (%)	0.59%	0.51%	0.75%	1.17%
V(65)				
Between-state	0.41	0.43	0.56	0.79
Within-state	68.24	79.17	76.61	79.64
Share due to between-state (%)	0.60%	0.55%	0.72%	0.99%

privileged groups. Considering the persistent and widening place-based inequality in mortality in the US (Cosby et al., 2019; Fenelon, 2013; James et al., 2018), we extend this line of inquiry by considering geography (i.e., state) as a social stratifier and investigating how lifespan variations differ and change within the US over the last six decades (1959–2017). Distinct from the large body of research on trends in state life expectancy, a measure of *average* life span within a state, our study contributes to the literature on geographic differences in mortality within the US by explicitly examining state differences in the *variability* in life spans around that average, a measure that more directly speaks to inequalities both within and across state boundaries. Our results reveal spatial and temporal patterns within the US that suggest state-level factors increasingly influence overall mortality inequality, but that inequality within states – potentially driven by factors that operate on a more local scale – continues to drive the observed disparities.

We found substantial cross-state differences in V(0), V(10) and V(35) in 2017. States with the highest lifespan variations generally cluster in the Central South and Appalachia regions, reflecting the concentration of health and mortality disadvantage (Dollar et al., 2020; Singh et al., 2017) and its many determinants (An et al., 2016; Drope et al., 2018; Horev et al., 2004) in these areas. Males have higher lifespan variations than females in every state, attributable to their greater mortality risks. There was also a strongly positive spatial correlation in lifespan variations between males and females: states with higher lifespan variations among males also tend to have higher lifespan variations among females. This correlation implies that state context is salient to lifespan variations in both males and females, despite their very distinct mortality patterns. State differences in V(65), however, were much less pronounced. This finding echoes prior research noting a leveling of disparities at older ages, possibly because access to health care and income supports becomes more equal across states when older adults become eligible for Medicare and Social Security, reducing the variability in mortality across geographic areas in this age group.

The overall trend in mean state V(0) mirrors the historical gains in life expectancy at birth in the US as well as its declines in recent years (Woolf & Schoomaker, 2019). Our results of the average state trajectory of V(10) are consistent with Acciai and Firebaugh (2019)'s analyses on the US national trend in lifespan variation (their study examined the US trend between 2000 and 2017 and used standard deviation of age at death conditional on survival to age 10 as the lifespan variability measure). Increasing mean state V(65) since 2000 suggests an improvement in older age mortality. Indeed, the probability of surviving from age 65 to age 66 in the total population increased from 0.82 in 2000 to 0.84 in 2017 (from 0.78 to 0.80 in males and from 0.86 to 0.88 in females) and remaining life expectancy at the age 65 increased from 17.71 years in 2000 to 19.70 years in 2017. Meanwhile, recent studies of age- and cause-specific mortality changes in the US have revealed rising mortality between the age 25 and 64 years since 1999, mainly attributable to external causes such as drug poisoning and suicide (Braden et al., 2017; Hedegaard et al., 2020; Warner et al., 2011). Both survival improvement at older ages and rising premature mortality may have concurrently contributed to the dramatic increase in V(10) and V(35) after the year 2000.

The overall decline and convergence in state Vs over the last six decades is the capstone of the remarkable mortality reduction in the US during the period. Improvement in socioeconomic resources, medical innovation and its diffusion and public health interventions may have contributed to greater survival improvement in states that started the period with the worst outcomes. Individuals across states can now expect to have much more similar levels of lifespan variation (both unconditional and conditional on survival to different ages) than in 1959. However, the divergence in state V(0), V(10), and V(35) over the past two decades indicates that states are becoming more differentiated again in terms of the inequality captured by these measures of lifespan dispersion. Our findings mirror the those in cross-country studies that demonstrate a similar reversal from convergence to divergence in life expectancy in recent decades (Gerry et al., 2018; MacKenbach, 2013; Moser et al., 2005).

Notably, the divergence in state V(0, 10, 35) coincided with persistent convergence in state V(65) during the past two decades, suggesting that the observed divergence was largely driven by changes in mortality under age 65. These include long-term improved survival for multiple segments of the US population (including groups of color and white Americans with a college education) even as those with lower levels of education and residents of some rural areas experience rising mortality (Case & Deaton, 2015; Jensen et al., 2020; Sasson, 2016). The increase and convergence in V(65)s across states indicates both growing lifespan variability among the growing group of survivors to age 65 (Engelman et al., 2010) and growing similarity across state populations in the distribution of deaths over age 65, possibly a function of increased access to federal programs such as Social Security and Medicare that rely less on state-specific resources than the health and economic supports available

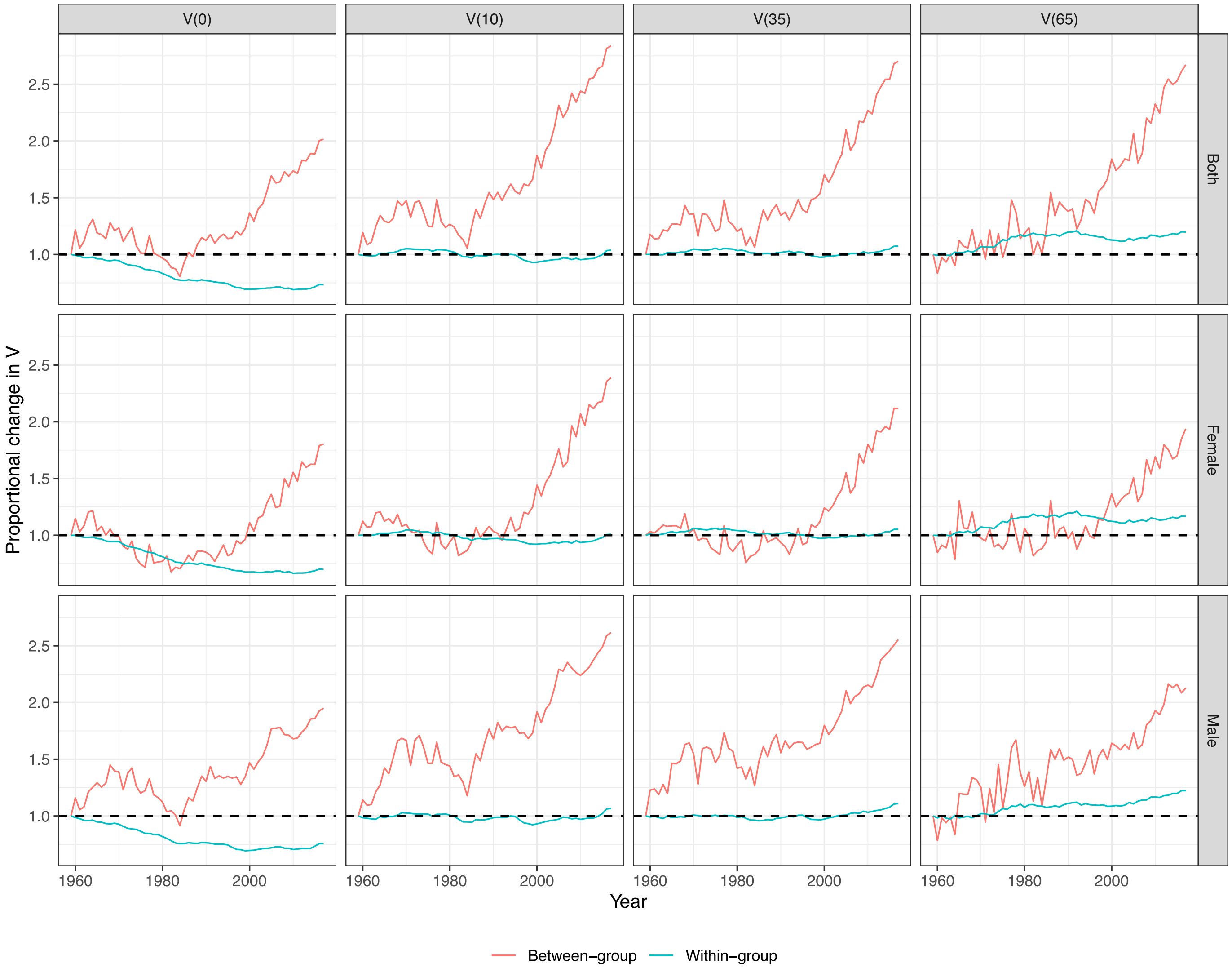

Fig. 5. Relative change in the between-group and within-group components of overall lifespan variation.

to younger people.

We also observed that the timing of divergence in state lifespan variations varied between males and females: state V(0, 10, 35) among females started reversing from convergence to divergence much earlier than among males. This is consistent with the greater sensitivity of women's mortality to contextual factors such as states' social cohesion and economic conditions (Montez et al., 2016) and with the troubling rise in maternal mortality rates over the past two decades (Sofer, 2018) which has disproportionately affected Black women and pregnant individuals in areas (like the rural south) with fewer women's healthcare providers (Snyder et al., 2020).

Our decomposition analyses reveal the relative magnitudes of the between- and within-state contributions to overall lifespan variability in the United States. First, the between-state component (i.e., state differences in life expectancy) makes up a small proportion of the overall lifespan variation relative to the contribution of within-state variation over the past six decades. This is similar to findings in cross-country studies that the vast majority of the overall lifespan variation is due to internal variation within countries (Clark & Snawder, 2020; Edwards, 2011; Pradhan et al., 2003; Smits & Monden, 2009). Despite the mortality disparities observed across American states, these differences are probably smaller than those among countries at different stages of the demographic transition. Furthermore, state-level comparisons hide considerable heterogeneity within states – e.g., between cities, suburbs, and rural regions, or across counties and metropolitan regions with varied industries and socioeconomic profiles. While state differences in life expectancy might not have been large enough to substantially influence overall lifespan variability, their impact in recent years is comparable to or greater than the contribution of educational inequalities to overall lifespan variation in many high-income European countries (Permanyer et al., 2018; van Raalte et al., 2012).

Over time and especially after the 1980s, both overall and within-state variation in the length of life have declined, leading between-state variation in life expectancy to comprise a small yet growing proportion of the overall lifespan variations in the US. Among survivors to age 65, both between-state and within-state variation have increased over the decades, with the former increasing at a much faster pace than the latter. The consequence is similar to the patterns we observed for unconditional lifespan variations: cross-state differences in life expectancy at age 65 are making an increasingly greater contribution to the overall lifespan variations among older adults.

What explains the divergence in state lifespan variations and the increasing importance of state differences in the overall lifespan variations, especially to mortality at younger ages? Recent research provides some clues. First of all, decades of deindustrialization, technological change and union decline have jointly resulted in rising economic insecurity and income inequality in the US (Autor et al., 2008; Frank, 2014; Gottschalk & Moffitt, 2009; Kollmeyer, 2018). The gap in the top decile income share across states increased from 6.3% in the 1950s to 14.1% in the early 2000s (Frank, 2014). This profound change in socioeconomic structures has been associated with increasing mortality from alcohol and drug poisoning and suicide, the so-called "deaths of despair" (Knapp et al., 2019; Seltzer, 2020). The effect of this transformation, however, has not been felt equally across the country. Regions such as the South, Appalachia, and the West have experienced a dramatic increase in these external deaths, especially among young and middle-age non-Hispanic whites with less education (Case and Deaton, 2015, 2017). In combination with other causes of death, including maternal mortality, spatial inequality in mortality has risen over the last two decades, particularly in early to mid-adulthood (Vierboom et al., 2019). This geographic divergence in mortality, especially at younger ages, may have contributed to the disparate patterns of mortality compression/expansion across places as a result.

Second, increasing variations of state policy environments may have also contributed to the diverging state lifespan variations in recent decades. The hyper inter-state partisan polarization since 2000 (Grumbach, 2018) means that many structural determinants of residents' economic, physical and mental wellbeing are becoming increasingly different across states. A number of studies have associated differences in policy contexts with disparities in health and mortality across states (Montez et al., 2017, 2020; Montez & Farina, 2021; Wolf et al., 2021). These studies generally find that residents in states adopting more liberal policies – expanding economic regulation, strengthening social safety net, accepting a wider range of personal behaviors – on average enjoy better health and lower mortality. As a result, more deaths are compressed to older ages in liberal states than in conservative states (Montez & Farina, 2021). A more specific example is state cigarette tax rates. Studies have shown that there were little regional variations in 1981; however, by 2011 the average state cigarette tax rate in the Northeast was 3 times of the average rate in the South. The gap in cigarette tax rates between tobacco-growing-states and non-tobacco-growing-states also widened (Golden et al., 2014). In this context, cigarette smoking has been identified as a significant contributor to the divergence in mortality across US regions (Fenelon, 2013). The polarization of state policy environments therefore may be one of many factors driving the divergence in age patterns of deaths across states.

5. Conclusion

Overall lifespan variation across US states declined and converged in the latter part of the twentieth century before diverging again in recent decades, likely reflecting the long-term consequences of rising social, economic, and political stratification for health inequalities. The continued convergence in lifespan variations among older adults presents a notable contrast, possibly pointing to the consequences of mortality inequities at younger ages as well as underscoring the potential of universal federal health and income supports to reduce mortality disparities at older ages.

Previous studies have found that states are playing an increasingly salient role in shaping life expectancy in the US. Our results show that the uncertainty surrounding the age of death is also becoming increasingly tied to states of residence. Although within-state differences remain the biggest contributors to lifespan variation in the US as a whole, the widening gaps in life expectancy across states are increasingly important drivers of overall lifespan variation in the US, with no signs that this trend will slow down in the near future.

Investigations of lifespan variability across US states help focus attention on the impact of diverging social, economic, and policy contexts on fundamental inequalities in the length of life. They also highlight the potential of state-level interventions to address internal inequities. Reducing lifespan disparities both within and across state lines is thus essential for improving overall population health.

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Author statement

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Declaration of competing interest

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2021.100987.

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