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Educational disparities in joint pain within and across US states: do macro sociopolitical contexts matter?

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Abstract

Despite growing recognition of the importance of social, economic, and political contexts for population health and health inequalities, research on pain disparities relies heavily on individual-level data, while neglecting overarching macrolevel factors such as state-level policies and characteristics. Focusing on moderate or severe arthritis-attributable joint pain—a common form of pain that considerably harms individuals' quality of life—we (1) compared joint pain prevalence across US states; (2) estimated educational disparities in joint pain across states; and (3) assessed whether state sociopolitical contexts help explain these 2 forms of cross-state variation. We linked individual-level data on 407,938 adults (ages 25-80 years) from the 2017 Behavioral Risk Factor Surveillance System with state-level data on 6 measures (eg, the Supplemental Nutrition Assistance Program [SNAP], Earned Income Tax Credit, Gini index, and social cohesion index). We conducted multilevel logistic regressions to identify predictors of joint pain and inequalities therein. Prevalence of joint pain varies strikingly across US states: the age-adjusted prevalence ranges from 6.9% in Minnesota to 23.1% in West Virginia. Educational gradients in joint pain exist in all states but vary substantially in magnitude, primarily due to variation in pain prevalence among the least educated. At all education levels, residents of states with greater educational disparities in pain are at a substantially higher risk of pain than peers in states with lower educational disparities. More generous SNAP programs (odds ratio [OR] = 0.925; 95% confidence interval [CI]: 0.963-0.957) and higher social cohesion (OR = 0.819; 95% CI: 0.748-0.896) predict lower overall pain prevalence, and state-level Gini predicts higher pain disparities by education.

Keywords: Education, Disparity, Sociopolitical context, US states, Pain, Arthritis

1. Introduction

In the United States, 23.7% of adults—approximately 58.5 million people— experience arthritis, and at least 15 million of them experience severe arthritis-attributable joint pain.[5,29,55] Moderate or severe arthritis-attributable joint pain (abbreviated as "joint pain" or "pain" hereafter for brevity) is strongly associated with poor functioning, disability, and mortality[5,47,60,63]; employment, financial, and interpersonal problems[60,63]; and high healthcare costs, partly due to joint replacement surgeries.[28] Moreover, ample studies document that people with less education are more likely to experience joint pain and resultant functional limitations[5,46,59,61] due to behavioral risk factors such as smoking, limited access to healthcare resources, or delayed diagnosis and treatment.[31,35,61]

Existing analyses of educational differences in joint pain, similar to most studies of socioeconomic disparities in health, rely primarily on individual-level data. However, individuals are embedded in social contexts, which affect their education, their health, and the relationship between the two. Indeed, macrolevel social, economic, and political contexts may be "causes of the causes of the causes" of disparities.[4] While the macrolevel context operates across multiple levels (eg, neighborhoods, countries), states represent an important level of influence. Particularly in the United States, state-level sociopolitical environments and policies vary dramatically and can influence many aspects of life, including opportunities, resources, behaviors, norms, and social relationships.[33,40]

Recent studies have shed light on the role of state-level contexts for individuals' health outcomes. For instance, states' economic policies (eg, minimum wage and earned income tax credits) may reduce individuals' financial stress and improve health.[34,53,58] Legal protections for adoption, abortion, and same-sex relationships increase people's well-being.[26,43] Policies regarding tobacco control (eg, public smoking bans and tobacco taxes), food security (eg, the Supplemental Nutrition Assistance Program), and marijuana legalization can modify health-related behaviors and thus promote better health.[13,21,43]

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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Moreover, state social, economic, and political contexts shape the mechanisms that undergird (or attenuate) the association between education and health.[40] For example, strong social safety nets may mitigate the negative impacts of low education on health outcomes. Thus, a full understanding of disparities in pain by education requires an examination of structural or institutional factors,[24] including at the state level. Indeed, studies have identified state macrolevel factors that affect educational stratification for various health outcomes,[33,41,43] including disability,[43] mortality,[20,45] and sleep.[50] However, research has yet to explore how pain prevalence and pain disparities, including for arthritis-attributable joint pain, vary across state contexts.

We leverage individual-level and state-level data from multiple sources to: (1) assess the prevalence of joint pain in each of the 50 US states; (2) estimate educational disparities in joint pain within each state; and (3) examine how state-level characteristics, such as economic and social welfare policies, explain cross-state variation in both outcomes. Overall, this study provides evidence for policy interventions to reduce pain and pain disparities and to improve pain-related quality of life in the United States. It also identifies key sociopolitical domains and factors that could be analyzed in pain disparities research within and/or across other countries or regions.

2. Methods

2.1. Individual-level data source

Our individual-level data are from the 2017 Behavioral Risk Factor Surveillance System (BRFSS), the United States' premier system of state-based health-related cross-sectional surveys. In cooperation with the Center for Disease Control and Prevention (CDC) and state health departments, the BRFSS annually surveys US residents aged 18 years and older about sociodemographic characteristics, health status and behaviors, the use of health services, etc. The BRFSS is well-suited for our study because it aims to be a representative of noninstitutionalized adults at the state level and collects detailed health-related information. Its large sample size and advanced weighting method for better representing underrepresented groups and adjusting for nonresponse allow us to obtain reliable estimates when conducting multilevel analyses.[15] In 2017, BRFSS interviewed 450,016 respondents from all 50 states, plus the District of Columbia, Puerto Rico, and Guam.

We excluded observations from the latter 3 territories because selected state-level variables are not available for them. We restricted our sample to adults 25 years or older because younger people may still be in the process of completing their education.[50] Our outcome variable, moderate or severe arthritis-attributable joint pain, was missing in 1.17% of cases, and covariates (education, sex, race/ethnicity, and state of residence) were missing in 0.1% to 2.2% of cases. In total, 3.7% of participants were missing data on variables of interests. After deleting these observations, our sample size was 407,938. Sociodemographic characteristics of the respondents (individual-level variables) are summarized in **Table 1**, and sample sizes for each state are summarized in Supplemental Table S1 (available at http://links.lww.com/PAIN/B848).

2.2. Dependent variable

The primary outcome was *moderate or severe* arthritis-attributable joint pain. The BRFSS asks respondents about diagnosed arthritis. ("Has a doctor, nurse, or other health professional ever told you that you had arthritis?"). Arthritis was defined expansively to include osteoarthritis, rheumatoid arthritis, ankylosing spondylitis, and many other rheumatic joint disorders. Respondents with arthritis are asked to rate the intensity of joint pain or aching in the past 30 days on a 0 to 10 scale. Following prior research,[9] we dichotomized this measure to define "moderate or severe joint pain" as scores of 6 or more, and "no or little pain" as scores of 0 to 5, or no arthritis. We focused on moderate or severe pain, given the evidence of its strong links with functional limitations, disability, and death.[1,16]

2.3. Individual-level predictor

The key individual-level independent variable was educational attainment. We classified it into 3 categories: less than high school (<HS), high school or some college (HS/SC), and bachelor's degree or above (BA+).

2.4. State-level predictors

We combined individual-level variables from the BRFSS with state-level predictors from multiple sources (details presented below). Macintyre et al.[36] suggest that individuals' health is primarily influenced by 2 major "place effect" domains: (1) material or infrastructural resources and (2) collective social functioning and practices. Material/infrastructural resources include social services, affordable and nutritious food, and transportation. Collective social functioning and practices refer to social cohesion and social norms.[36,44] Although this framework was initially applied to analyze small geographic areas (eg, neighborhoods), it can guide in selecting and categorizing critical state-level contextual variables.

Therefore, we selected 6 state-level variables: Earned Income Tax Credit (EITC), Supplemental Nutrition Assistance Program (SNAP), Medicaid Generosity Score (MGS), Gini index (Gini), Social Capital Index (SCI), and tobacco taxes. These are described in more detail below, but in brief, the EITC, SNAP, and Medicaid programs are the 3 of the largest means-tested transfer programs in the US social safety net[39] and hence are important components of states' material/infrastructural environments. So, too, is the Gini index, which in this study measures state-level income inequality (and hence is arguably reflective of social cohesion as well). The SCI is a comprehensive measure of social cohesion, and tobacco tax policies represent states' commitments to collective improvement of health behaviors. Although these variables do not represent an exhaustive list of state contextual measures, they reflect core aspects of states' approaches to establishing material and social environments that are critical for health.

2.4.1. The Gini index

We used 5-year estimates of the Gini index retrieved from the 2013 to 2017 American Community Survey.[56] The Gini index is an indicator of income inequality and ranges from 0 to 1; higher values indicate higher inequality.

2.4.2. Earned income tax credit

The earned income tax credit (EITC) is an antipoverty program in the United States, which enhances low-income to moderate-income workers' economic security through refundable tax credits. In addition to the federal EITC, states may elect to provide state-level EITCs. We collected state EITC data from the Correlates of State Policy Project (CSPP) at Michigan State

Table 1

Individual-level characteristics of analytic sample (N = 407,938).

	Proportion or mean (unadjusted)	Proportion or mean (sample-weight adjusted)	N
Moderate/severe arthritis-attributable joint pain			
Yes	0.12	0.11	49,697
No or little pain	0.88	0.89	358,241
Education			
<HS	0.07	0.14	29,001
HS/SC	0.54	0.57	220,230
BA+	0.39	0.30	158,707
Age	57.14	51.05	407,938
Sex			
Male	0.44	0.48	178,196
Female	0.56	0.52	229,742
Race/ethnicity			
Non-Hispanic White	0.79	0.65	322,043
Non-Hispanic Black	0.08	0.12	31,095
Hispanic	0.07	0.15	28,018
Other	0.07	0.08	26,782

<HS, less than high school; HS/SC, high school or some college; BA+, bachelor's degree or above.

University.[14] Following Montez et al.,[42] we calculated cumulative years of EITC implementation for each state between 1988 and 2014. Higher values indicate longer periods of EITC implementation.

2.4.3. Supplemental Nutrition Assistance Program

The Supplemental Nutrition Assistance Program (SNAP), formerly known as "food stamps," is the largest federal nutrition assistance program in the United States, aiming to supplement low-income families' and individuals' food budgets. We used 2017 SNAP data from the Kaiser Family Foundation's database, measured as average monthly dollars received per person in each state.[32] Thus, higher values of SNAP indicate greater average received benefits.

2.4.4. Social Capital Index

Social capital refers to many aspects of associational life among individuals, families, and communities, such as trust, social cohesion, and civic engagement. It has been shown to predict better health.[18,57] We measured it using the 2018 Social Capital Index from the US Congress Joint Economic Committee.[57] The Social Capital Index is generated from 25 state-level factors indicating family unit cohesion, family interactions, social support, community health and services, institutional cohesion, philanthropy, and collective efficacy.[57] Higher values indicate more socially cohesive states.

2.4.5. Medicaid Generosity Score

Medicaid is the largest source of public health insurance in the United States, targeting low-income and disabled individuals. Each state crafts its own Medicaid program based on federal requirements, and thus states differ in terms of program eligibility, types of benefits, etc. We used the Medicaid Generosity Score developed by Montez et al. using data from the Public Health Citizen Research Group and Kaiser Family Foundation.[17,19,42] The MGS summarizes the average reimbursement, quality of care, healthcare services, etc., of each state's Medicaid program from 1987 to 2007. Higher scores indicate more generous Medicaid programs.[42]

2.4.6. Tobacco taxes

Tobacco taxes are an effective strategy to deter smoking[49] and are indicative of states' policy approaches to and leanings towards restricting unhealthy behaviors.[43] We used data on 2017 state tobacco taxes from the Tax Foundation, measured in cents per pack.[8]

To facilitate meaningful estimates, all state-level variables were standardized as Z-scores before analysis; thus, a 1-unit increase corresponds to a 1-SD increase. Descriptive statistics for state-level variables are summarized in **Table 2**, and values of these variables for each state are summarized in Supplementary Table S1 (available at http://links.lww.com/PAIN/B848).

2.5. Covariates

We included individual-level and state-level covariates. Individual-level covariates were age, sex, and race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, Other). Age was cluster mean centered for each state to better fit the models and make efficient estimates.[52]

We also included 1 state-level covariate: the proportion of immigrants. Given the health advantages of immigrants,[38] states with higher proportions of immigrants may show better health outcomes. Because the BRFSS does not collect data on respondents' immigration status or birthplace, we included a measure of the percentage of immigrants in each state obtained from 2013 to 2017 ACS 5-year estimates.[33,56]

2.6. Statistical analysis

Leveraging the 2-level hierarchical structure with individual respondents (level 1) nested within states (level 2), we estimated a series of multilevel logistic regressions. First, to estimate the cross-state variations in joint pain prevalence, the base model (model 1) is a covariate-only model that adjusts for age, sex, race/ethnicity, and percentage of immigrants. The magnitude of the random effect indicates the degree of state-level variation. Second, we added education to estimate variations in educational disparities across states (model 2). Third, we added the 6 state-level predictors to estimate the effect of state

Table 2

Characteristics of state-level factors before standardization (N = 50).

	Mean	Standard deviation	Median (IQR)
Percentage of immigrants	10.03	6.32	7.80 (9.30)
EITC (# of years)	7.80	9.07	3.00 (15.00)
SNAP (monthly dollars/person)	123.34	17.43	121.00 (10.00)
MGS	338.07	53.04	329.40 (66.10)
Gini index	0.46	0.02	0.46 (0.03)
SCI	0.04	1.00	−0.02 (1.49)
Tobacco (cents)	173.75	108.73	160.00 (184.00)

EITC, Earned Income Tax Credit; Gini, Gini index; MGS, Medicaid Generosity Score; SCI, Social Capital Index; SNAP, Supplemental Nutrition Assistance Program; Tobacco, tobacco taxes.

characteristics (model 3). Finally, we added cross-level interactions between education and each state-level variable one at a time to assess whether state contextual characteristics can explain cross-state differences in educational disparities (models 4-9). Except in the base model (model 1), we allowed the slope for education to vary randomly across states because we hypothesized that the degree of educational disparities (ie, slopes) differs across states, and including a random slope can avoid potentially overestimating the significance of cross-level interactions due to misspecification.[27] Moreover, the models with random slopes have better goodness-of-fit than those without, based on likelihood ratio tests and Akaike information criterion (AIC) and Bayesian information criterion (BIC).

In addition, we conducted a series of extensive auxiliary analyses to examine the sensitivity of results, including (1) models in which we added state level predictors one at a time; (2) models with cross-level interactions estimating how one state factor moderates educational disparities while excluding the other 5 state-level predictors; (3) sex-stratified analyses; and (4) a full set of parallel models of cross-state variation in the prevalence of and educational disparities in *arthritis diagnosis* (rather than arthritis-attributable pain). These are described in the Results section.

All models are adjusted with sampling weights and are analyzed with *melogit* in Stata 17.0. We assessed multicollinearity by computing variance inflation factors (VIFs), and no multicollinearity was detected. (A correlation matrix for state-level variables is summarized in Supplementary Table S2, available at http://links.lww.com/PAIN/B848).

3. Results

3.1. Joint pain prevalence and educational disparities in joint pain across states

Figures 1and 2 demonstrate how the prevalence of moderate or severe arthritis-attributable joint pain and educational disparities in such pain vary across states. The prevalence for high-pain and low-pain states, overall and by educational category, is summarized in **Table 3**.

Specifically, **Figure 1** shows the weighted predicted probability of joint pain by state, adjusted for age, sex, race/ethnicity, and percentage of immigrants (based on regression results from model 1 in **Table 4**). Controlling for these covariates, the average prevalence of joint pain among the 50 states was 12.9%. However, the prevalence varied substantially across states (which are ordered from the lowest to the highest prevalence in the Figure). Prevalence was the lowest in Minnesota (6.9%; see also **Table 3**) followed by Hawaii (7.5%) and Utah (7.7%); it was the highest in West Virginia (23.1%), followed by Alabama (21.6%) and Arkansas (21.4%). Residents of high-prevalence states are thus more than 3 times more likely to experience joint pain than residents of low-prevalence states.

Figure 2 presents the weighted predicted probability of joint pain *by education* across states, again controlling for age, sex, race/ethnicity, and proportion of immigrants (based on regression results from model 2, **Table 4**). The figure shows a clear educational gradient in the prevalence *within* states. In all 50 states, the risk of joint pain was highest among residents without high school degrees, lowest among those with college degrees, and intermediate for those with intermediate education. At the same time, educational disparities varied strikingly *across* states. The average gap in pain prevalence between the <HS and BA+ groups was 18.5% points (see Supplementary Table S3, available at http://links.lww.com/PAIN/B848), but it ranged from 8.8% in California to 31.1% in West Virginia (see also **Table 3**). We also observed that cross-state variation in the prevalence was greatest for those with the least education: this is shown visually in **Figure 2** and is confirmed by the higher standard deviations in pain prevalence for the <HS group (SD = 0.068) than for the HS/SC group (SD = 0.034) or BA+ group (SD = 0.015).

For parsimony, **Table 3** summarizes the 10 states with the highest joint pain and the 10 with the lowest. (Data for all 50 states are provided in Supplementary Table S3, available at http://links.lww.com/PAIN/B848). The first column in **Table 3** presents the adjusted prevalence of joint pain for all adults; the next 3 columns show the estimated prevalence among respondents with <HS, HS/SC, and BA+ levels of education, respectively; and the last column shows the educational gap in joint pain prevalence between the <HS and BA+ groups. To illustrate the associations between overall pain prevalence and pain educational disparities, cells are shaded in red if the state ranks among the top 10 states in pain prevalence within a given educational category, and shaded green if it ranks among the bottom 10. We also calculated Spearman rank correlations coefficients.

Table 3 indicates that, at all educational levels, people in states with larger educational disparities tend to have a higher risk of joint pain. That is, not only are people with <HS dramatically more likely to experience joint pain in high-disparity states such as West Virginia than in lower-disparity states such as California (40.7% vs 12.6%), but even individuals with college degrees are more likely to experience pain if they live in states with large educational gaps. College graduates in West Virginia (9.6%), Kentucky (8.4%), and Arkansas (8.3%), for example, are at a higher risk than college graduates in California (3.8%), Utah (3.4%), and Nevada (4.4%). Spearman rank correlation coefficients confirm

Table 3

Arthritis-attributable moderate/severe joint pain prevalence among US adults aged 25 to 80 years, in high-prevalence and low-prevalence states, by education; adjusted for age and other demographic characteristics.

	All	<HS	HS/SC	BA+	Education Gap*
10 highest pain states					
West Virginia	0.231	0.407	0.230	0.096	0.311
Alabama	0.216	0.373	0.218	0.090	0.283
Arkansas	0.214	0.380	0.213	0.083	0.297
Kentucky	0.213	0.381	0.212	0.084	0.297
Mississippi	0.203	0.363	0.198	0.080	0.283
South Carolina	0.169	0.323	0.174	0.069	0.254
Tennessee	0.167	0.329	0.170	0.065	0.264
Oklahoma	0.162	0.274	0.175	0.069	0.205
Louisiana	0.161	0.292	0.162	0.065	0.227
Michigan	0.157	0.309	0.173	0.065	0.243
10 lowest pain states					
North Dakota	0.100	0.217	0.111	0.041	0.176
Washington	0.099	0.166	0.120	0.044	0.122
South Dakota	0.099	0.187	0.109	0.041	0.146
Nebraska	0.096	0.171	0.111	0.040	0.131
Iowa	0.096	0.182	0.108	0.039	0.143
Alaska	0.091	0.188	0.102	0.041	0.147
Colorado	0.085	0.150	0.106	0.040	0.109
California	0.085	0.126	0.099	0.038	0.088
Utah	0.077	0.135	0.091	0.034	0.101
Hawaii	0.075	0.173	0.083	0.035	0.138
Minnesota	0.069	0.145	0.081	0.030	0.114
Spearman's rank correlation coefficient (N = 50)					
All and education gap	0.862				
Education gap and <HS	0.986				
Education gap and HS/SC	0.851				
Education gap and BA+	0.827				

* Education Gap = prevalence for <HS group − prevalence for BA+ group.

Table sorted from highest to lowest pain prevalence for adults aged 25 to 80 years. All prevalences are adjusted for age, sex, race/ethnicity, and percentage of immigrants. All estimates are sample weight adjusted. <HS, less than high school; HS/SC, high school or some college; BA+, bachelor's degree or above. Cell shadings reflect prevalence rankings within each educational category: states among the top 10 are red, and those among the the bottom 10 are green.

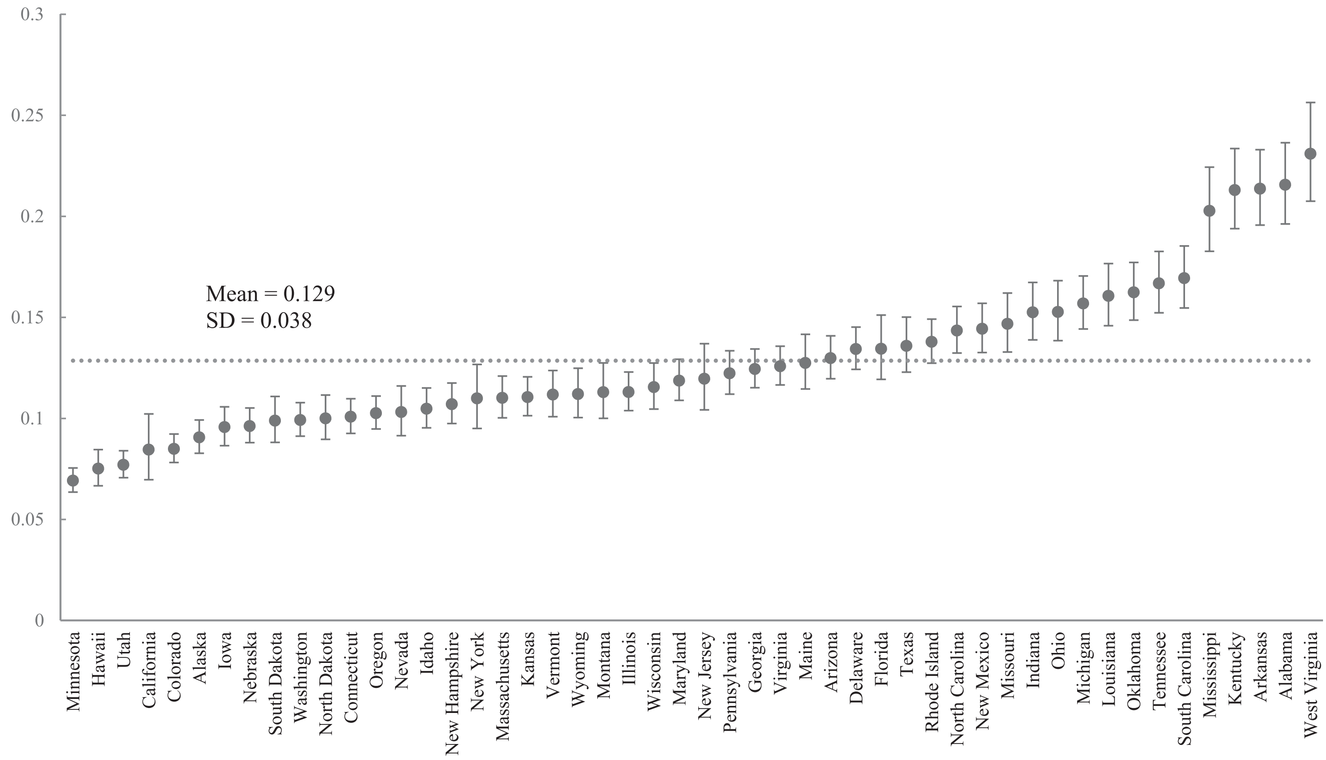

Figure 1. Predicted probability of arthritis-attributable moderate/severe joint pain in adults aged 25 to 80 years, by state. Predicated probabilities are adjusted for age, sex, race/ethnicity, and state's percentage of immigrants. All estimates are sample weight adjusted. Bars show 95% confidence intervals. <HS, less than high school; HS/SC, high school or some college; BA+, bachelor's degree or above.

that states with high educational disparities in joint pain have a higher prevalence, overall and within specific education categories.

Figures 3 and 4 provide a geographic view of cross-state variation in joint pain prevalence and in educational disparities in joint pain, respectively. The 50 states are divided into 5

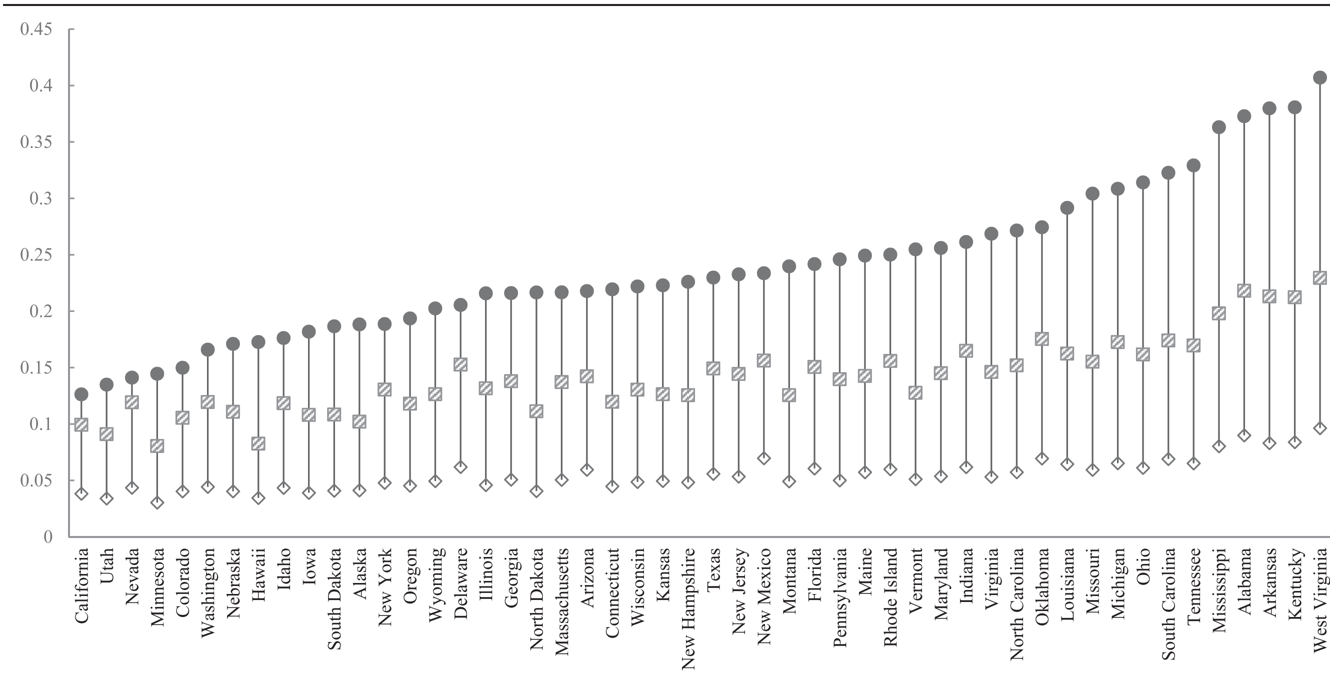

Figure 2. Predicted probability of arthritis-attributable moderate/severe joint pain in adults aged 25 to 80 years, by state and level of education. Predicted probabilities are adjusted by age, sex, race, and percentage of immigrants. All estimates are sample weight adjusted. <HS, less than high school; HS/SC, high school or some college; BA+, bachelor's degree or above.

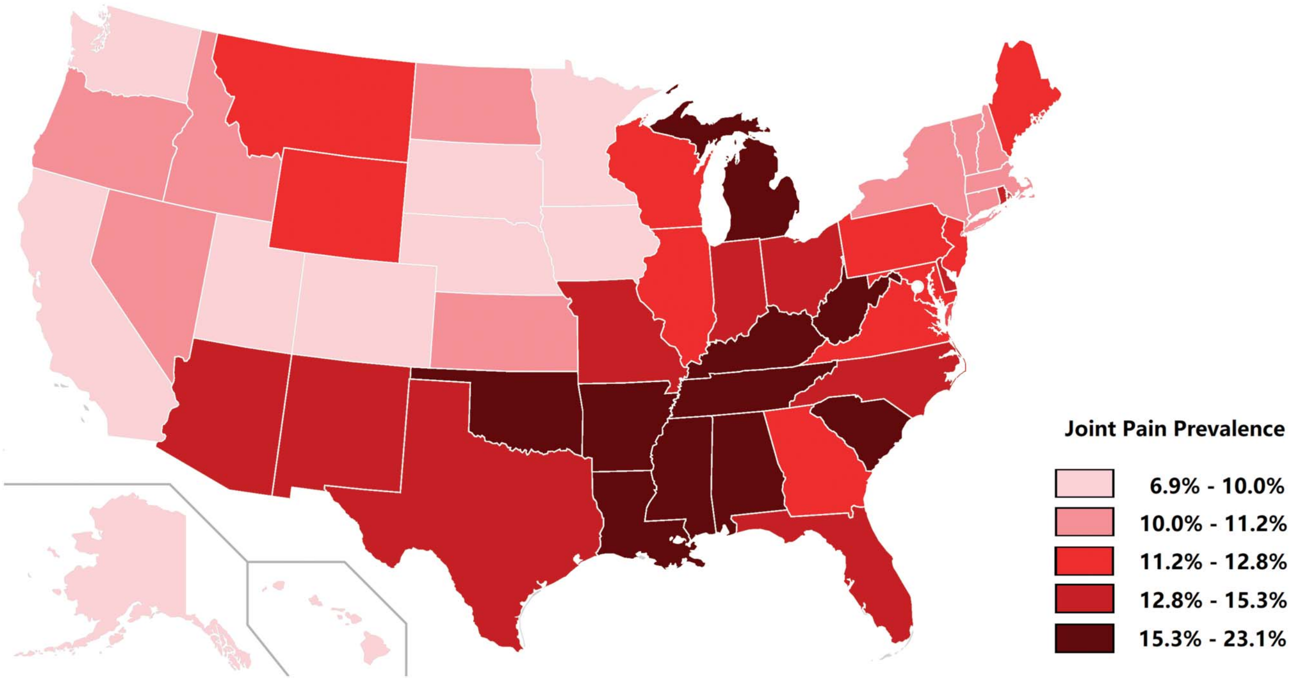

Figure 3. Map of predicted probability of arthritis-attributable moderate/severe joint pain prevalence in adults aged 25 to 80 years, by state, adjusted for age and other demographic characteristics. Predicted probabilities are adjusted for age, sex, race, and percentage of immigrants; with sample-weight adjustment. The 50 states are divided into 5 color-coded categories, each with 10 states, based on rankings of prevalence.

categories, each with 10 states, based on their rankings. Darker shades of red indicate a higher prevalence (in **Fig. 3**) and greater educational gaps (in **Fig. 4**). Similar to **Figure 1**, **Figure 3** presents the predicted probability of joint pain adjusted for age, sex, race/ethnicity, and percentage of immigrants. **Figure 4** presents the odds ratios for <HS vs BA+ groups, controlling for all covariates (model 2). Patterns in **Figures 3 and 4** are very similar, illustrating that the prevalence of joint pain tends to be high in states with large educational gaps. States in the South (especially in the lower Mississippi Valley), the eastern Midwest, and southern and

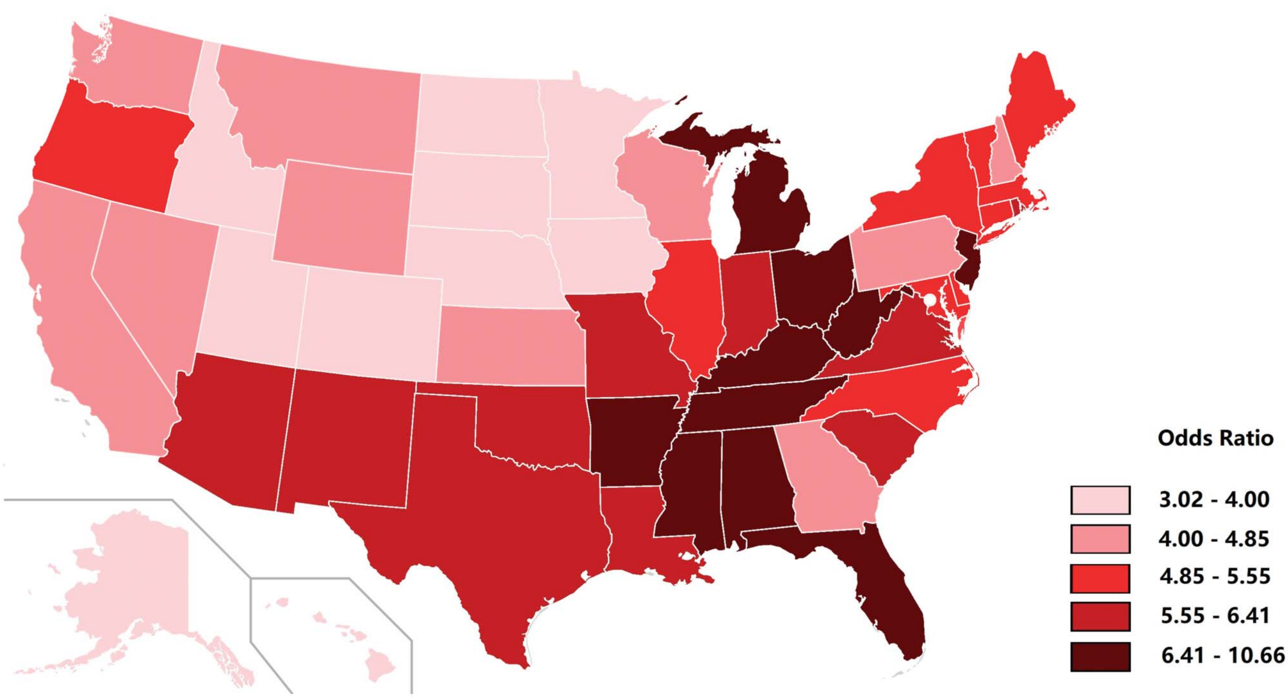

Figure 4. Map of educational disparities in arthritis-attributable moderate/severe joint pain among adults aged 25 to 80 years, by state: Odds ratios for less than high school vs bachelor's degree or more. Odds ratios are generated from model 2, a multilevel logistic regression of arthritis-attributable moderate/severe joint pain on education controlling for age, sex, race/ethnicity, and percentage of immigrants. The 50 states are divided into 5 color-coded categories, each with 10 states, based on rankings of educational disparities in pain.

Table 4

Multilevel logistic regression of arthritis-attributable moderate/severe joint pain on individual-level and state-level factors, among adults aged 25 to 80 years.

	Model 1		Model 2		Model 3	
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
Individual-level factors						
Education (ref: BA+)						
<HS			5.381***	4.923-5.881	5.376***	4.918-5.876
HS/SC			2.694***	2.565-2.829	2.674***	2.542-2.812
Age	1.032***	1.031-1.034	1.029***	1.027-1.031	1.029***	1.027-1.031
Sex (ref: male)						
Female	1.692***	1.625-1.762	1.732***	1.666-1.801	1.732***	1.666-1.801
Race (ref: Whites)						
Blacks	1.749***	1.621-1.887	1.518***	1.416-1.627	1.507***	1.406-1.616
Hispanics	1.201**	1.070-1.348	0.785**	0.681-0.904	0.783**	0.681-0.901
Other	1.248***	1.131-1.378	1.220***	1.113-1.337	1.224***	1.121-1.336
State-level factors						
Percentage of immigrants	0.864***	0.801-0.931	0.922**	0.872-0.976	0.855***	0.800-0.914
EITC					1.008	0.958-1.060
SNAP					**0.925*** **	**0.963-0.957**
MGS					1.022	0.953-1.097
Gini					1.040	0.981-1.102
SCI					**0.819*** **	**0.748-0.896**
Tobacco					1.020	0.956-1.090
Random effects						
State (variance)	0.078	0.053-0.115	0.067	0.047-0.098	0.021	0.012-0.037
Education (variance)						
<HS			0.013	0.004-0.040	0.016	0.006-0.042
HS/SC			0.003	0.001-0.011	0.002	0.000-0.010

†$P < 0.1$. *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

All models are sample weight adjusted. All state-level variables are standardized as Z-scores.

<HS, below high school; HS/SC, high school or some college; BA+, bachelor's degree or above; CI, confidence interval; EITC, Earned Income Tax Credit; Gini, Gini index; MGS, Medicaid Generosity Score; OR, odds ratio; SCI, Social Capital Index; SNAP, Supplemental Nutrition Assistance Program; Tobacco, tobacco taxes. State-level factors significantly predicting joint pain are shown in bold.

central Appalachia have particularly a high prevalence of joint pain as well as high educational inequalities therein.

3.2. State-level predictors of joint pain and educational disparities in joint pain

Table 4 summarizes sample weight–adjusted multilevel logistic regressions of joint pain on key predictors and covariates. Model 1, our baseline model including covariates only, is used to estimate variation in pain prevalence across states, as presented earlier. Model 2 adds fixed and random effects of education to estimate educational disparities. As shown, individuals with <HS have over 5 times higher odds of joint pain than their peers with BA+ (odds ratio [OR] = 5.381, 95% confidence interval [CI]: 4.923-5.881), and individuals with HS/SC have over twice the odds (OR = 2.694, 95% CI: 2.565-2.829).

Table 5

Multilevel logistic regression of arthritis-attributable moderate/severe joint pain on individual-level and state-level predictors, with interactions between education and state-level variables.

State variable in interaction	Model 4 EITC	Model 5 SNAP	Model 6 MGS	Model 7 Gini	Model 8 SCI	Model 9 Tobacco
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Main effect of education (ref: BA+)						
<HS	5.372*** 4.912-5.895	5.373*** 4.915-5.874	5.380*** 4.923-5.880	5.368*** 4.910-5.868	5.384*** 4.931-5.879	5.374*** 4.918-5.871
HS/SC	2.671*** 2.538-2.810	2.673*** 2.542-2.811	2.676*** 2.546-2.811	2.675*** 2.545-2.811	2.670*** 2.541-2.806	2.677*** 2.548-2.812
Main effect of state-level variable	0.987 0.935-1.041	0.940* 0.889-0.996	1.000 0.928-1.076	1.001 0.938-1.068	0.813* 0.741-0.892	0.993 0.943-1.047
Interaction with < HS	1.030 0.964-1.100	0.998 0.963-1.035	1.035 0.966-1.109	1.055 0.979-1.137	1.014 0.994-1.101	1.019 0.958-1.083
Interaction with HS/SC	1.024 0.981-1.069	0.975 0.921-1.032	1.030 0.980-1.083	**1.043*** 1.001-1.087	0.996 0.946-1.050	1.036 0.992-1.083

†$P < 0.1$. *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

All models are sample weight adjusted and are analyzed using multilevel logistic regressions with random intercepts and education slopes, controlling for all covariates and structural variables. All state-level variables are standardized as Z-scores.

<HS, below high school; HS/SC, high school or some college; BA+, bachelor's degree or above; CI, confidence interval; EITC, Earned Income Tax Credit; Gini, Gini index; MGS, Medicaid Generosity Score; OR, odds ratio; SCI, Social Capital Index; SNAP, Supplemental Nutrition Assistance Program; Tobacco, tobacco taxes. State-level factors significantly predicting joint pain are shown in bold.

Model 3 estimates the effects of state-level factors on joint pain. As the Model shows, net of other factors, each standard deviation increase in SNAP is associated with a 7.5% decrease in individuals' odds of joint pain (OR = 0.925, 95% CI: 0.963-0.957), and a 1 standard deviation increase in SCI predicts a 18.1% decrease in joint pain (OR = 0.819, 95% CI: 0.748-0.896). The table also shows that the state random effect indicating the average variation is reduced from 0.067 to 0.021 when moving from model 2 to model 3, ie, these state-level variables explain 68.7% of cross-state variations in joint pain.

Table 5 summarizes the results of sample weight–adjusted multilevel logistic regressions of joint pain on all individual-level and state-level variables, similar to **Table 4**, but now adding interactions between education and each state-level variable in turn. For parsimony, only odds ratios for education and the select state variable (main and interactive effects) are provided. As in **Table 5**, the main effects show strong negative educational gradients in risk of joint pain and significant pain-related benefits from more generous SNAP programs and from higher social cohesion. The cross-level interaction term between HS/SC education and the Gini is statistically significant (OR = 1.043, 95% CI: 1.001-1.087), indicating that respondents with HS/SC in states with higher-income inequality have higher odds of joint pain. However, there is no comparable significant interaction between the Gini and <HS. Interactions between education and the other 5 state-level variables are never statistically significant, indicating that these state structural factors fail to explain divergent educational gradients in joint pain across states.

3.2.1. Additional analyses

Table S4, available at http://links.lww.com/PAIN/B848, summarizes results of models adding state-level predictors one by one, rather than all at once. In these models, higher Gini index and lower SNAP, SCI, and Medicaid Generosity Scores are each associated with a higher risk of joint pain. This suggests that correlative impacts of different state-level characteristics may dampen the unique effects of any single indicator. Next, complementary to models 4 to 9, we estimated cross-level interactions between education and each state contextual characteristic while excluding the other 5 state-level predictors from models. Results are presented in Table S5, available at http://links.lww.com/PAIN/B848, and they are substantially very similar to results in **Table 5**. Next, we performed a series of sex-stratified analyses (Tables S6 and S7, available at http://links.lww.com/PAIN/B848). Results in Table S6 are substantively extremely similar to those in **Table 4** for both men and women. Estimates in Table S7 indicate that educational disparities between HS/SC and BA+ among women (but not among men) are moderated by income inequality (Gini).

Finally, we conducted analyses similar to those summarized in **Tables 4 and 5** and **Figures 1 and 2**, except with dichotomous arthritis diagnosis (yes/no) as the outcome variable. These are shown in Supplementary Tables S8 and S9 and presented in Figures S1 and S2, available at http://links.lww.com/PAIN/B848. Findings for arthritis diagnosis are quite similar to those for moderate or severe joint pain, both for geographic distribution and state-level predictors. However, the magnitude of cross-state variation in both the prevalence of and educational disparities in arthritis are clearly attenuated. That is, arthritis prevalence and educational disparities therein differ by state, but these differences are less pronounced than differences in moderate or severe arthritis-attributable joint pain. Thus, our findings confirm that the effect of state contexts on moderate or severe arthritic joint pain cannot be reduced to an effect of state contexts on the incidence of arthritis. States matter for arthritis, but they matter *more* for moderate or severe arthritis-attributable pain.

4. Discussion

Arthritis-attributable joint pain is a very common, costly, and disabling health problem and disproportionately affects individuals with lower levels of education.[11,55,60,61,65] Although a growing literature documents the importance of social, economic, and political contexts for health inequalities, to our knowledge, this is the first study linking state level factors to educational disparities in pain. Focusing on moderate or severe joint pain among adults aged 25 to 80 years, we estimated (1) the prevalence of joint pain in each of the 50 US states, (2) educational disparities in joint pain within each state, and (3) the extent to which state characteristics (such as social policies) help explain observed cross-state variation in these outcomes.

Our study yields several critical findings. First, joint pain prevalence—even after adjusting for age, sex, race/ethnicity, and a state's percentage of immigrants—varies strikingly across states, from 6.9% in Minnesota (the lowest state prevalence) to 23.1% in West Virginia (the highest). That is, risk of joint pain is more than 3 times higher in some states than in others. Our findings are consistent with previous research on the geographic distribution of arthritis[65] and all-cause pain.[64] Specifically, our geographic findings (**Fig. 3**) show high prevalence of joint pain in regions (such as the South and Appalachia) identified in previous research as pain "hotspots," where residents report extremely high pain scores.[64]

Second, while educational disparities in joint pain are observed in all states, they vary substantially in magnitude (again, even after adjustment for demographic characteristics). The percentage-point difference in pain prevalence between the least educated (who did not complete high school) and the most educated (those with college degrees or more) is much larger in some states, such as West Virginia (31.1 percentage points), Arkansas (29.7), and Alabama (28.3), than in others, such as California (8.8), Nevada (9.8), and Utah (10.1). These variations are driven primarily by the variability in pain prevalence among the least educated. Cross-state variation in joint pain prevalence exists, but is smaller for college graduates. These findings suggest that the least educated are more sensitive, in terms of pain risk, to state-level contexts. For individuals with college or higher degrees, their educational attainment may function as a "personal firewall" that protects them from unfavorable state-level contexts.[41,50]

Nonetheless, members of *all* educational categories, even college graduates, have a higher risk of joint pain if they live in states with high educational disparities (eg, West Virginia) than in low-disparity states (eg, California). That is, large educational disparities in joint pain at the state level predict worse pain outcomes for *everyone* in that specific state, not just the educationally disadvantaged (although this group is particularly affected).

Third, we find that state-level factors help explain cross-state variations in joint pain prevalence and disparities. Specifically, net of other factors, states with higher levels of SNAP benefits (formerly known as food stamps) and higher social cohesion (measured by the SCI) have a lower prevalence of joint pain. These findings are consistent with prior studies examining state-level predictors of disability and mortality.[22,23,42,44] We also find that income inequality helps explain cross-state variation in educational disparities, with higher within-state income inequality predicting greater educational disparities in joint pain.

The significant negative associations of both SNAP benefits and SCI with joint pain suggest that both "place effect" domains identified by Macintyre et al.[36]—material resources and collective social functioning—play a role in shaping pain risk, and hence should be targets of policies designed to reduce pain rates and disparities. The SNAP, as a primary source of nutrition assistance in the United States, provides the disadvantaged with material resources to improve food security.[13] More generous SNAP benefits might reduce pain by enabling healthier diets and reducing food insecurity–related stress.[25] Social cohesion (as measured by the SCI) is a key component of collective social functioning. It may be negatively associated with pain because adverse social environments and "social threats"—including social conflicts, isolation, and devaluation—provoke physiological responses, including inflammation and immune system changes, which may increase the risk of pain.[51] Enhancing collective social functioning may require multilevel coordination (eg, at state, community and individual levels) and policies targeting multiple domains (eg, inequality, unemployment, and health-related behaviors).[44]

Our study did not find statistically significant links between 3 other state-level factors (Earned Income Tax Credit, Medicaid generosity, and tobacco taxes) and joint pain. Some ostensibly salubrious state policies may be unable to overcome the fact that less educated people encounter multiple domains of deprivation, which constrain their ability to deploy available resources.[7] However, the nonsignificant results in our study do not necessarily mean that these factors have no influence on educational disparities in all 50 states. By using multilevel logistic regressions, this study can only examine the *average* contribution of each state-level structural factor. The importance or efficacy of one economic-political factor may depend on other aspects of state contexts, which are shaped by the nexus of a state's history, sociocultural factors, political environment, etc.[30,41,43]

Moreover, the influence of state-level contexts and policies may vary across demographic subgroups. For example, our supplementary analyses show that state income inequality (Gini) matters more for women than men, suggesting that there may be an interplay between sex and state contexts. As Gkiouleka et al.[24] argue, institutions create "the rules of games" and generate "winners" and "losers," but how to play these games is subject to individuals' multilayered (privileged or disadvantaged) sociodemographic characteristics. Further research could explore additional interactions between such characteristics, state contexts, and pain outcomes.

Although this study focuses on US states, similar approaches could be used to analyze subnational and/or cross-national pain disparities elsewhere. Outside of the United States, some emerging research examines within-country health disparities (albeit not specifically pain disparities) as a function of social policies.[6,48,54] Whether provincial or regional sociopolitical contexts modify educational effects on health, however, is largely unknown. In tandem, extensive cross-national studies show that the importance of education on health is shaped by national-level sociopolitical factors.[2,3,10,12,37] However, knowledge of how these factors shape the education–pain association is lacking. This study underscores the importance of redirecting focus toward macro contextual factors that affect pain inequalities. It specifically suggests macro material resources and social functioning as promising factors to explore to better understand—and address—subnational and cross-national pain disparities across the globe.

We acknowledge several limitations of this study. First, due to lack of data, we do not know how long respondents have lived in their current state, and hence how much exposure they have had to a given state context. This may lead to less precise estimates of state effects. Second, we did not have individual-level data on immigrant status, although we controlled for states' percentage of immigrants in all models. Because immigrants tend to have less pain than native-born Americans,[62] the absence of this covariate could bias findings. Third, some state-level data do not exactly match the survey year of individual-level data from the BRFSS (2017). Specifically, data on cumulative years of EITC availability include years 1988 to 2014, and MGSs are generated using 2007 data. However, this is unlikely to cause appreciable bias in our analyses because macrolevel contexts rarely change dramatically over short periods, and state-level policies often have lagged effects. Fourth, there are likely other state-level factors that contribute to pain and pain disparities. Research on macro effects on pain is in its infancy, so we encourage future studies to expand the knowledge base in this area. Finally, this study uses cross-sectional data. We believe this is not a major concern in understanding joint pain disparities because education is typically completed early in life, and our respondents were all age 25 years and older. Nonetheless, longitudinal analyses could be invaluable in tracing the long-term influences of economic-political contexts and examining the causal pathways between state-level factors and educational disparities in pain.

In conclusion, this study has shown that the prevalence of joint pain and educational disparities therein vary considerably across the 50 US states and that at all educational levels, individuals in states with high educational disparities have a higher pain risk. These findings indicate that macro sociopolitical contexts not only play a critical role in shaping individuals' pain experiences but also modify the protective function of education. Our findings thus suggest that state governments could invest in policies to improve food security, increase social cohesion, and reduce income inequality to reduce pain prevalence and disparities. In particular, action is urgently needed to manage (and in the future prevent) the extremely high levels of joint pain in certain US states, especially among the less educated, who are affected disproportionately by this disabling pain condition. Broadly, our findings also highlight the importance of moving beyond individual-level factors in pain research. Further work is needed to understand additional contextual factors that shape the risk of pain and pain disparities and to clarify how social policies could prevent and reduce pain. Future subnational and cross-national comparative studies could draw on our approach to further investigate the role of macro sociopolitical contexts in shaping pain-related outcomes.

Conflict of interest statement

The authors have no conflict of interest to declare.

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