

Rural-urban differences in pain intensity, pain interference, and physical function among cancer survivors

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Additional Declarations: Competing interest reported. D.E.K. is an inventor of the Insight Mobile Health Platform, which was not used or evaluated in the current study, and receives royalties for the external use of the platform outside of the University of Oklahoma Health Sciences Center. D.E.K. is also a member of the Scientific Advisory Board of Qnovia, Inc., a drug development company focused on inhaled therapies, including prescription inhaled nicotine replacement therapy for smoking cessation; no medications were provided or evaluated in the current study. D.E.K. previously received varenicline at no cost from Pfizer to support a completed pilot study; no medications were provided or evaluated in the current study. Except as disclosed above, the authors declare no conflicts of interest.

Abstract

Rural cancer survivors may face structural barriers to symptom management and rehabilitation, yet rural-urban differences in pain and physical function remain understudied. This secondary analysis examined rural-urban differences in pain intensity, pain interference, and physical function among 232 adults receiving care at a National Cancer Institute-designated cancer center in Oklahoma. Rural-urban residence was classified using 2020 Rural-Urban Commuting Area codes based on residential ZIP code. Outcomes were assessed using the Patient-Reported Outcomes Measurement Information System-29. Multivariable linear regression and mixed-effects models examined baseline and longitudinal associations, adjusting for sociodemographic and clinical covariates. Among participants, 92 (39.7%) were rural and 140 (60.3%) were urban. Compared with urban participants, rural participants reported higher baseline pain intensity (4.3 vs 3.2; $p = 0.003$), higher pain interference (57.3 vs 53.6; $p = 0.011$), and lower physical function (41.8 vs 44.4; $p = 0.034$). In longitudinal models, rural residence remained associated with higher pain intensity ($\beta = 0.99$; $p = 0.006$), higher pain interference ($\beta = 3.45$; $p = 0.018$), and lower physical function ($\beta = -2.51$; $p = 0.048$). Findings support targeted pain management, rehabilitation, and virtual care strategies for rural cancer survivors.

Introduction

Advances in cancer screening, detection, and treatment have contributed to a growing population of individuals surviving cancer in the United States ^{1,2}. An estimated 18.6 million cancer survivors reside in the United States in 2025, and this number is expected to exceed 22 million by 2035 ². Although survival rates have improved, many continue to experience persistent symptoms and functional limitations that adversely affect their long-term health and quality of life ^{3,4}. Consequently, survivorship research is increasingly shifting from a focus on traditional clinical outcomes, such as survival, recurrence, disease progression and mortality, toward understanding patient-reported outcomes that influence daily functioning, independence, and overall well-being ⁵.

Pain is among the most common and burdensome symptoms experienced by cancer survivors ^{6,7}. Approximately 30–40% of cancer survivors report experiencing chronic pain, while the prevalence may exceed 50% among those receiving active treatment or living with advanced disease ^{8,9}. Pain may result from the cancer itself (e.g., tumors pressing on nerves, bones, or organs), cancer treatments (e.g., surgery, chemotherapy, and radiation therapy), treatment-related side effects (e.g., peripheral neuropathy, mucositis, and mouth sores), and/or diagnostic and therapeutic procedures ^{10,11}. Cancer-related pain may persist long after treatment completion and is associated with physical disability, reduced quality of life, psychological distress, increased healthcare utilization, and poorer overall health outcomes ^{12–17}. Closely related to pain, physical function reflects survivors' ability to perform daily activities, maintain independence, and participate in meaningful social and occupational roles ^{18,19}. Together, pain and physical function are critical patient-centered indicators of survivorship well-being ^{19–22}.

Substantial rural-urban disparities exist across the cancer continuum^{23–25}. Rural populations in the United States experience higher cancer mortality and poorer survivorship outcomes than urban populations^{26–28}. These disparities are shaped by socioeconomic disadvantages, healthcare workforce shortages, transportation barriers, and limited access to oncology and supportive care services^{29–31}. These structural challenges contribute to lower cancer screening rates, delayed diagnosis, reduced access to guideline-concordant treatment, and higher cancer mortality^{23–25,32}. Oklahoma reflects these rural-urban challenges: approximately 35% of the state's population resides in nonmetropolitan areas³³, where poverty, underinsurance, and cancer mortality rates exceed those in urban areas^{34,35}. Oklahoma is also a unique context for studying symptom management and substance use among cancer survivors because medical cannabis is legal and patient licenses are not restricted to specific qualifying medical conditions³⁶. Although rural cancer disparities in cancer screening, treatment access, and mortality are well documented, less is known about rural-urban differences in pain intensity, pain interference, and physical function among cancer survivors.

Rural survivors may be particularly vulnerable to persistent pain and functional impairment because effective symptom management often depends on resources that may be less available to those living in non-metropolitan areas, such as timely access to multidisciplinary supportive care, rehabilitation services, pain specialists, and longitudinal follow-up^{9,37}. Geographic barriers, longer travel distances, and limited healthcare resources may hinder access to these services among rural populations^{23,38}. Recent evidence suggests that rural cancer survivors are more likely to experience chronic pain than their urban counterparts, even after accounting for demographic, socioeconomic, and health-related factors^{9,39}. However, prior studies have primarily focused on the presence or absence of chronic pain and have relied largely on cross-sectional data³⁹. Less is known about whether rural cancer survivors experience greater pain intensity, pain interference, and poorer physical function or whether these disparities persist over time. Addressing these gaps is important because pain and functional limitations represent potentially modifiable survivorship outcomes and may contribute substantially to broader rural cancer disparities.

Identifying populations at elevated risk for persistent pain and functional impairment may inform the development of targeted supportive care interventions and resource allocation strategies aimed at reducing rural survivorship disparities. Therefore, the primary objective of this study was to examine whether rural residence compared with urban residence was independently associated with pain intensity, pain interference, and physical function after adjustment for relevant sociodemographic and clinical characteristics. Secondary objectives were to characterize rural-urban differences in participant characteristics and to determine whether these associations persisted over six months of follow-up. We hypothesized that rural residence would be independently associated with greater pain burden and poorer physical function and that these associations would remain stable over the six-month follow-up period.

Methods

Study Design and Participants

This study is a secondary analysis of data from a prospective observational cohort study designed to examine cannabis use, symptom burden, and health-related quality of life among cancer survivors receiving care at the National Cancer Institute (NCI)-designated Stephenson Cancer Center in Oklahoma City, Oklahoma. Data collection occurred between June 2020 and June 2022. Detailed descriptions of the parent study design, recruitment procedures, eligibility criteria, and data collection methods have been published elsewhere^{40,41}. Briefly, parent study eligibility criteria included being 18 years of age or older, receiving care at Stephenson Cancer Center, being able to read and complete study questionnaires without assistance, and having internet access to complete questionnaires. Participants were not restricted by cancer type or stage; cancer type, cancer stage, cancer status, and other health diagnoses were collected from the electronic medical record. Participants completed a baseline survey assessing cannabis use, health-related quality of life, symptom burden, and health behaviors, followed by three additional surveys administered at 2-, 4-, and 6-month follow-up visits. The present secondary analysis examined whether rural residence was independently associated with pain intensity, pain interference, and physical function at baseline and whether these associations persisted from baseline to 6-month follow-up.

A total of 270 participants completed the baseline survey. For the present study, participants were required to have residential ZIP code information available to classify rural-urban residence using 2020 Rural-Urban Commuting Area (RUCA) codes. Therefore, 38 participants without residential ZIP code information were excluded from analyses. The final analytic sample included 232 participants, of whom 92 (39.7%) resided in rural areas and 140 (60.3%) resided in urban areas.

The parent study was approved by the University of Oklahoma Health Campus Institutional Review Board (Protocol #11680), and all participants provided written informed consent before enrollment.

Variables

Rural-Urban Residence

The primary exposure was rural-urban residence, classified using the 2020 RUCA codes based on the participants' residential ZIP codes⁴². RUCA codes classify geographic areas using urban area size and commuting patterns; primary codes range from 1 to 10, with codes 1–3 representing metropolitan areas, codes 4–6 representing micropolitan areas, codes 7–9 representing small-town areas, and code 10 representing rural areas. The ZIP code-level RUCA codes used in this study are derived from census tract RUCA codes and assign each ZIP code to the primary RUCA code representing the largest resident population within that ZIP code area. Participants residing in ZIP code areas associated with RUCA

codes 1–3 were classified as urban and participants residing in ZIP code areas associated with RUCA codes 4–10 were classified as rural.

Sociodemographic and Clinical Characteristics

Sociodemographic characteristics included age (continuous), sex (male or female), race (White or non-White), ethnicity (Hispanic/Latino or non-Hispanic/Latino), marital status (married/partnered or other), educational attainment ($\leq$ high school or $>$ high school), employment status (employed or not employed), annual household income ($<$ \$50,000 or $\geq$ \$50,000), and insurance type. Insurance was categorized as Medicaid/SoonerCare or uninsured versus all other insurance types, including Medicare, private/employer-sponsored insurance, and military/Veterans Affairs (VA) insurance.

Clinical characteristics included cancer type (breast, gynecologic, gastrointestinal, genitourinary, or other), cancer stage (stage 0-II vs stage III-IV), treatment burden (0–1, 2, or $\geq$ 3 treatment modalities), and comorbid medical conditions. Cancer stage data were available for a subset of participants ($n = 176$). Comorbidities were grouped into cardiometabolic conditions (yes/no), pulmonary disease (yes/no), and other chronic conditions (yes/no). Cardiometabolic conditions included hypertension, diabetes, hyperlipidemia, cardiovascular disease, and overweight/obesity. Pulmonary diseases include asthma, chronic bronchitis, emphysema, and chronic obstructive pulmonary disease (COPD). Other comorbidities and chronic conditions that were assessed included depression, anxiety, posttraumatic stress disorder, bipolar disorder, kidney disease, epilepsy, traumatic brain injury, hepatitis, and HIV/AIDS.

COVID-19 Experiences

Additional clinical variables included COVID-19 experiences, measured at baseline, and included history of a positive COVID-19 test, vaccination status (unvaccinated, one dose, or two doses), and difficulty accessing healthcare appointments during the pandemic.

Behavioral Health and Substance Use

Behavioral health and substance use variables were assessed at baseline and included lifetime and past 30-day use of tobacco, alcohol, over-the-counter (OTC) painkillers, and prescription opioid use. Cannabis-related variables assessed at baseline included lifetime and past 30-day cannabis use, medical cannabis use, recreational cannabis use, medical marijuana card status, and cannabidiol (CBD) use. Medical cannabis use was defined in the survey as cannabis use “to treat or help improve symptoms of a medical condition or health problem,” whereas recreational cannabis use was defined as use “for pleasure/satisfaction, for fun at a social gathering.” The Cannabis Use Disorder Identification Test-Revised (CUDIT-R) was used to assess hazardous cannabis use among participants reporting cannabis use in the past 6 months, with scores ≥ 8 indicating hazardous use⁴³. Attitudes toward cannabis legalization were assessed using two items: agreement that recreational cannabis use among adults

aged 21 years and older should be legalized in Oklahoma and agreement that medical cannabis legalization has been good for Oklahoma. Responses were categorized as support versus do not support.

Patient-Reported Outcomes

The primary outcomes were measured at both the baseline survey and 6-month follow-up and included pain intensity, pain interference, and physical function, assessed using the Patient-Reported Outcomes Measurement Information System (PROMIS)-29 Profile version 2.0⁴⁴. Pain intensity was measured using a single-item numeric rating scale ranging from 0 to 10, with higher scores indicating greater pain severity. Pain interference and physical function were assessed using four-item PROMIS-29 domains, with raw summed scores ranging from 4 to 20 and converted to standardized PROMIS T-scores (mean = 50; SD = 10), with higher pain interference scores indicating greater pain-related burden and higher physical function scores indicating better functioning⁴⁵. Additional PROMIS-29 domains included fatigue, sleep disturbance, and social function. Fatigue, sleep disturbance, and social function were also assessed using four-item PROMIS-29 domains, with raw summed scores ranging from 4 to 20 and converted to standardized T-scores. Higher fatigue and sleep disturbance scores indicate greater symptom burden, whereas higher social function scores indicate better functioning. These domains were examined descriptively and in supplementary models.

Statistical Analysis

Participant characteristics were summarized using means (SDs) for continuous variables and frequencies (proportions) for categorical variables. Rural–urban differences at the baseline survey were evaluated using independent samples t-tests for continuous variables and χ^2 tests or Fisher exact tests, as appropriate, for categorical variables. Behavioral health and substance use variables, COVID-19-related variables, and patient-reported outcomes other than the primary study outcomes were summarized descriptively to characterize the study population. Additional multivariable models were estimated for the supplementary PROMIS-29 domains of fatigue, sleep disturbance, and social function. Separate multivariable linear regression models were estimated with rural-urban residence as the primary independent variable and pain intensity, pain interference, and physical function as separate dependent variables. Analytic sample sizes varied across models because participants with missing outcome or covariate data were excluded from the corresponding complete-case model. Models were adjusted for prespecified sociodemographic and clinical covariates based on clinical relevance and existing literature, including age, sex, annual household income, insurance type, cancer type, treatment burden, cardiometabolic conditions, pulmonary disease, and other chronic conditions. Results are presented as unstandardized regression coefficients (β) with 95% confidence intervals (CIs). Variance inflation factors (VIFs) were examined to assess multicollinearity, with VIF values < 5 considered acceptable and values ≥ 5 indicating potential multicollinearity⁴⁶. To evaluate whether associations between rural-urban residence and patient-reported outcomes persisted over time, linear mixed-effects

models with participant-level random intercepts were estimated using restricted maximum likelihood with data from baseline and 6-month follow-up assessments. Fixed effects included rural-urban residence, time, the rural-urban residence $\times$ time interaction, and the same covariates included in the baseline survey regression models. The interaction term was used to assess whether rural-urban differences changed from baseline to 6-month follow-up. Mixed-effects models included 461 observations. All analyses were conducted using IBM SPSS Statistics version 31 (IBM Corp., Armonk, NY). Statistical significance was defined as a two-sided $p < 0.05$.

Results

Participant Characteristics

The final analytic sample included 232 cancer survivors, of whom 92 (39.7%) resided in rural areas and 140 (60.3%) resided in urban areas (Table 1). Participants had a mean age of 58.3 years (SD = 13.8). Most participants were female (68.5%), White (90.1%), non-Hispanic/Latino (94.8%), and married or had a partner (65.1%). Nearly two-thirds were not employed at baseline (65.1%), and 47.3% reported annual household income below \$50,000. Urban and rural participants were similar with respect to age, sex, race, ethnicity, marital status, annual household income, and employment status. A greater proportion of rural versus urban participants had a high school education or less (25.0% vs 12.9%; $p = 0.018$) and Medicaid/SoonerCare coverage or were uninsured (22.8% vs 7.9%; $p = 0.001$). Clinical characteristics were generally comparable across groups. Cancer type, treatment burden, cancer stage, and comorbidity burden did not differ significantly between urban and rural participants.

Table 1
Sociodemographic and Clinical Characteristics of Cancer Survivors by Rural-Urban Residence

Demographics	Total (N = 232)	Rural (N = 92; 39.7%)	Urban (N = 140; 60.3%)	p
Age, mean (SD), y	58.3 (13.8)	58.4 (13.3)	58.2 (14.2)	0.916
Sex, n (%)				0.784
Female	159 (68.5)	64 (69.6)	95 (67.9)	—
Male	73 (31.5)	28 (30.4)	45 (32.1)	—
Race, n (%)				0.693
White	209 (90.1)	82 (89.1)	127 (90.7)	—
Non-White	23 (9.9)	10 (10.9)	13 (9.3)	—
Ethnicity, n (%)				0.068
Hispanic/Latino	12 (5.2)	8 (8.7)	4 (2.9)	—
Non-Hispanic/Latino	220 (94.8)	84 (91.3)	136 (97.1)	—
Marital status, n (%)				0.550
Married/have a partner	151 (65.1)	62 (67.4)	89 (63.6)	—
Other	81 (34.9)	30 (32.6)	51 (36.4)	—
Education, n (%)				0.018
≤High school	41 (17.7)	23 (25.0)	18 (12.9)	—
>High school	191 (82.3)	69 (75.0)	122 (87.1)	—
Annual household income, n (%) ^a				0.236
<\$50,000	107 (47.3)	46 (52.3)	61 (44.2)	—
≥\$50,000	119 (52.7)	42 (47.7)	77 (55.8)	—
Employment status, n (%)				0.149
Employed	81 (34.9)	27 (29.3)	54 (38.6)	—
Not employed	151 (65.1)	65 (70.7)	86 (61.4)	—
Insurance type, n (%)				0.001
Medicaid/SoonerCare or uninsured	32 (13.8)	21 (22.8)	11 (7.9)	—

Demographics	Total (N = 232)	Rural (N = 92; 39.7%)	Urban (N = 140; 60.3%)	p
All other insurance types	200 (86.2)	71 (77.2)	129 (92.1)	—
Clinical Characteristics				
Cancer type, n (%)				0.496
Breast	41 (17.7)	18 (19.6)	23 (16.4)	—
Gynecologic	52 (22.4)	19 (20.7)	33 (23.6)	—
Gastrointestinal	38 (16.4)	19 (20.7)	19 (13.6)	—
Genitourinary	32 (13.8)	13 (14.1)	19 (13.6)	—
Other	69 (29.7)	23 (25.0)	46 (32.9)	—
Cancer treatment burden, n (%)				0.652
0–1 modality	60 (25.9)	25 (27.2)	35 (25.0)	—
2 modalities	84 (36.2)	30 (32.6)	54 (38.6)	—
≥3 modalities	88 (37.9)	37 (40.2)	51 (36.4)	—
Cancer stage, n (%) [§]				0.500
Stage 0–II (early)	68 (38.6)	28 (41.8)	40 (36.7)	—
Stage III–IV (advanced)	108 (61.4)	39 (58.2)	69 (63.3)	—
Comorbidities, n (%)				
Cardiometabolic condition [¶]	171 (73.7)	68 (73.9)	103 (73.6)	0.954
Pulmonary disease [¶]	48 (20.7)	16 (17.4)	32 (22.9)	0.315
Other chronic condition [¶]	156 (67.2)	64 (69.6)	92 (65.7)	0.541

Demographics	Total (N = 232)	Rural (N = 92; 39.7%)	Urban (N = 140; 60.3%)	p
<i>Note. Rural-urban residence was classified using the 2020 Rural-Urban Commuting Area (RUCA) classification system based on participants' residential ZIP codes (urban = RUCA 1–3; rural = RUCA 4–10). Continuous variables were compared using independent samples t-tests; categorical variables were compared using Pearson chi-square tests or Fisher exact tests where expected cell counts were < 5. Bolded p-values indicate statistical significance at $p < 0.05$.</i>				
☒ N = 226 (6 missing). ☒ N = 176 (56 missing; 24.1%); Pearson chi-square reported.				
☒ <i>Cardiometabolic: hypertension, diabetes, high cholesterol, cardiovascular disease, overweight/obesity.</i>				
☒ <i>Pulmonary: chronic bronchitis, COPD, emphysema, asthma.</i>				
☒ <i>Other chronic: depression, anxiety, PTSD, bipolar disorder, kidney disease, epilepsy, TBI, hepatitis, HIV/AIDS.</i>				
<i>Insurance type was categorized as Medicaid/SoonerCare (N = 25) or uninsured (N = 7) versus all other insurance types, including Medicare (N = 103), private insurance (N = 92), and VA/military insurance (N = 5).</i>				

Behavioral Health and Substance Use

Behavioral health and substance use characteristics at the baseline survey are summarized in Table 2. Compared with urban residing participants, a greater proportion of rural participants reported ever using other tobacco products, excluding cigarettes and e-cigarettes (13.0% vs 3.6%; $p = 0.009$), past 30-day use of other tobacco products (4.3% vs 0.0%; $p = 0.029$), and past 30-day prescription opioid use (43.5% vs 30.0%; $p = 0.036$). No other significant rural-urban differences in behavioral health, substance use, or cannabis-related characteristics emerged. Cannabis policy attitudes differed by residence. Specifically, a greater proportion of urban than rural participants supported recreational cannabis legalization (50.7% vs 33.0%; $p = 0.009$) and medical cannabis legalization (68.0% vs 51.8%; $p = 0.018$).

Table 2
Behavioral Health and Substance Use Characteristics of Cancer Survivors by Rural-Urban Residence at Baseline Survey

Tobacco Use, n (%)	Total (N = 232)	Rural (N = 92)	Urban (N = 140)	p
Cigarettes, ever use	56 (24.1)	24 (26.1)	32 (22.9)	0.574
Cigarettes, past 30-day use	23 (9.9)	11 (12.0)	12 (8.6)	0.399
E-cigarettes, ever use [‡]	16 (6.9)	6 (6.5)	10 (7.1)	1.000
Other tobacco products, ever use [‡]	17 (7.3)	12 (13.0)	5 (3.6)	0.009
Other tobacco products, past 30-day use [‡]	4 (1.7)	4 (4.3)	0 (0.0)	0.029
Alcohol Use, n (%)				
Ever use	169 (72.8)	63 (68.5)	106 (75.7)	0.225
Past 30-day use	88 (37.9)	30 (32.6)	58 (41.4)	0.176
OTC Painkiller Use, n (%)				
Ever use	219 (94.4)	84 (91.3)	135 (96.4)	0.097
Past 30-day use	130 (56.0)	52 (56.5)	78 (55.7)	0.904
Prescription Opioid Use, n (%)				
Ever use	173 (74.6)	74 (80.4)	99 (70.7)	0.096
Past 30-day use	82 (35.3)	40 (43.5)	42 (30.0)	0.036
Cannabis Use, n (%)				
Cannabis, ever use	82 (35.3)	34 (37.0)	48 (34.3)	0.677
Cannabis, past 30-day use	60 (25.9)	24 (26.1)	36 (25.7)	0.949
Medical cannabis, past 30-day use	55 (23.7)	22 (23.9)	33 (23.6)	0.952
<i>Note. Categorical variables were compared using Pearson chi-square tests or Fisher exact tests where expected cell counts were < 5. Bolded p-values indicate statistical significance at p < 0.05. OTC = over-the-counter; CBD = cannabidiol; CUDIT-R = Cannabis Use Disorder Identification Test-Revised.</i>				
[‡] Small cell sizes; Fisher exact test used; interpret with caution.				
[‡] CUDIT-R was completed by participants who reported cannabis use in the past 6 months (N = 67; urban N = 40; rural N = 27). Percentages were calculated among participants with complete CUDIT-R data.				

Tobacco Use, n (%)	Total (N = 232)	Rural (N = 92)	Urban (N = 140)	p
Recreational cannabis, past 30-day use	17 (7.3)	4 (4.3)	13 (9.3)	0.158
Medical marijuana card	41 (17.8)	12 (13.2)	29 (20.9)	0.160
CUDIT-R hazardous use (≥ 8) [‡]	14 (20.9)	7 (25.9)	7 (17.5)	0.405
CBD ever use	100 (43.1)	41 (44.6)	59 (42.1)	0.716
CBD past 30-day use	55 (23.7)	21 (22.8)	34 (24.3)	0.798
Cannabis Policy Attitudes, n (%)				
Support recreational legalization	97 (43.7)	29 (33.0)	68 (50.7)	0.009
Support medical legalization	130 (61.6)	43 (51.8)	87 (68.0)	0.018
<i>Note. Categorical variables were compared using Pearson chi-square tests or Fisher exact tests where expected cell counts were < 5. Bolded p-values indicate statistical significance at $p < 0.05$. OTC = over-the-counter; CBD = cannabidiol; CUDIT-R = Cannabis Use Disorder Identification Test-Revised.</i>				
[‡] Small cell sizes; Fisher exact test used; interpret with caution.				
[‡] CUDIT-R was completed by participants who reported cannabis use in the past 6 months (N = 67; urban N = 40; rural N = 27). Percentages were calculated among participants with complete CUDIT-R data.				

Patient-Reported Outcomes

Patient-reported outcomes and COVID-19 experiences at baseline are presented in Table 3. Compared with urban participants, rural participants reported higher pain intensity (4.3 [2.9] vs 3.2 [2.5]; $p = 0.003$), higher pain interference (57.3 [11.3] vs 53.6 [10.0]; $p = 0.011$), and lower physical function than urban participants (41.8 [9.7] vs 44.4 [8.7]; $p = 0.034$). Fatigue, sleep disturbance, and social function did not differ significantly by rural–urban residence. COVID-19-related experiences also differed by residence. A smaller proportion of rural than urban participants reported a previous positive COVID-19 test (5.5% vs 16.2%; $p = 0.015$), whereas a greater proportion reported difficulty accessing healthcare appointments during the pandemic (42.9% vs 28.7%; $p = 0.027$). Among participants with available COVID-19 vaccination data (N = 92), a greater proportion of rural participants were unvaccinated (33.3% vs 10.7%) and a lower proportion completed the two-dose vaccination series (61.1% vs 87.5%; $p = 0.013$).

Table 3

Patient-Reported Outcomes and COVID-19 Experiences of Cancer Survivors by Rural-Urban Residence at Baseline Survey

PROMIS-29 Profile, Version 2.0	Total (N = 232) Mean (SD)	Rural (N = 92) Mean (SD)	Urban (N = 140) Mean (SD)	p
Pain Intensity (NRS 0–10) ^a	3.6 (2.7)	4.3 (2.9)	3.2 (2.5)	0.003
Pain Interference ^a	55.1 (10.7)	57.3 (11.3)	53.6 (10.0)	0.011
Physical Function ^b	43.4 (9.2)	41.8 (9.7)	44.4 (8.7)	0.034
Fatigue ^b	52.8 (12.0)	54.3 (12.4)	51.9 (11.8)	0.144
Sleep Disturbance ^b	51.5 (5.5)	51.4 (5.8)	51.5 (5.3)	0.833
Social Function ^a	48.2 (10.6)	46.5 (10.9)	49.3 (10.3)	0.052
COVID-19 Experiences, n (%)				
Ever tested COVID-19 positive	27 (11.9)	5 (5.5)	22 (16.2)	0.015
COVID-19 vaccination status [‡]				0.013
Unvaccinated	18 (19.6)	12 (33.3)	6 (10.7)	—
One dose	3 (3.3)	2 (5.6)	1 (1.8)	—
Two doses	71 (77.2)	22 (61.1)	49 (87.5)	—
Difficulty accessing healthcare appointments [‡]	78 (34.4)	39 (42.9)	39 (28.7)	0.027
<i>Note. Continuous variables compared using independent samples t-tests; categorical variables compared using Pearson chi-square tests. Bolded p-values indicate statistical significance at p < 0.05.</i>				
<i>PROMIS-29 = Patient-Reported Outcomes Measurement Information System 29-item Profile, Version 2.0. T-scores reported (mean = 50, SD = 10). Higher Physical Function and Social Function scores indicate better functioning; higher Fatigue, Sleep Disturbance, and Pain Interference scores indicate greater burden. Pain intensity was assessed using a numeric rating scale (NRS) ranging from 0 to 10.</i>				
^a N = 226 (6 missing); ^b N = 227 (5 missing) [‡] Vaccination status available for N = 92 (2-month follow-up completers). [‡] N = 227 (5 missing).				

Multivariable Regression Models

Multivariable regression models included 221 participants in the pain intensity and pain interference models and 222 participants in the physical function model because of outcome-specific missingness

and available covariate data (Table 4). After adjustment for age, sex, annual household income, insurance type, cancer type, treatment burden, and comorbidities, rural residence remained independently associated with higher pain intensity ($\beta = 0.94$; 95% CI, 0.21 to 1.67; $p = 0.012$), higher pain interference ($\beta = 3.38$; 95% CI, 0.50 to 6.25; $p = 0.022$), and lower physical function ($\beta = -2.60$; 95% CI, -5.02 to -0.19; $p = 0.035$), compared with urban residence.

Table 4

Multivariable Linear Regression Models Predicting Baseline-Survey Pain Intensity, Pain Interference, and Physical Function by Rural-Urban Residence

	Pain Intensity (N = 221)		Pain Interference (N = 221)		Physical Function (N = 222)	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Primary Predictor						
Rural residence (ref: Urban)	0.94 (0.21, 1.67)	0.012	3.38 (0.50, 6.25)	0.022	-2.60 (-5.02, -0.19)	0.035
Sociodemographic Covariates						
Age	-0.02 (-0.05, 0.01)	0.262	0.01 (-0.10, 0.13)	0.843	-0.16 (-0.25, -0.06)	0.001
Male sex (ref: Female)	-0.67 (-1.67, 0.33)	0.188	-3.33 (-7.27, 0.62)	0.098	3.37 (0.05, 6.69)	0.047
Income $\geq$ \$50,000 (ref: <\$50,000)	-0.52 (-1.30, 0.27)	0.195	-0.77 (-3.87, 2.32)	0.623	2.07 (-0.54, 4.67)	0.119
Medicaid/Uninsured (ref: All other)	0.83 (-0.32, 1.97)	0.157	4.47 (-0.05, 8.98)	0.052	-1.67 (-5.47, 2.13)	0.387
Clinical Covariates						
Cancer: Breast (ref: Other)	-1.31 (-2.52, -0.10)	0.033	-4.60 (-9.36, 0.17)	0.059	4.91 (0.90, 8.91)	0.017
Cancer: GI (ref: Other)	-0.39 (-1.49, 0.72)	0.492	-2.47 (-6.82, 1.89)	0.265	4.13 (0.46, 7.79)	0.028
Cancer: Gynecologic (ref: Other)	-1.76 (-2.83, -0.69)	0.001	-6.23 (-10.43, -2.02)	0.004	5.19 (1.65, 8.72)	0.004
<i>Note. Fully adjusted models. Reference categories: Urban residence; Female sex; Income <\$50,000; All other insurance types (Medicare, private/employer-sponsored, military/VA); Other cancer type; 0–1 treatment modalities; No comorbidity. β = unstandardized coefficient; CI = confidence interval. Higher Pain Interference = greater burden; higher Physical Function = better functioning; Pain Intensity = NRS 0–10. All VIF < 2.0. Bolded p-values indicate statistical significance at $p < 0.05$.</i>						

	Pain Intensity (N = 221)		Pain Interference (N = 221)		Physical Function (N = 222)	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Primary Predictor						
Cancer: Genitourinary (ref: Other)	-1.28 (-2.52, -0.03)	0.045	-5.17 (-10.08, -0.25)	0.040	3.65 (-0.50, 7.79)	0.084
Treatment: 2 modalities (ref: 0-1)	-0.38 (-1.33, 0.58)	0.438	-0.96 (-4.71, 2.80)	0.616	-1.38 (-4.54, 1.77)	0.389
Treatment: 3 + modalities (ref: 0-1)	-0.20 (-1.18, 0.78)	0.690	-1.27 (-5.14, 2.60)	0.518	-1.82 (-5.08, 1.45)	0.274
Comorbidities						
Cardiometabolic condition (ref: No)	0.08 (-0.77, 0.93)	0.858	0.03 (-3.33, 3.38)	0.987	-0.87 (-3.68, 1.95)	0.544
Pulmonary disease (ref: No)	0.14 (-0.71, 0.99)	0.745	1.80 (-1.56, 5.16)	0.292	-1.94 (-4.77, 0.89)	0.178
Other chronic condition (ref: No)	0.85 (0.07, 1.62)	0.033	3.35 (0.29, 6.40)	0.032	-3.51 (-6.09, -0.94)	0.008
Model Fit						
R ²	0.181		0.164		0.199	
n	221		221		222	
<i>Note. Fully adjusted models. Reference categories: Urban residence; Female sex; Income <\$50,000; All other insurance types (Medicare, private/employer-sponsored, military/VA); Other cancer type; 0-1 treatment modalities; No comorbidity. β = unstandardized coefficient; CI = confidence interval. Higher Pain Interference = greater burden; higher Physical Function = better functioning; Pain Intensity = NRS 0-10. All VIF < 2.0. Bolded p-values indicate statistical significance at $p < 0.05$.</i>						

Insurance type was not significantly associated with pain intensity or physical function in baseline survey models, although Medicaid/SoonerCare or uninsured status was associated with higher pain interference at a level approaching statistical significance ($\beta = 4.47$; 95% CI, -0.05 to 8.98; $p = 0.052$). Other chronic conditions were consistently associated with worse primary outcomes. Participants with other chronic conditions reported higher pain intensity ($\beta = 0.85$; 95% CI, 0.07 to 1.62; $p = 0.033$), higher pain interference ($\beta = 3.35$; 95% CI, 0.29 to 6.40; $p = 0.032$), and lower physical function ($\beta = -3.51$; 95% CI, -6.09 to -0.94; $p = 0.008$) than those without these conditions. Older age was associated with lower

physical function ($\beta = -0.16$; 95% CI, -0.25 to -0.06 ; $p = 0.001$) but not with pain intensity or pain interference. Model R^2 values were 0.181 for pain intensity, 0.164 for pain interference, and 0.199 for physical function, and all variance inflation factors were below 2.0, suggesting no evidence of problematic multicollinearity.

Longitudinal Analyses

Results of the linear mixed-effects models are presented in Table 5. Across 461 observations, rural residence remained independently associated with all three primary outcomes from baseline to 6-month follow-up. Compared with urban residence, rural residence was associated with higher pain intensity ($\beta = 0.99$; 95% CI, 0.29 to 1.70; $p = 0.006$), higher pain interference ($\beta = 3.45$; 95% CI, 0.59 to 6.31; $p = 0.018$), and lower physical function ($\beta = -2.51$; 95% CI, -5.01 to -0.02 ; $p = 0.048$) at baseline. The main effect of time was not statistically significant for pain intensity, pain interference, or physical function, indicating that these outcomes did not significantly change from baseline to 6-month follow-up among urban participants, who served as the reference group. The rural residence $\times$ time interaction was also not significant for any of the three primary outcomes, indicating that changes over time did not differ significantly between rural and urban participants. Participants with Medicaid/SoonerCare coverage or no insurance had higher pain interference across time compared with participants with other insurance types ($\beta = 4.54$; 95% CI, 0.60 to 8.48; $p = 0.024$). Insurance status was not significantly associated with pain intensity or physical function in longitudinal models. Intraclass correlation coefficients were 0.477 for pain intensity, 0.450 for pain interference, and 0.676 for physical function, indicating moderate to substantial within-person stability in outcomes over time.

Table 5
Mixed-Effects Models Examining Rural-Urban Differences in Pain Intensity, Pain Interference, and Physical Function From Baseline Survey to 6-Month Follow-Up

	Pain Intensity		Pain Interference		Physical Function	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Primary Predictor						
Rural residence (ref: Urban)	0.99 (0.29, 1.70)	0.006	3.45 (0.59, 6.31)	0.018	-2.51 (-5.01, -0.02)	0.048
Time						
6 months (ref: baseline survey)	-0.81 (-1.98, 0.37)	0.178	-3.87 (-8.71, 0.97)	0.117	-2.44 (-6.00, 1.12)	0.179
Sociodemographic Covariates						
Age	-0.01 (-0.03, 0.02)	0.678	0.04 (-0.06, 0.14)	0.418	-0.15 (-0.24, -0.06)	< 0.001
Male sex (ref: Female)	-0.34 (-1.05, 0.37)	0.349	-1.97 (-4.85, 0.91)	0.178	2.03 (-0.56, 4.62)	0.124
Income $\geq$ \$50,000 (ref: <\$50,000)	-0.42 (-1.07, 0.24)	0.209	-1.13 (-3.77, 1.52)	0.402	2.12 (-0.32, 4.55)	0.088
Medicaid/Uninsured (ref: All other)	0.69 (-0.29, 1.67)	0.167	4.54 (0.60, 8.48)	0.024	-2.96 (-6.61, 0.68)	0.110
Clinical Covariates						
Cancer: Breast (ref: Other)	-0.93 (-1.93, 0.08)	0.072	-3.17 (-7.31, 0.97)	0.133	2.42 (-0.67, 5.51)	0.124
Cancer: GI (ref: Other)	0.01 (-0.96, 0.99)	0.981	-1.13 (-5.13, 2.87)	0.579	1.71 (-1.32, 4.73)	0.267
Cancer: Gynecologic (ref: Other)	-1.14 (-2.02, -0.26)	0.011	-3.63 (-7.24, -0.02)	0.049	1.32 (-1.36, 4.00)	0.332

Note. Mixed-effects models with random intercepts for participant ID, estimated using REML. Models included rural residence, time, rural $\times$ time interaction, and all covariates simultaneously. Non-significant interaction terms (all $p > 0.28$) indicate rural-urban disparities remained stable from baseline survey to 6-month follow-up. ICC = intraclass correlation coefficient. Bolded p-values indicate statistical significance at $p < 0.05$.

	Pain Intensity		Pain Interference		Physical Function	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Primary Predictor						
Cancer: Genitourinary (ref: Other)	-1.39 (-2.42, -0.35)	0.009	-5.49 (-9.74, -1.24)	0.011	1.67 (-1.49, 4.83)	0.298
Treatment: 2 modalities (ref: 0-1)	-0.25 (-1.08, 0.58)	0.554	-1.50 (-4.90, 1.91)	0.389	-1.83 (-4.38, 0.73)	0.160
Treatment: 3 + modalities (ref: 0-1)	-0.44 (-1.31, 0.42)	0.313	-2.31 (-5.86, 1.24)	0.201	-1.71 (-4.39, 0.96)	0.208
Comorbidities						
Cardiometabolic condition (ref: No)	-0.16 (-0.89, 0.58)	0.674	-0.96 (-3.97, 2.05)	0.531	-0.63 (-2.86, 1.60)	0.579
Pulmonary disease (ref: No)	0.08 (-0.67, 0.82)	0.844	1.67 (-1.40, 4.75)	0.286	-1.13 (-3.44, 1.17)	0.334
Other chronic condition (ref: No)	0.64 (-0.04, 1.31)	0.064	1.74 (-1.04, 4.52)	0.219	-2.13 (-4.20, -0.05)	0.044
Rural-Urban $\times$ Time Interaction						
Rural $\times$ 6 months	-0.43 (-1.21, 0.36)	0.282	-1.08 (-4.34, 2.18)	0.515	0.60 (-1.64, 2.83)	0.599
Model Information						
ICC	0.477		0.450		0.676	
Marginal R ²	0.108		0.100		0.103	
Observations	461		461		461	
<i>Note. Mixed-effects models with random intercepts for participant ID, estimated using REML. Models included rural residence, time, rural$\times$time interaction, and all covariates simultaneously. Non-significant interaction terms (all $p > 0.28$) indicate rural-urban disparities remained stable from baseline survey to 6-month follow-up. ICC = intraclass correlation coefficient. Bolded p-values indicate statistical significance at $p < 0.05$.</i>						

Supplementary models for fatigue, sleep disturbance, and social function are presented in Supplementary Tables S1 and S2. In baseline survey regression models, fatigue ($\beta = 2.32$; 95% CI, - 0.81 to 5.45; $p = 0.146$), sleep disturbance ($\beta = -0.30$; 95% CI, - 1.85 to 1.25; $p = 0.705$), and social function (β

= -2.52; 95% CI, - 5.32 to 0.28; $p = 0.078$) were not significantly different between rural and urban cancer survivors. Similarly, in mixed-effects models, fatigue ($\beta = 2.56$; 95% CI, - 0.74 to 5.85; $p = 0.128$), sleep disturbance ($\beta = -0.25$; 95% CI, - 1.79 to 1.29; $p = 0.750$), or social function ($\beta = -2.67$; 95% CI, - 5.52 to 0.17; $p = 0.066$) were not significantly different between rural and urban cancer survivors, at the baseline survey. Rural residence $\times$ time interactions were not significant for any supplementary PROMIS domain. Overall, supplementary analyses suggested that rural-urban differences were most consistent for pain intensity, pain interference, and physical function rather than the additional PROMIS domains.

Discussion

In this prospective cohort of cancer survivors receiving care at an NCI-designated cancer center in Oklahoma, approximately 40% resided in a rural area. Rural residence was independently associated with greater pain intensity, greater pain interference, and poorer physical function at the baseline survey. Over the six-month follow-up period, rural residence remained associated with higher pain intensity, higher pain interference, and lower physical function. These findings support our hypothesis and suggest that rural cancer survivors may experience a distinct and persistent burden of pain and functional limitation that is not fully explained by measured sociodemographic or clinical characteristics.

Our findings align with prior evidence that pain is a common, persistent, and clinically meaningful problem among cancer survivors^{6-9,12-17,47}. Cancer-related pain may persist after treatment and is associated with functional impairment, psychological distress, reduced quality of life, and greater healthcare utilization¹²⁻¹⁷. The present study extends this literature by showing that rural survivors reported not only greater pain intensity but also greater pain interference, indicating that pain may be more disruptive to daily activities and functioning among rural patients. These findings are also consistent with national survey data showing that rural cancer survivors have higher odds of chronic pain than urban survivors, even after adjustment for demographic and socioeconomic factors⁹. However, prior work has largely examined chronic pain as a binary outcome and relied primarily on cross-sectional data^{9,39}. Our study adds to this literature by examining multiple patient-reported outcomes, including pain intensity, pain interference, and physical function, and by evaluating whether rural-urban differences persisted over time. The persistence of differences in pain intensity, pain interference, and physical function suggests that rural disparities in symptom burden and functioning may represent a sustained survivorship concern rather than a transient baseline survey difference.

The magnitude of these associations should be interpreted with attention to clinical as well as statistical significance. The adjusted rural-urban difference in pain intensity was approximately one point on the 0–10 numeric rating scale, suggesting a modest difference relative to commonly used benchmarks for meaningful pain change, such as a 2-point or 30% reduction on a 0–10 pain scale⁴⁸. For PROMIS Pain Interference, prior studies have estimated minimally important difference ranges of approximately 2.0–6.0 T-score points, depending on the measure, population, and analytic approach^{49,50}. In the present study, the adjusted rural–urban differences in pain interference were 3.38 points at the baseline survey

and 3.45 points longitudinally, suggesting that these differences may be clinically meaningful or near clinically meaningful thresholds. However, the pain intensity and physical function differences were modest and should be interpreted cautiously. Overall, the consistent pattern across pain intensity, pain interference, and physical function suggests worse pain-related functioning among rural cancer survivors.

This study also expands the broader rural cancer disparities literature, which has primarily focused on screening, stage at diagnosis, access to treatment, survival, and mortality^{23–28,32}. Although these outcomes remain central to cancer control, our findings suggest that rural disparities also extend into survivorship experiences after diagnosis, particularly pain and daily functioning. Rural residence remained associated with worse pain and functional outcomes after adjustment for cancer type, treatment burden, insurance status, and comorbidity burden, suggesting that rural disparities in pain and physical function may reflect broader structural and contextual barriers. Geographic and socioeconomic barriers may compound one another for rural survivors, particularly when travel distance, limited local supportive care resources, insurance barriers, and financial strain occur simultaneously^{23,29–31,38,51,52}. Medicaid/SoonerCare or uninsured status was associated with higher pain interference in longitudinal models and approached significance in the baseline survey pain interference model, reinforcing the potential role of socioeconomic and insurance-related barriers in symptom management. Rural participants were also more likely to report past 30-day prescription opioid use, which may reflect greater underlying pain burden; whether this pattern also reflects limited access to nonpharmacologic or multidisciplinary pain management services should be examined in future research⁵³. Effective cancer pain care often requires coordinated pharmacologic and nonpharmacologic approaches, including rehabilitation, behavioral health support, palliative care, and longitudinal follow-up^{16,37,38}.

Cancer type was also associated with pain and physical function in several adjusted models. Compared with participants in the heterogeneous “other cancer types” category, participants with gynecologic cancers and genitourinary cancers reported lower pain intensity and lower pain interference. This finding suggests that symptom burden may vary by cancer type and treatment experience, consistent with literature indicating that cancer-related pain can arise from disease processes, treatment effects, and procedure-related factors^{3,10,11,16}. Because cancer type was included as a covariate rather than a primary exposure, these findings should be interpreted cautiously and examined in larger studies. Notably, rural residence was not significantly associated with fatigue, sleep disturbance, or social function in supplementary models. This pattern suggests that rural-urban differences were not uniformly observed across all PROMIS-29 domains but were concentrated in pain intensity, pain interference, and physical function. The persistence of the physical function association over time suggests that rural survivors may experience ongoing functional limitations in addition to greater pain burden. Physical function is likely influenced by multiple factors, including age, comorbidities, treatment history, rehabilitation access, recovery trajectory, daily or occupational physical demands and physical activity engagement among cancer survivors^{18,19,54}. Thus, future studies should examine mechanisms linking rural residence with functional impairment.

These findings have implications for survivorship care delivery in cancer centers serving rural catchment areas. Routine patient-reported outcome screening may help identify rural survivors with elevated pain intensity, pain interference, or functional limitation and support timely referral to supportive care^{37,44}. However, screening alone may be insufficient without scalable strategies that reduce geographic, financial, insurance-related, and healthcare access barriers. Such strategies may include telehealth-based symptom management, virtual rehabilitation support, transportation and financial navigation, local supportive care partnerships, referral pathways to rehabilitation and palliative care, hybrid care models, and coordination with local clinicians^{16,18,19,23,29–31,37,38,55}. Future research should evaluate whether remote patient-reported outcome monitoring and digitally supported triage approaches improve timely identification and management of pain and functional limitations among rural survivors.

This study has several strengths. First, data were collected from an NCI-designated cancer center serving a geographically diverse patient population that included both urban and rural cancer survivors. Second, rural-urban residence was classified using RUCA codes, which incorporate population density, urbanization, and commuting patterns and provide a more nuanced measure of rurality than broad county-level classifications. Third, pain intensity, pain interference, and physical function were assessed using the PROMIS-29 Profile, a standardized patient-reported outcome measure. Fourth, the study incorporated both baseline and longitudinal analyses, allowing us to examine whether rural-urban differences persisted over time rather than relying only on cross-sectional comparisons. Finally, multivariable models adjusted for key sociodemographic and clinical factors, including cancer type, treatment burden, insurance status, and comorbidity burden, which helps reduce the likelihood that observed rural-urban differences were explained only by measured demographic or clinical differences.

Several limitations should be considered. First, the study was conducted at a single NCI-designated cancer center in Oklahoma, which may reduce generalizability to other healthcare systems and geographic regions. Rural survivors who are able to access an academic cancer center may have more resources, stronger referral pathways, or fewer access barriers than rural survivors treated exclusively in community settings; therefore, the disparities observed in this study may underestimate the burden experienced by rural patients with less access to specialty cancer care. Second, ZIP code-based RUCA classifications may not fully capture dimensions of rurality such as travel burden, transportation access, geographic isolation, or local healthcare resource availability. Third, the six-month follow-up period may not capture longer-term survivorship trajectories. Fourth, as a secondary analysis of an existing dataset, the study could not directly evaluate mechanisms underlying rural disparities, including supportive care access, pain management resources, transportation barriers, financial toxicity, health literacy, or social support. Fifth, substance use and behavioral health measures were self-reported and may be subject to recall or social desirability bias. Sixth, because this study was conducted in Oklahoma, where medical cannabis was legal during the study period, findings may not generalize to cancer survivor populations in states where medical cannabis is not legal or is less accessible. Finally, the sample was predominantly White and non-Hispanic, which may limit generalizability to more diverse cancer survivor populations. Future research should intentionally recruit racially, ethnically, and socioeconomically diverse rural

survivors to examine how rurality, race, socioeconomic status, and healthcare access may intersect to shape pain and functional outcomes.

Conclusion

In this study of cancer survivors receiving care at an NCI-designated cancer center, rural residence was independently associated with greater pain intensity, greater pain interference, and poorer physical function at the baseline survey. In longitudinal analyses, rural residence remained associated with higher pain intensity, higher pain interference, and lower physical function over the six-month follow-up period. These findings suggest that rural cancer survivors experience a persistent burden of pain and functional limitation that is not fully explained by measured sociodemographic or clinical characteristics. Efforts to reduce rural survivorship disparities should prioritize timely pain assessment, functional screening, and improved access to supportive care and rehabilitation services. Telehealth-based symptom management, virtual rehabilitation support, care navigation, palliative care consultation, and coordination with local clinicians may help reduce geographic and structural barriers faced by rural patients. Future research should examine mechanisms underlying rural disparities in pain and functional outcomes and test scalable interventions to improve survivorship care for rural cancer survivors.

Declarations

Competing Interests

D.E.K. is an inventor of the Insight Mobile Health Platform, which was not used or evaluated in the current study, and receives royalties for the external use of the platform outside of the University of Oklahoma Health Sciences Center. D.E.K. is also a member of the Scientific Advisory Board of Qnovia, Inc., a drug development company focused on inhaled therapies, including prescription inhaled nicotine replacement therapy for smoking cessation; no medications were provided or evaluated in the current study. D.E.K. previously received varenicline at no cost from Pfizer to support a completed pilot study; no medications were provided or evaluated in the current study. Except as disclosed above, the authors declare no conflicts of interest.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of the University of Oklahoma Health Campus, Oklahoma City, Oklahoma, USA. Informed consent was obtained from all participants before enrollment.

Consent to Publish

Not applicable.

Supplementary Materials

The following supporting information can be downloaded online: Table S1: Multivariable Linear Regression Models Predicting baseline survey Fatigue, Sleep Disturbance, and Social Function by Rural-Urban Residence; Table S2: Mixed-Effects Models for Fatigue, Sleep Disturbance, and Social Function from baseline survey to 6-Month Follow-Up.

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Author Contribution

Conceptualization: Gaurav Kumar and Darla E. Kendzor; Methodology: Gaurav Kumar and Darla E. Kendzor; Formal analysis and investigation: Gaurav Kumar, Amy M. Cohn, and Darla E. Kendzor; Writing - original draft preparation: Gaurav Kumar; Writing - review and editing: Gaurav Kumar, Motolani E. Ogunsanya, Amy M. Cohn, Deeksha Gupta, Nathalia M. Machado, Brittany L. Hudson, Munjireen Sifat, Christina Henson, Susanna Ulahannan, and Darla E. Kendzor; Funding acquisition: Darla E. Kendzor; Resources: Darla E. Kendzor; Supervision: Darla E. Kendzor. All authors have read and agreed to the published version of the manuscript.

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Data Availability

The data presented in this study are not publicly available due to privacy and ethical restrictions related to participant confidentiality and the terms of institutional review board approval. Data may be available from the corresponding author upon reasonable request and with appropriate institutional approvals.

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