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Socioeconomic status and race are correlated with affective symptoms in multiple sclerosis

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Abstract

Objective—Investigate the relationship between socioeconomic status (SES) and race with self-reported fatigue, depression, and anxiety levels in multiple sclerosis (MS).

Methods—Cross-sectional review of the MS Partners Advancing Technology and Health Solutions (MS PATHS) database for adults with MS in the United States. We evaluated race and socioeconomic status (available markers: insurance, employment status, or level of education) as predictors of fatigue, depression, and anxiety sub-scores of the Neuro-QoL (Quality of life in neurological disorders), with particular interest between Caucasians/whites (CA) and African Americans/blacks (AA). Multivariate linear regression models included as covariates age, sex, disability status, smoking status, body mass index, and disease-modifying therapy.

Results—7,430 individuals were included; compared to CA, AA tended to be younger, more female-pre-dominant, and had a higher level of disability. AA had completed slightly less education, had a higher level of Medicaid coverage or uninsured status, and had higher rates of unemployed or disabled status. In the univariate model, markers of lower SES, by whichever definition we used, correlated with worse affective symptoms. In the multivariate model stratified by race, CA showed similar trends. In contrast, in AA, only lower SES by employment status was correlated with worse affective symptoms. In both CA and AA, moderate and severe level of disability correlated with worse affective symptoms.

Conclusion—SES and race may influence affective symptoms reported by individuals with MS. The reasons for the correlation are likely multifactorial. Longitudinal studies should strive to identify factors associated with risk of affective symptoms in MS that may be modifiable.

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Declaration of Competing Interest
None.

Supplementary materials

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Keywords

Multiple sclerosis; Epidemiology; Health outcomes; Quality of life

1. Introduction

Socioeconomic status (SES) is a measure of an individual's social standing in relation to others, which includes access to resources, opportunity, privilege, amongst others. (Galobardes et al., 2006) Studies have linked lower SES to the development of various health conditions and with increased disability and mortality. (Isaacs and Schroeder, 2004) Similar to the effects of lower SES, African American race has been associated with increased mortality and higher level of chronic diseases. (Cunningham et al., 2017) Disentangling the effects of SES and race is difficult in the United States (US). (Sohn, 2017; Williams et al., 2016; Williams et al., 2010) How SES and race, alone or in combination, may affect health outcomes is important to consider when working toward addressing healthcare disparities. (Williams et al., 2016; Williams et al., 2010)

The effect of SES on outcomes in multiple sclerosis (MS) is also gaining interest. Recent studies have demonstrated that lower SES is associated with higher risk of disability progression in the UK and Canada (Harding et al., 2019) and a single-center, US cohort. (Briggs et al., 2019) A prior study in MS (Marrie et al., 2006) showed that accounting for SES might explain some of differing outcomes between Caucasians and African Americans. Most prior studies have focused upon physical disability and associated outcomes. (Briggs et al., 2019; Marrie et al., 2006; Kister et al., 2010; Weinstock-Guttman et al., 2003; Kaufman et al., 2003) Affective symptoms are important to study, as mental comorbidities are common in MS (Marrie et al., 2009) and associated with worse outcomes, including greater long-term disability and mortality. (Marrie et al., 2008; Mohr et al., 1997; Feinstein, 2002; McKay et al., 2018)

There is a lack of studies evaluating how race and SES relate to patient-reported outcomes encompassing affective symptoms in MS. Thus, we aimed to investigate the relationship between markers of SES and race, and self-reported measures of affective disorders in a large population of US-based people with MS.

2. Methods

2.1. Standard protocol approvals, registrations, and patient consents

Institutional Review Board approval was granted by all US sites including Johns Hopkins University School of Medicine. Participants provided informed consent or an authorization to use their data when an institution granted a waiver of written informed consent.

2.2. Design

Cross-sectional observational study of individuals with MS in the US.

2.3. Study population

This study utilized data available from the Multiple Sclerosis Partners Advancing Technology and Health Solutions (MS PATHS) network, which is a network of seven MS centers in the US and three in Europe, comprised of patients with confirmed clinically isolated syndrome (CIS) or MS, and is supported by Biogen. US centers were exclusively included in this study since the social implications of race likely differ dramatically between countries. The US centers include the Cleveland Clinic, Cleveland Clinic Nevada, New York University, Ohio Health Research Institute, Johns Hopkins University, University of Rochester, and Washington University in St. Louis. Data are collected using an iPad-based system during participants' routine clinical care activities at each center. Participants enter demographic characteristics including age, sex, ethnicity, race (American Indian/Alaska Native, Asian, Black or African American [AA], Native Hawaiian/Other Pacific Islander, White or Caucasian American [CA]), as well as MS characteristics including age at symptom onset, disease subtype, and disease modifying therapy (DMT) use. Clinical and lifestyle information, including height and weight (used to calculate body mass index [BMI]) and smoking status, is also available. Participants complete the MS Performance Test (MSPT), which is an iPad-based adaptation of the MS Functional Composite (MSFC) and includes assessment of walking speed, manual dexterity, vision, and processing speed, in addition to a health questionnaire and the Neuro-QoL (see details of the latter below). (Rudick et al., 2014)

2.4. Defining markers of socioeconomic status

Measurable indicators of SES include income, education, employment, amongst others. (Galobardes et al., 2006) Three markers of SES were available, including education, employment status, and type of medical insurance. Education was grouped into the following categories: (1) Less than or equal to 12 years (high school diploma or equivalent), (2) 13–15 years (some college or vocational), (3) 16 years (college graduate), and (4) 17 years or more (graduate degrees). Employment status was grouped into three categories: (1) Full-time, homemaker, student, or retired, (2) Part-time, and (3) Unemployed or disabled. Medical insurance was grouped into two categories: (1) Medicaid or uninsured and (2) Non-Medicaid (Medicare, Private, and Military).

2.5. Inclusion criteria

Adult individuals (18 years or older) who received care in one of the US centers with a diagnosis of MS were included. Individuals with at least one demographic or SES data and completed the Neuro-QoL questionnaire were included. When several visits were available, the first completed Neuro-QoL questionnaire was selected.

2.6. Health-related quality of life in neurologic disease (Neuro-QoL)

At each clinic visit, participants reported health-related quality of life via the Neuro-QoL for 12 domains. Specifically, the Neuro-QoL computer adaptive test short-form (Neuro-QoL 2019) was used, with the sub-scores for fatigue, depression, and anxiety as the primary outcome measures of interest. The NeuroQoL has been validated in persons with MS. (Miller et al., 2016) The scoring generates a T-score with a mean of 50 and a standard

deviation of 10. The fatigue measurement utilized a clinical reference population, while the anxiety and depression measurements utilized a general population reference sample. (Neuro-QoL 2019) A higher T-score represents more of the concept being measured, thus in our measurements of interest, a higher T-score represents worse symptoms.

2.7. Statistical analysis

Our statistical analysis was designed with the primary objective of examining whether race and markers of SES are associated with fatigue, depression, and anxiety in people with MS. Chi-square tests were used to compare demographics and clinical characteristics between the two major racial groups (CA and AA). We then assessed the associations between race and the SES measures with fatigue, depression, and anxiety using linear models adjusting for age, sex, self-reported MS disease subtype and Patient Determined Disease Steps (PDDS) level (i.e., disability status). We performed supplementary analyses with the adjustment for additional confounders of smoking status, BMI, and DMT used. DMT was divided into injectable (including glatiramer acetate and interferons), oral (teriflunomide, fingolimod, and dimethyl fumarate), infusion therapies (natalizumab, ocrelizumab, rituximab, and alemtuzumab), no therapy, or therapy not listed. Missing information was relatively uncommon (<5% for all covariates). We imputed missing values using multiple imputation by chained equations (van Buuren, 2007) with 50 imputations. All analyses were conducted within each dataset of the imputed sets and the overall estimate and standard error were calculated by using the Rubin's rules. (Rubin, 2004) We additionally compared the demographic characteristics between the complete information and the imputed dataset. No significant differences were found (Supplemental Table 1), which suggests that the data were likely to be missing at random and the multiple imputation method was appropriate to use.

We assessed the effect modification by race for each of the SES measures on fatigue, depression and anxiety using cross-product terms and likelihood ratio tests. Since results suggested significant effect modification by race, we stratified analyses by racial groups (CA and AA). The stratified multivariate models were performed on both the imputed data and the complete cases dataset, and no significant differences were observed. We additionally conducted sensitivity analysis to model without PDDS, and we found that the main effects of SES were not significantly changed by removing this covariate.

All statistical analyses were conducted using R programming (version 3.6.1). Missing data imputation was performed using the "mice" package. (van and Groothuis-Oudshoorn, 2011) General linear hypotheses testing was performed using the R function "glht" (multcomp package). (Hothorn et al., 2008) All P-values were reported at the 0.05 significance level.

2.8. Data availability

MS PATHS data is currently only accessible to Biogen or participating healthcare institutions in the MS PATHS program.

3. Results

A total of 11,878 individuals were enrolled in MS PATHS across US and Europe as of September 14, 2018, 9309 (78%) of whom were residing in the US. Based on the

abovementioned inclusion criteria, 7430 (80%) individuals with MS in the US were included in this study, 5504 (74%) of whom were female (Table 1). Age range was 18–85 years old, with a mean of 48 years old (SD: 12.68 years). The majority of participants were CA (79%), and the largest minority group was AA (12%).

Relative to CA individuals, AA individuals tended to be younger and female. AA individuals also had a higher level of disability based on PDDS, lower level of attained education, higher levels of Medicaid or uninsured status, and higher rates of either unemployed or disabled employment status (Table 1). In addition, AA had higher levels of fatigue, depression, and anxiety in univariate models (Table 1).

In the univariate model, all markers of lower SES were associated with worse scores in all outcomes (fatigue, depression, and anxiety) (Table 2). When employment status was used as the SES measure, the group of unemployed or disabled individuals had worse scores in all outcomes (mean difference for fatigue: 6.93 points, 95% confidence interval [CI] 6.43–7.43; depression: 5.51 points, 95% CI 5.10–5.92; anxiety: 5.43 points, 95% CI 4.95–5.92). When insurance status was used, individuals with Medicaid or uninsured status, compared to all other insurance types, showed worse scores in all outcomes (mean difference for fatigue: 4.19 points, 95% CI 3.36–5.01; depression: 4.17 points, 95% CI 3.50–4.84; anxiety: 4.40 points, 95% CI 3.62–5.19). When education was used as the SES measure, relative to individuals with high school or equivalent level or lower, individuals with advanced degrees demonstrated better scores in all outcomes (mean difference for college graduates, fatigue: –3.64 points, 95% CI –4.31 to –2.96; depression: –3.13 points, 95% CI –3.68 to –2.57; anxiety: –2.91 points, 95% CI –3.56 to –2.26. For individuals with graduate degrees, fatigue: –4.24 points, 95% CI –4.89 to –3.58; depression –3.39 points, 95% CI –3.92 to –2.85; anxiety –3.53 points, 95% CI –4.16 to –2.90). In analyses assessing for effect modification, there were interactions between race and each SES marker (Table 3). As a result, we proceeded with analyses stratified by race.

In the CA group, we found that lower SES, by any definition, correlated with worse Neuro-QoL scores in fatigue, depression, and anxiety (Table 3). When employment status was used as the SES measure, the group of unemployed or disabled individuals had worse scores in all outcomes (mean difference for fatigue: 3.97 points, 95% CI 3.40–4.55; depression: 3.37 points, 95% CI 2.89–3.86; anxiety: 3.47 points, 95% CI 2.89–4.00). When insurance status was used, CA individuals with Medicaid or those that were uninsured, compared to all other insurance types, showed worse scores in all outcomes (mean difference for fatigue: 2.23 points, 95% CI 1.35–3.10; depression: 3.12 points, 95% CI 2.38–3.86; anxiety: 3.02 points, 95% CI 2.14–3.90). When education was used as a SES measure, relative to individuals with high school or equivalent level or lower, CA individuals with college or more advanced degrees demonstrated better scores in all outcomes (mean difference for college graduates, fatigue: –2.05 points, 95% CI –1.40 to –2.71 points; depression: –1.88 points, 95% CI –1.32 to –2.44 points; anxiety: –1.91 points, 95% CI –1.25 to –2.58 points; for graduate degree, fatigue: –2.61 points, 95% CI –1.97 to –3.25 points; depression: –2.02 points, 95% CI –1.47 to –2.57 points; anxiety: –2.40 points, 95% CI –1.75 to –3.04 points). Both moderate and severe disability correlated with worse scores (For moderate disability, fatigue: 6.35 points, 95% CI 5.77–6.93; depression: 3.50 points, 95% CI 3.01–4.00; anxiety: 4.25

points, 95% CI 3.66–4.83; for severe disability, fatigue: 3.84 points, 95% CI 2.90–4.77; depression: 2.87 points, 95% CI 2.08–3.67; anxiety: 1.45 points, 95% CI 0.51–2.40).

These findings are in contrast to the AA group where significantly worse Neuro-QoL scores were found for fatigue, depression, and anxiety when employment was used as the predictor (For disabled or un- employed status, fatigue: 1.83 points, 95% CI 0.37–3.29; depression: 2.98 points, 95% CI 1.77–4.19; anxiety: 2.43 points, 95% CI 1.01–3.85). When insurance status was used, no difference in outcomes was seen. When education was used, only graduate level or higher education correlated with better scores (–1.72 points, 95% CI –0.19 to –3.26). Similar to the CA group, both moderate and severe disability correlated with worse scores (For moderate disability, fatigue: 5.89 points, 95% CI 4.38–7.40; depression: 3.96 points, 95% CI 2.69–5.22; anxiety: 5.15 points, 95% CI 3.67–6.63; for severe disability, fatigue: 3.17 points, 95% CI 0.88–5.45; depression: 2.63 points, 95% CI 0.71–4.54).

After adjustments for additional confounders of smoking status, BMI, and DMT, we did not see a meaningful change in the results (Table 4).

4. Discussion and conclusions

This study demonstrates that markers of lower SES are correlated with worse self-reported scores in fatigue, depression, and anxiety in US-based individuals with MS treated at tertiary MS centers. We also demonstrate that there are race-based differences in these outcomes, and that the effects of SES differ between CA and AA.

In the univariate model, prior to stratification by race, disabled or unemployed status and Medicaid or uninsured status are correlated with worse self-reported levels of fatigue, depression, and anxiety, while a higher attained education level (college or greater) is correlated with better outcomes. This is in keeping with a recent study that identified lower median income and Medicaid or uninsured status as associated with higher depressive scores in individuals with MS. (Briggs et al., 2019) In addition, a few recent studies have demonstrated that lower SES is associated with a higher risk of MS disability progression in UK and Canada (Harding et al., 2019) and a Cleveland Clinic cohort. (Briggs et al., 2019) There is evidence for a biological basis for these differences, with studies indicating low SES associated with a proinflammatory phenotype. (Loucks et al., 2010; Tabassum et al., 2008; Miller et al., 2009) Modifiable features that may well influence MS disease progression, such as smoking and higher BMI, are generally over-represented in lower SES groups. (Pampel et al., 2010) In our study, adjustment for smoking status and BMI did not meaningfully change our results, suggesting that these modifiable features are likely not the only influencers of outcomes. These factors associated with disability progression may also be associated with worse affective symptomatology.

Similar to the findings of the univariate model, within CA, markers of lower SES (disabled or unemployed status and Medicaid coverage or uninsured status) are correlated with worse outcomes, while marker of higher SES (higher attained education) is correlated with better outcomes. Within AA, similar to CA, disabled or unemployed status correlated with worse

self-reported levels of fatigue, depression, and anxiety. However, Medicaid or uninsured status was not associated with these outcomes. In addition, another difference is that higher attained education level (graduate degree or higher) is correlated with lower level of depression only. This indicates that contrary to what was seen within CA, SES may have less of an association with these out- comes in AA people with MS. The underlying mechanisms for this race- based difference are not explored in this study, but they are likely to be multi- factorial, and a number of potential explanations exist, which we explore below.

First, our study is powered to detect more of a correlation in CA due to the larger size of that racial subgroup. In addition, when we look at the demographics of CA versus AA, we see that the distribution of the sample within the various subgroups of the markers of SES assessed was less widely distributed in the AA group, again affecting the power to detect associations within the AA group. Alternatively, it is possible that the markers that we have used for SES are not true gauges of the underlying social stratification within the groups. (Isaacs and Schroeder, 2004) Another potential explanation for why SES does not appear as meaningful in AA compared to CA is the clinical differences between the two racial groups, which are not fully accounted for, that may factor into predicting the outcomes. Prior studies point toward a more aggressive MS disease course in AA, (Marrie et al., 2006; Kister et al., 2010; Weinstock-Guttman et al., 2003; Kaufman et al., 2003) and in our cohort, similar to previously published studies, AA tended to be younger, female, and have a higher level of disability. (Marrie et al., 2006; Kister et al., 2010; Weinstock-Guttman et al., 2003; Kaufman et al., 2003; Cree et al., 2004) An individual's genetic admixture may also influence immune system reactivity and susceptibility to immune-mediated disease, such as a study that indicated that AA are more likely to have alleles that are associated with a pro-inflammatory response, (Nédélec et al., 2016) and inflammation has been proposed as a contributor to affective symptomatology in people with MS. (Rossi et al., 2017; Colasanti et al., 2016) However, the mechanisms for the abovementioned racial difference are likely more complex than these clinical variations. It is possible that additional stressors of being AA in the US supersede much of the SES effect (Williams et al., 2016) that we clearly see in the CA group. Notably, AA face significant challenges in healthcare, including access to services, cultural stigma, and systemic racism. (Beatty et al., 2003; Russell and Jewell, 1992; Saadi et al., 2017; Fabius et al., 2018)

There are some limitations of the study. Firstly, the study was cross- sectional rather than longitudinal. SES is dynamic throughout an individual's life; therefore, it would be particularly helpful to assess how changes in SES (such as in employment status, insurance coverage, and such) may influence disability and quality of life. This would provide a stronger evidence for an association. Additional SES components, such as geographic or zip- code data and household income, would be beneficial in creating a more comprehensive measure of SES. In addition, separation of SES and race effects is quite difficult, as these are tightly linked in the US. (Sohn, 2017; Williams et al., 2016; Williams et al., 2010; Marrie et al., 2006) Even though our study attempted to evaluate their synergistic effects, we recognize that this may not be fully possible (though the large size of our study mitigates this to an extent). The correlation identified between lower SES and worse affective symptoms may be a bi-directional relationship; we did not evaluate the risk of lower SES conferred by the degree of affective symptomatology. Future longitudinal analyses would be

better suited to address these issues. Additional limitations, which are inherent in such studies, include unidentified confounders and issues related to self-reported information. While a main strength of our study is the inclusion of a large cohort of individuals with MS, who are all receiving care in established MS clinics, it still may be that participants receiving care in these centers are different from those with MS who do not. Non-participants and non-responders may have contributed to selection bias in our study. Individuals from particularly low SES groups and those with more significant mental co-morbidities are likely to be more represented in these categories. (A need for greater reporting of socioeconomic status and race in clinical trials 2019; Gross et al., 2005; Svensson et al., 2012)

Identifying affective symptoms and mental comorbidities is important, as they are associated in longitudinal studies with worse disability and increased mortality in individuals with MS. (Marrie et al., 2009; McKay et al., 2018) Despite their prevalence in individuals with MS, these comorbidities are under-diagnosed and under-treated. (Marrie et al., 2009) Identifying individuals at risk is important in assessing for these comorbidities. Prior studies have shown that affective symptoms are particularly under-recognized in lower SES groups. (Marrie et al., 2009) SES is an important determinant of health outcomes, and incorporation of social stratification into future studies may help to allow for further exploration of the underlying mechanisms of these differences. (Isaacs and Schroeder, 2004; Williams et al., 2016; Marrie et al., 2008; Schroeder, 2007) Our study shows that among MS individuals, those in lower SES groups are at increased risk for affective symptomatology and potentially at risk for having mental comorbidities. In addition, we note that there are race-based differences in the presence of affective symptoms. Our study adds to the large body of evidence that SES and race are important determinants of health that should be recognized by clinicians, and importantly, that their role in MS outcomes should be addressed on a national level. (Williams et al., 2016; Schroeder, 2007)

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Baseline characteristics of participants.

Characteristic	Whole sample, <i>n</i> = 7430	Caucasian/white, <i>n</i> = 5846	African American/black, <i>n</i> = 924	<i>p</i> value
Age, mean $\pm$ SD; y	48.50 $\pm$ 12.68	49.49 $\pm$ 12.46	45.02 $\pm$ 12.44	< 0.001
Female, <i>n</i> (%)	5504 (74.10)	4262 (72.90)	752 (81.39)	< 0.001
Race, <i>n</i> (%)	5846 (78.70)			
	924 (12.40)			
	660 (8.90)			
Age at onset, mean $\pm$ SD; y	32.80 $\pm$ 11.38	33.29 $\pm$ 11.23	32.10 $\pm$ 11.60	0.07
Age at diagnosis, mean $\pm$ SD; y	35.74 $\pm$ 11.16	36.33 $\pm$ 10.98	34.58 $\pm$ 11.43	< 0.001
Body Mass Index (BMI), mean $\pm$ SD; kg/m ²	29.11 $\pm$ 7.15	28.92 $\pm$ 7.05	30.67 $\pm$ 7.65	0.03
Smoking status, <i>n</i> (%)				< 0.001
Never	4212 (56.69)	3227 (55.20)	605 (65.48)	
Former	1898 (25.55)	1546 (26.45)	182 (19.70)	
Current	1033 (13.90)	835 (14.28)	113 (12.23)	
Unreported	287 (3.86)	238 (4.07)	24 (2.60)	
Employment status, <i>n</i> (%)				< 0.001
Group 1				
Full time	3242 (43.6)	2600 (44.47)	389 (42.10)	
Retired	816 (11.00)	682 (11.68)	80 (8.66)	
Homemaker	336 (4.50)	283 (4.84)	17 (1.84)	
Student	144 (1.90)	85 (1.45)	25 (2.71)	
Group 2:				
Part time	592 (8.00)	479 (8.19)	52 (5.63)	
Group 3:				
Disabled	1778 (23.90)	1357 (23.21)	262 (28.35)	
Unemployed	385 (5.20)	261 (4.46)	78 (8.44)	
Other	114 (1.50)	86 (1.47)	18 (1.95)	
Unreported	23 (0.30)	12 (0.21)	3 (0.32)	
Insurance, <i>n</i> (%)				< 0.001
Medicaid/Uninsured	642 (8.70)	394 (6.74)	152 (16.45)	

Characteristic	Whole sample, <i>n</i> = 7430	Caucasian/white, <i>n</i> = 5846	African American/black, <i>n</i> = 924	<i>p</i> value
Other	6749 (90.80)	5429 (92.87)	765 (82.79)	
Unreported	39 (0.50)	23 (0.67)	7 (0.76)	< 0.001
Education, <i>n</i> (%)				
High school or lower (12 years)	1772 (23.85)	1417 (24.24)	264 (28.57)	
Post-high school (13–15 years)	2177 (29.30)	1636 (27.98)	328 (35.50)	
College (16 years)	1603 (21.57)	1320 (22.58)	156 (16.88)	
Graduate (> 16 years)	1878 (25.28)	1473 (25.20)	176 (19.05)	
MS type, <i>n</i> (%)				0.006
Relapsing	4619 (62.20)	3671 (62.80)	539 (58.33)	
Progressive	2412 (32.50)	1850 (31.65)	335 (36.26)	
Unreported	399 (5.30)	325 (5.56)	50 (5.41)	
Patient-Determined Disease Steps (PDDS), <i>n</i> (%)				<0.001
Mild (0–1)	3952 (53.19)	3167 (54.17)	445 (48.16)	
Moderate (2–5)	2665 (35.87)	2060 (35.24)	350 (37.88)	
Severe (> 5)	743 (10.00)	563 (9.63)	119 (12.88)	
Unreported	70 (0.94)	56 (0.96)	10 (1.08)	
Current Disease Modifying Therapy, <i>n</i> (%)				< 0.001
Injectable	1683 (22.65)	1379 (23.59)	182 (19.70)	
Oral	2218 (29.85)	1779 (30.43)	243 (26.30)	
Infusion	1496 (20.13)	1087 (18.59)	243 (26.30)	
No therapy	1508 (20.30)	1194 (20.42)	177 (19.16)	
Not listed	511 (6.88)	393 (6.72)	79 (8.55)	
Unreported	14 (0.188)	14 (0.24)	0	
Neuro-QoL, T-score (SD)				
Fatigue	50.08 ± 9.87	49.80 ± 9.76	50.45 ± 10.05	< 0.001
Depression	47.05 ± 8.05	46.68 ± 7.94	48.49 ± 8.33	< 0.001
Anxiety	50.66 ± 9.39	50.26 ± 9.30	51.78 ± 9.68	< 0.001

Table 2

Univariate model. Neuro-QoL score change and 95th percentile confidence interval for correlations between socioeconomic status and fatigue, depression, and anxiety scores.

	Fatigue			Depression			Anxiety		
	Estimate	(95% CI)	p-value	Estimate	(95% CI)	p-value	Estimate	(95% CI)	p-value
Employment status									
Full time, retired, student and homemaker	Reference								
Part time	1.69	(0.85, 2.53)	<0.001	0.87	(0.18, 1.56)	0.01	0.99	(0.18, 1.81)	0.02
Disabled, unemployed	6.93	(6.43, 7.43)	<0.001	5.51	(5.10, 5.92)	<0.001	5.43	(4.95, 5.92)	<0.001
Other	4.45	(2.63, 6.26)	<0.001	2.99	(1.50, 4.47)	<0.001	3.75	(1.99, 5.51)	<0.001
Medicaid/Uninsured	4.19	(3.36, 5.01)	<0.001	4.17	(3.50, 4.84)	<0.001	4.40	(3.62, 5.19)	<0.001
Education									
High school or lower	Reference								
Post-high school	-0.27	(-0.90, 0.36)	0.40	-1.26	(-1.78, -0.75)	<0.001	-0.90	(-1.51, -0.30)	0.003
College	-3.64	(-4.31, -2.96)	<0.001	-3.13	(-3.68, -2.57)	<0.001	-2.91	(-3.56, -2.26)	<0.001
Graduate	-4.24	(-4.89, -3.58)	<0.001	-3.39	(-3.92, -2.85)	<0.001	-3.53	(-4.16, -2.90)	<0.001

Table 3

Neuro-QoL score change and 95th percentile confidence interval for adjusted associations between socioeconomic status and fatigue, depression, and anxiety scores. All values were adjusted for age, sex, disease subtype, and PDDS.

	Fatigue			Depression			Anxiety		
	Estimate (95% CI)	p-value		Estimate (95% CI)	p-value		Estimate (95% CI)	p-value	
White/Caucasian									
Employment status									
Full time, retired, student and homemaker	Reference								
Part time	0.98 (0.15, 1.80)	0.02		0.59 (−0.11, 1.29)	0.10		0.37 (−0.46, 1.20)	0.38	
Disabled, unemployed	3.97 (3.40, 4.55)	<0.001		3.37 (2.89, 3.86)	<0.001		3.47 (2.89, 4.00)	<0.001	
Other	3.69 (1.86, 5.53)	<0.001		2.55 (0.99, 4.12)	0.001		3.23 (1.38, 5.09)	<0.001	
Medicaid/Uninsured	2.23 (1.35, 3.10)	<0.001		3.12 (2.38, 3.86)	<0.001		3.02 (2.14, 3.90)	<0.001	
Education									
High school or lower	Reference								
Post-high school	0.19 (−0.42, 0.81)	0.54		−0.84 (−1.36, −0.31)	0.002		−0.58 (−1.20, −0.05)	0.07	
College	−2.05 (−2.71, −1.40)	<0.001		−1.88 (−2.44, −1.32)	<0.001		−1.91 (−2.58, −1.25)	<0.001	
Graduate	−2.61 (−3.25, −1.97)	<0.001		−2.02 (−2.57, −1.47)	<0.001		−2.40 (−3.04, −1.75)	<0.001	
Patient-Determined Disease Steps (PDDS)									
Mild (0–1)	Reference								
Moderate (2–5)	6.35 (5.77, 6.93)	<0.001		3.50 (3.01, 4.00)	<0.001		4.25 (3.66, 4.83)	<0.001	
Severe (> 5)	3.84 (2.90, 4.77)	<0.001		2.87 (2.08, 3.67)	<0.001		1.45 (0.51, 2.40)	0.003	
Black/African American									
Employment status									
Full time, retired, student and homemaker	Reference								
Part time	−0.70 (−3.40, 1.99)	0.61		−0.21 (−2.45, 2.04)	0.86		−0.26 (−2.89, 2.36)	0.84	
Disabled, unemployed	1.83 (0.37, 3.29)	0.01		2.98 (1.77, 4.19)	<0.001		2.43 (1.01, 3.85)	0.001	
Other	−0.29 (−4.67, 4.08)	0.89		0.35 (−3.28, 3.97)	0.85		0.13 (−4.12, 4.38)	0.95	
Medicaid/Uninsured	−0.025 (−1.67, 1.62)	0.98		0.44 (−0.95, 1.83)	0.53		0.81 (−0.81, 2.42)	0.33	
Education									
High school or lower	Reference								
Post-high school	0.20 (−1.32, 1.72)	0.79		−1.16 (−2.43, 0.12)	0.08		−0.83 (−2.44, 0.78)	0.43	

	Fatigue			Depression			Anxiety		
	Estimate (95% CI)	p-value		Estimate (95% CI)	p-value		Estimate (95% CI)	p-value	
College	-0.35 (-2.21, 1.50)	0.71		-1.31 (-2.87, 0.25)	0.10		0.029 (-1.89, 1.95)	0.61	
Graduate	-0.63 (-2.46, 1.20)	0.50		-1.72 (-3.26, -0.19)	0.03		-1.23(-3.07, 0.61)	0.52	
PDDS									
Mild (0–1)	Reference								
Moderate (2–5)	5.89 (4.38, 7.40)	< 0.001		3.96 (2.69, 5.22)	< 0.001		5.15 (3.67, 6.63)	< 0.001	
Severe (> 5)	3.17 (0.88, 5.45)	0.007		2.63 (0.71, 4.54)	0.007		2.05 (-0.18, 4.28)	0.07	

Interaction *p*-values: For employment: fatigue ($p < 0.001$), depression ($p = 0.65$), anxiety ($p = 0.42$). For Medical/uninsured: fatigue ($p = 0.03$), depression ($p = 0.001$), anxiety ($p = 0.04$). For education: fatigue ($p = 0.02$), depression ($p = 0.83$), anxiety ($p = 0.02$).

Table 4

Neuro-QoL score change and 95th percentile confidence interval for adjusted associations between socioeconomic status and fatigue, depression, and anxiety scores. All values were adjusted for age, sex, disease subtype, PDDS, smoking status, BMI, and disease modifying therapy group.

	Fatigue			Depression			Anxiety		
	Estimate (95% CI)	p-value		Estimate (95% CI)	p-value		Estimate (95% CI)	p-value	
White/Caucasian									
Employment status									
Full time, retired, student and homemaker	Reference								
Part time	1.02 (0.21, 1.84)	0.01		0.58 (−0.11, 1.28)	0.10		0.35 (−0.48, 1.17)	0.41	
Disabled, unemployed	3.50 (2.93, 4.07)	<0.001		2.99 (2.50, 3.47)	<0.001		3.11 (2.53, 3.69)	<0.001	
Other	3.45 (1.63, 5.27)	<0.001		2.24 (0.69, 3.79)	0.005		2.91 (1.06, 4.75)	0.002	
Medicaid/Uninsured	1.51 (0.64, 2.39)	0.007		2.48 (1.74, 3.23)	<0.001		2.36 (1.48, 3.24)	<0.001	
Education									
High school or lower	Reference								
Post-high school	0.42 (−0.19, 1.04)	0.18		−0.60 (−1.12, −0.07)	0.002		−0.35 (−0.97, 0.27)	0.27	
College	−1.36 (−2.03, −1.70)	<0.001		−1.22 (−1.79, −0.65)	<0.001		−1.29 (−1.96, −0.61)	0.0002	
Graduate	−1.76 (−2.42, −1.11)	<0.001		−1.23 (−1.80, −0.67)	<0.001		−1.66 (−2.33, −0.99)	<0.001	
Patient-Determined Disease Steps (PDDS)									
Mild (0–1)	Reference								
Moderate (2–5)	6.06 (5.49, 6.63)	<0.001		3.31 (2.82, 3.80)	<0.001		4.12 (3.53, 4.70)	<0.001	
Severe (> 5)	3.61 (2.68, 4.54)	<0.001		2.70 (1.90, 3.49)	<0.001		1.36 (0.42, 2.30)	0.003	
Black/African American									
Employment status									
Full time, retired, student and homemaker	Reference								
Part time	−0.88 (−3.23, 1.47)	0.46		−0.42 (−2.39, 1.55)	0.77		−0.53 (−2.83, 1.78)	0.65	
Disabled, unemployed	1.50 (0.023, 2.97)	0.05		2.68 (1.45, 3.91)	<0.001		2.10 (0.66, 3.54)	0.004	
Medicaid/Uninsured	−0.61 (−2.27, 1.05)	0.47		0.013 (−1.38, 1.41)	0.99		0.32 (−1.31, 1.95)	0.70	
Education									
High school or lower	Reference								
Post-high school	0.18 (−1.35, 1.70)	0.82		−1.01 (−2.30, 0.27)	0.12		−0.40 (−1.90, 1.10)	0.60	
College	−0.054 (−1.94, 1.83)	0.96		−0.98 (−2.57, 0.61)	0.23		0.98 (−0.87, 2.83)	0.30	

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	Fatigue		Depression		Anxiety	
	Estimate (95% CI)	p-value	Estimate (95% CI)	p-value	Estimate (95% CI)	p-value
Graduate	-0.17 (-2.04, 1.70)	0.86	-1.30 (-2.87, 0.28)	0.11	0.022 (-1.81, 1.86)	0.98
PDDS						
Mild (0-1)	Reference					
Moderate (2-5)	5.83 (4.33, 7.34)	<0.001	4.13 (2.87, 5.39)	<0.001	5.34 (3.86, 6.82)	0.06
Severe (> 5)	3.40 (1.14, 5.66)	0.003	2.99 (1.10, 4.88)	<0.001	2.42 (0.20, 4.63)	0.03