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Cumulative social disadvantage and its impact on long COVID: insights from a U.S. national survey

Junwei Xiang[1†], Hu Zheng[1†], Yuhang Cai[1], Siyuan Chen[1], Yuanyin Wang[1*] and Ran Chen[1,2,3*]

Abstract

Background The COVID-19 pandemic has exacerbated health disparities, with long COVID emerging as a major global public health challenge. Although clinical risk factors for long COVID are well-documented, the cumulative burden of adverse social determinants of health (SDoH) remains underexplored. This study aims to investigate the association between cumulative social disadvantage and long COVID.

Methods Using data from the 2022 and 2023 National Health Interview Survey cycles ($n = 16,446$ U.S.adults), cumulative social disadvantage was quantified through 18 SDoH indicators and categorized into quartiles. The highest quartile represents the most disadvantaged individuals. Long COVID was defined as self-reported symptoms persisting for three months or longer. Weighted logistic regression models were used to examine the association, adjusting for demographic and clinical variables.

Results Adults in the highest quartile of cumulative social disadvantage exhibited an increased odds of experiencing long COVID compared to those in the lowest quartile (AOR = 2.52, 95% CI: 2.13, 2.98). This association persisted across demographic subgroups, with particularly pronounced effects among women and non-Hispanic Blacks. Hispanics and non-Hispanic Whites showed weaker, but still statistically significant. Key contributors included mental health difficulties, economic instability, and healthcare access barriers. Furthermore, cumulative social disadvantage was linked to fair or poor general health status among individuals with long COVID.

Conclusions This study highlights the positive association between cumulative social disadvantage and long COVID. Addressing systemic inequities through integrated public health strategies is essential to mitigate the burden of long COVID and reduce social disparities in health.

Keywords Long COVID, Social Determinants of Health, Cumulative social disadvantage, Health disparities

Background

Since the outbreak of the COVID-19 pandemic, global public health has encountered unprecedented challenges [1, 2]. The pandemic has disrupted healthcare systems, strained economies, and exposed existing health disparities. In particular, long COVID, or post-COVID-19 syndrome, has emerged as a significant health concern. Increasing evidence indicates that some patients continue to experience symptoms long after infection [3, 4]. It is estimated that approximately 400 million individuals are affected by long COVID, drawing growing attention

†Junwei Xiang and Hu Zheng contributed equally to this work and share first authorship.

*Correspondence:
Yuanyin Wang
wyy1970548@sohu.com
Ran Chen
ahmuchenran@163.com
[1] College & Hospital of Stomatology, Anhui Medical University, Key Lab. of Oral Diseases Research of Anhui Province, Hefei 230032, China
[2] Anhui Med Univ, Affiliated Hosp 1, Hefei 230032, China
[3] Anhui Public Health Clinical Center, Hefei 230032, China

from public health systems worldwide [5]. Long COVID is characterized by symptoms that persist for weeks or even months after the acute phase, including fatigue, cognitive impairment, difficulty breathing, and mental health issues [4]. Patients with these symptoms suffer from reduced work capacity, functional decline, and rising healthcare costs, leading to decreased productivity and a greater healthcare burden. Long COVID not only profoundly affects patients' health and quality of life but also places immense pressure on social and economic systems, with an estimated economic loss of about $1 trillion [5, 6]. The long-term health impacts of this condition remain unclear. This uncertainty highlights the need for further research and targeted support.

Existing studies have identified several risk factors for long COVID, such as older age, being female, smoking, and comorbid conditions [7, 8]. However, most research has focused on clinical and biological factors, leaving the role of social determinants less explored. Social determinants of health (SDoH) refer to non-medical factors that influence health outcomes, including the environments where people are born, grow, live, work, and age [9]. According to the Kaiser Family Foundation (KFF) framework, SDoH can be categorized into six key domains: economic stability, access to and quality of education, food, healthcare access and quality, neighborhood and physical environment, and social and community context [10]. These domains capture various aspects of non-medical factors that influence health outcomes. Social disadvantage or adverse SDoH can significantly affect the likelihood of experiencing and reporting long COVID symptoms [11, 12]. Individuals with lower socioeconomic status, limited access to healthcare resources, or poor living environments face higher risks of long COVID. Although the influence of SDoH on health conditions is well established, its relationship with long COVID has yet to be sufficiently explored. Notably, certain social disadvantages may not show statistical or public health significance in relation to long COVID [8, 13].

Moreover, individuals experience multiple adverse SDoH simultaneously, leading to cumulative social disadvantage [14]. The adverse effects of cumulative social disadvantage on health are long-lasting and widespread [15–17]. Understanding these associations could reduce health disparities and promote equity in public health policies and resource allocation. Studies suggest that integrating preventive and therapeutic services with multifaceted interventions addressing these social risk factors can improve health outcomes [18–20]. Nevertheless, research on the cumulative impact of social disadvantage on long COVID remains limited. Most research has focused on single social factors, rather than systematically evaluating the combined impact of multiple adverse SDoH. This research gap constrains our understanding of how long COVID manifests in vulnerable populations and limits the development of effective interventions.

Understanding the relationship between cumulative social disadvantage and long COVID is crucial for identifying vulnerable populations and offering more tailored management and support. Therefore, this study aims to explore the effect of cumulative social disadvantage on long COVID among U.S. adults using nationally representative data. Additionally, we will examine associations between specific adverse SDoH, such as unemployment, food insecurity, and lack of insurance, with long COVID. We hypothesize that cumulative social disadvantage would be associated with a higher likelihood of long COVID, and that this association varies by gender, race and ethnicity, and age.

Methods

Data source and study participants

This study sought to investigate associations between cumulative social disadvantage and long COVID among U.S. adults. This study used data from the 2022 and 2023 cycles of the National Health Interview Survey (NHIS). The NHIS is conducted annually by the National Center for Health Statistics with support from the Centers for Disease Control and Prevention [21]. The survey employs a multistage area probability sampling technique to ensure national representation. The questionnaire includes demographic information, health status, activity limitations, and other health-related data. As the data are de-identified and publicly available, this study did not require ethics committee approval.

We restricted the study population to individuals who reported a positive COVID-19 test or were diagnosed with COVID-19 by a doctor or other healthcare professional. From 2022 to 2023, the NHIS database provided the most extensive data on social determinants and long COVID reports. A total of 24,237 adults with a history of COVID-19 from the combined two cycles were included, regardless of whether they developed long COVID. The sample includes all adults with a history of COVID-19, not just those with long COVID symptoms. A total of 7,791 participants were excluded, including 7,326 due to missing SDoH data and 465 for missing critical covariate and general health status data (Fig. 1).

Cumulative social disadvantage

In assessing the impact of social determinants on health, the study applied the Kaiser Family Foundation (KFF) framework, which encompasses six major domains: economic stability, neighborhood and physical environment, education, food, community and social context, and the healthcare system [10]. Building upon this framework,

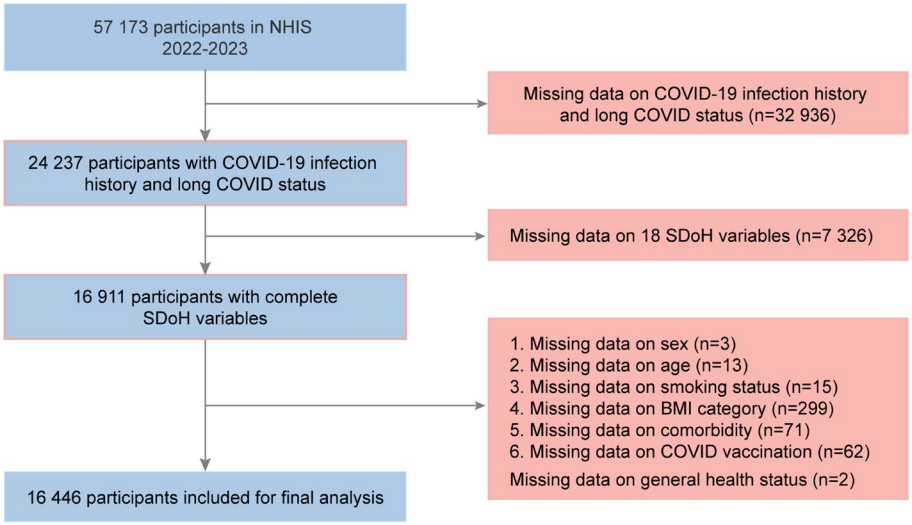

Fig. 1 Flowchart depicting the inclusion process of NHIS participants. Abbreviations: NHIS, National Health Interview Survey; SDoH, Social Determinants of Health

Javed et al. integrated 38 SDoH indicators and introduced the concept of a cumulative social disadvantage score [16]. This innovative approach has been widely validated and applied in studies investigating various health outcomes, such as cardiovascular health, mortality risk, and health-related quality of life, underscoring its reliability and versatility [22–24].

The indicators in the Javed et al. framework were all based on NHIS data from the 2013–2018 cycle, and all subsequent studies using this framework relied on the same data. However, since this study used NHIS data from 2022 and 2023, the surveys in these years did not include all the indicators in the framework. In the present study, we retained the available indicators from the Javed framework for the 2022 and 2023 cycles and referenced indicators from other studies [10, 15, 16, 25]. However, it should be noted that these variables were not entirely consistent across the two cycles (Additional file 1: Table S1 and Table S2). To maximize the sample size and enhance statistical power, we merged the data from both cycles, identifying 18 shared variables to assess social disadvantage (Additional file 1: Table S1 and Table S2). The variance inflation factors for these variables ranged from 1.03 to 1.59, suggesting no significant multicollinearity concerns.

We developed a list of 18 SDoH covering six domains, as shown in Additional file 1: Table S1. Most SDoH variables had minimal missing responses, except for the cost-related medication adherence variable, which accounted for 81.2% of the total missing responses (Additional file 1: Table S3). Then, each determinant was assigned a score based on its favorable or unfavorable attribute: unfavorable factors were scored as 1 (e.g., unemployment, no insurance), and favorable factors as 0 (e.g., employment, insured). Finally, the SDoH total score was calculated by summing the scores of each determinant, with higher scores indicating greater social disadvantage. This method has been used and published in a previous study [16].

The cumulative social disadvantage score provides a comprehensive approach to assessing social risks by integrating multiple domains. By standardizing indicators across different cycles of the NHIS, this method enhances comparability and ensures compatibility with future research. The score also has limitations, including the exclusion of certain indicators due to data constraints. Finally, to evaluate the cumulative impact of disadvantageous social conditions across different populations, participants were grouped into quartiles. The first quartile represented the least disadvantaged, while the fourth quartile represented the most disadvantaged.

Long COVID status

The status of long COVID was defined by the following follow-up question: "Did you have any symptoms lasting 3 months or longer that you did not have before having coronavirus or COVID-19?" If participants reported such conditions, they were categorized as long COVID patients; otherwise, they were classified as non-long COVID patients. The secondary outcome focused on participants' self-reported general health status.

Covariates

We prespecified covariates for our statistical model based on a comprehensive literature review and clinical practice guidelines [4, 26]. These variables include sociodemographic covariates such as gender, race and ethnicity, age, and U.S. region. Additionally, clinical confounders like current smoking status, body mass index, functional impairment, number of comorbidities, and the number of COVID-19 vaccinations were included as covariates. Detailed definitions and classifications of these variables are provided in Additional file 1: Table S4.

Statistical method

Following NHIS guidelines, survey weights were adjusted to account for the combination of data from multiple cycles. Specifically, for this study, data from the 2022 and 2023 cycles were merged, and the adjusted weight was calculated by dividing the original weight by two. Continuous variables were presented as weighted means with standard errors (SE), while categorical variables were reported as counts (n) and survey-weighted percentages (%).

We first conducted bivariate logistic regression analyses, followed by multivariate logistic regression, adjusting for all covariates, to assess the association between cumulative social disadvantage and long COVID. To further illustrate the association between cumulative social disadvantage (as quartiles) and long COVID, three predefined subgroup analyses were performed based on gender (male and female), age (18–44 years, 45–64 years, and ≥ 65 years), and race (White, Black, Hispanic, and Asian/other races). Interaction terms between cumulative social disadvantage and these demographic variables were also tested to examine possible heterogeneity in the observed effects.

In sensitivity analyses, we utilized multivariate logistic regression to examine the association between individual SDoH sub-items and long COVID. Separate logistic regression models were also conducted for the 2022 and 2023 data, acknowledging that certain SDoH indicators were specific to each cycle. For instance, barriers to healthcare access were only assessed in 2022, while housing issues and everyday discrimination were unique to 2023. These year-specific indicators complemented the combined data analysis, offering a more comprehensive perspective on social disadvantage. Considering the high missing rate of the "Cost-related medication non-adherence" variable, we reclassified the quartiles of cumulative social disadvantage based on the remaining 17 indicators. In this sensitivity analysis, the missing sample rate was reduced to 8.41%, staying within an acceptable range, and the weighted sample maintained national representativeness. Finally, given the dual role of mental health issues as both social disadvantages and symptoms of long COVID, we performed a sensitivity analysis, excluding depression and anxiety while including other indicators.

Results

Characteristics of study participants

A total of 16,446 participants were included in the study, of whom 3,111 reported long COVID, representing 18.6% of the weighted population (74,768,013). Compared to the included sample, excluded participants were significantly less likely to have functional disabilities (4.4% vs. 9.8%, $P < 0.001$) and comorbidities (≥ 3 conditions: 4.5% vs. 22.1%, $P < 0.001$), but more likely to be younger and unvaccinated (Additional file 1: Table S5). As shown in Table 1, the average age of participants was 48.12 years, with long COVID being more prevalent among individuals aged 45 to 64 years. Females, individuals with obesity, smoking history, functional disabilities, and multiple comorbidities were more likely to report long COVID. Non-Hispanic Whites comprised the majority; however, no significant racial or ethnic differences in prevalence were observed. A higher proportion of unvaccinated individuals reported long COVID. Participants with long COVID had significantly higher unfavorable SDoH scores (Mean = 4.22, SE = 0.12). The highest social disadvantage burden was more prevalent in the long COVID group (29.2% vs. 15.17%, $P < 0.001$).

Social disadvantage and Long COVID

The association between cumulative social disadvantage and long COVID was evaluated using quartiles based on 18 SDoH indicators (Fig. 2). Participants experiencing the highest level of social disadvantage were 152% more likely to report long COVID compared to those in the lowest quartile (adjusted odds ratio (AOR) = 2.52, 95% confidence intervals (95% CI): 2.13, 2.98, $P < 0.001$). As shown in Fig. 2, participants with existing conditions in the most disadvantaged group were over six times more likely to report poor general health than those in the least disadvantaged group (AOR = 6.34, 95% CI: 4.22, 9.52, $P < 0.001$). Cumulative social disadvantage remains associated with an increased odds of long COVID after excluding mental health factors (Additional file 1: Table S6). The sensitivity analysis further supports this strong association among individuals in the 2022 and 2023 cycles (Additional file 1: Table S7 and Table S8). Individuals facing barriers to doctor access, housing affordability, or frequent discrimination are more likely to report long COVID. After excluding variable with a high missing response, the positive correlation remained

Table 1 Survey-weighted characteristics of adults with COVID-19, stratified by long COVID, U.S. NHIS 2022–2023 ($n = 16446$)

	Total	**No Long COVID**	**Long COVID**	
	***N* (Weighted %)**	**N (Weighted %)**	**N (Weighted %)**	***P* value**
Sample, *N*	16446	1335	3111	
Weighted sample, (weighted %)	74768013	60884892	13883120	
Age, years	48.12 ± 0.36	48.06 ± 0.40	48.35 ± 0.67	0.435
Age category				< 0.001
18–44 y	6124 (44.7)	4975 (45.0)	1149 (43.5)	
45–64 y	5593 (34.9)	4423 (34.0)	1170 (38.8)	
65 y or above	4729 (20.5)	3937 (21.1)	792 (17.8)	
Gender				< 0.001
Male	6695 (42.9)	5667 (44.9)	1028 (34.5)	
Female	9751 (57.1)	7668 (55.1)	2083 (65.5)	
Race and ethnicity				0.019
Non-Hispanic White	11742 (68.9)	9525 (69.0)	2217 (68.5)	
Non-Hispanic Black	1398 (9.0)	1127 (9.0)	271 (9.0)	
Hispanic	2197 (15.2)	1739 (14.8)	458 (16.8)	
Asian and other races	1109 (6.9)	944 (7.2)	165 (5.7)	
US region				0.203
Northeast	2687 (18.0)	2252 (18.4)	435 (16.4)	
Midwest	3738 (21.5)	2998 (21.4)	740 (21.9)	
South	6136 (38.1)	4946 (38.0)	1190 (38.5)	
West	3885 (22.4)	3139 (22.2)	746 (23.3)	
BMI category				< 0.001
Under/Healthy weight	4777 (29.3)	4037 (30.5)	740 (23.8)	
Overweight	5561 (33.0)	4601 (33.8)	960 (29.3)	
Obese	6108 (37.7)	4697 (35.6)	1411 (46.9)	
Smoking status				< 0.001
No current smoker	15001 (91.1)	1095 (8.4)	350 (11.5)	
Current smoker	1445 (8.9)	12240 (91.7)	2761 (88.5)	
Functional disability				< 0.001
No	14708 (90.2)	1224 (8.6)	514 (15.4)	
Yes	1738 (9.8)	12111 (91.4)	2597 (84.6)	
Comorbidity number				< 0.001
0	4843 (33.8)	4126 (35.6)	717 (25.9)	
1–2	7317 (44.1)	5936 (43.7)	1381 (45.6)	
≥ 3	4286 (22.1)	3273 (20.7)	1013 (28.4)	
COVID-19 vaccination				< 0.001
0	2689 (17.5)	2042 (16.5)	647 (22.0)	
1	809 (5.3)	626 (5.1)	183 (6.3)	
≥ 2	12948 (77.1)	10667 (78.4)	2281 (71.8)	
General health status				< 0.001
Good and excellent	13699 (83.6)	11370 (85.4)	2329 (75.4)	
Fair and poor	2747 (16.5)	1965 (14.6)	782 (24.6)	
Unfavourable SDoH score	3.31 ± 0.05	3.10 ± 0.06	4.22 ± 0.12	< 0.001
Unfavourable SDoH Quartile				< 0.001
Quantile 1	4382 (26.7)	3859 (28.8)	523 (17.2)	
Quantile 2	5840 (35.0)	4878 (35.9)	962 (30.8)	
Quantile 3	3331 (20.6)	2611 (20.1)	720 (22.7)	
Quantile 4	2893 (17.8)	1987 (15.2)	906 (29.2)	

Continuous variables are presented as weighted mean ± standard error (SE), and categorical variables are presented as counting (N) and survey-weighted percentage (%)

Abbreviations: *BMI* Body mass index, *NHIS* National Health Interview Survey, *SDoH* Social Determinants of Health

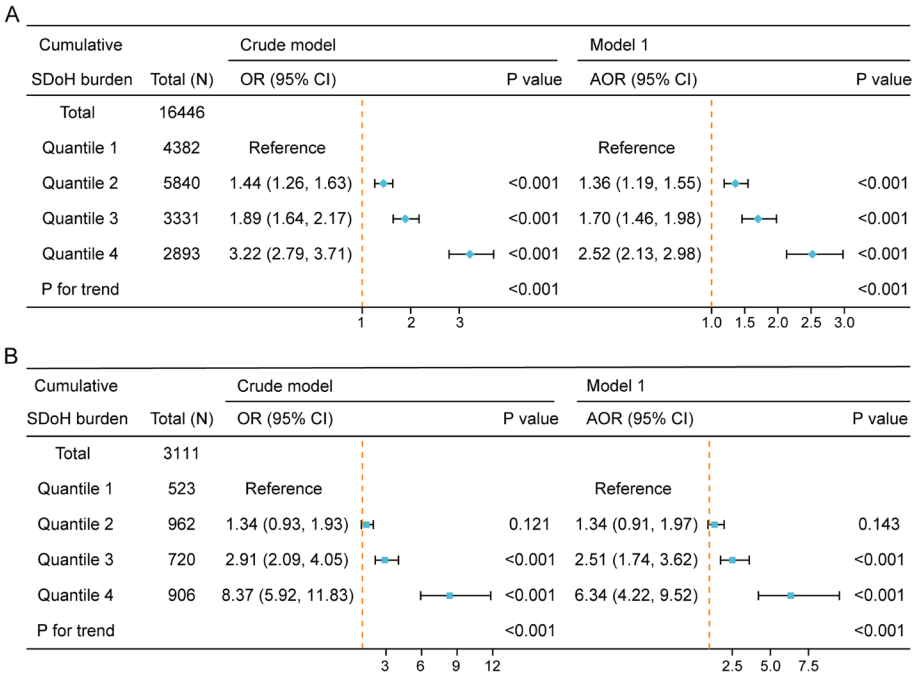

Fig. 2 The associations of cumulative social disadvantage with long COVID **(A)** and the relationship between cumulative social disadvantage and general health status among adults who have reported long COVID **(B)**. Crude model adjusted for none, Model 1 adjusted for gender, age, race and ethnicity, U.S. region, current smoking status, body mass index, functional impairment, number of comorbidities, and the number of vaccinations. Abbreviations: AOR, Adjusted odds ratio; CI, Confidence interval. SDoH, Social Determinants of Health

significant in the larger weighted sample (Additional file 1: Table S9).

Specific SDoH Sub-items and Long COVID

This study analyzed specific sub-items within SDoH and found that several specific factors were significantly associated with long COVID (Table 2). Economic stability was identified as a key factor. Low family income, difficulty paying medical bills, and delayed or forgone medical care were all associated with long COVID, highlighting the negative impact of economic barriers on health. Regarding the residential environment, participants living in rental housing were more likely to report long COVID. Mental health factors, including depressive and anxiety symptoms, were linked to a higher prevalence of long COVID. With regard to healthcare access, lack of health insurance, transportation, and access to virtual medical care were all associated with long COVID. These results underscore the impact of social and economic disadvantage in driving health disparities in long COVID, highlighting the need for targeted public health interventions.

Subgroup analyses

Subgroup analysis revealed differences in the associations between cumulative social disadvantage and long COVID risk across gender, race/ethnicity, and age groups (Table 3). Among females, those in the highest burden group had higher odds of long COVID. The interaction between gender and exposure showed marginal significance ($P=0.056$), suggesting potential gender-based differences in the effect of social disadvantage on long COVID. In terms of race/ethnicity, non-Hispanic Whites and non-Hispanic Blacks in the highest burden group were significantly more likely to report long COVID. Regarding age, all age groups exhibited a consistent trend of increased risk, with a slightly stronger association observed among older groups, although the interaction was not statistically significant.

Discussion

Although the peak of the outbreak has passed, long COVID remains a global public health issue, particularly among socially disadvantaged groups. Our study explores the association between the accumulation of social disadvantages and Long COVID, which is significant in both clinical and public health contexts. Those with a high cumulative social disadvantage burden were significantly more likely to report long COVID, with this trend consistent across population groups. Economic instability, mental health issues, and barriers to healthcare

Table 2 Association of each social determinants of health variable with long COVID

Components and sub-items of the unfavorable SDoH score	AOR (95% CI)	*P* value
Economic stability		
Never / previously employed	1.12 (0.97, 1.29)	0.127
Low family income	1.18 (1.05, 1.32)	0.004
Unable to pay medical bills	1.77 (1.56, 2.00)	< 0.001
Cost-related medication non-adherence	2.07 (1.77, 2.41)	< 0.001
Delayed/foregone medical care due to cost	2.05 (1.77, 2.37)	< 0.001
Worried about medical costs of illness / accident	1.48 (1.35, 1.64)	< 0.001
Neighborhood, physical environment, and social cohesion		
Housing was rental / from other arrangement	1.14 (1.02, 1.27)	0.021
Living in the Nonmetropolitan areas	1.09 (0.95, 1.25)	0.198
Community and social context		
Depressive symptoms	1.86 (1.64, 2.11)	< 0.001
Anxiety symptoms	1.71 (1.52, 1.93)	< 0.001
Not married nor living with a partner	0.98 (0.89, 1.08)	0.680
Difficulty participating in social activities	1.33 (1.15, 1.53)	< 0.001
Food insecurity		
Food insecurity	1.57 (1.35, 1.83)	< 0.001
Education		
Less than high school education	0.92 (0.82, 1.03)	0.129
Healthcare system		
Uninsured	1.36 (1.07, 1.71)	0.011
No usual source of care	1.18 (0.95, 1.47)	0.143
Delayed medical care: no transportation	1.43 (1.20, 1.71)	< 0.001
No virtual medical appointment	1.24 (1.13, 1.36)	< 0.001

Favorable variable groups as reference. Adjusted for age, gender, race and ethnicity, region, BMI category, smoking status, functional disability, comorbidity number, and COVID-19 vaccination

Abbreviations: *AOR* Adjusted odds ratio, *CI* Confidence interval, *SDoH* Social determinants of health

access were identified as the primary contributing factors. These findings are consistent with previous research linking cumulative social disadvantage to adverse health outcomes in other chronic conditions. Studies on diabetes and cardiovascular diseases show that socioeconomic disadvantage worsens metabolic dysfunction and chronic inflammation through limited healthcare access, chronic stress, and environmental exposures [27, 28]. These mechanisms are similar to those observed in long COVID. Social disadvantage prolongs recovery by amplifying oxidative stress and immune dysregulation. Additionally, health lifestyle theory suggests that socially disadvantaged groups are more likely to engage in harmful behaviors, which increases susceptibility to chronic conditions. Applying chronic disease frameworks and addressing systemic inequities in resource distribution—such as healthcare access and income support—could help mitigate both long COVID and other chronic conditions [7].

Recent studies have begun to unravel the significant role of SDoH in long COVID, demonstrating how these factors shape not only the likelihood of developing the condition but also its persistence and severity. Berger et al. underscore the significant impact of social factors such as employment, education, and income on both the occurrence and persistence of the condition [11, 29]. Food insecurity and housing instability are both closely associated with the persistence of long COVID symptoms. Economic factors also play a critical role. Greenhalgh et al. report that the incidence of chronic COVID is shaped not only by the severity of the initial infection but also by socioeconomic status [4]. Low-income individuals, constrained by limited access to healthcare, are more prone to experiencing long-term complications and often suffer from more severe symptoms. Al-Aly et al. further emphasize that recurrent infections, compounded by adverse socioeconomic conditions, greatly increase the risk of long COVID [5]. Beyond poverty, social inequalities such as occupational exposure and racial discrimination also make certain populations more vulnerable to virus exposure [30]. Workers in long-term care facilities and public service sectors, including education, social care, and transportation, are at higher risk for long COVID

Table 3 Associations between the cumulative social disadvantage and long COVID in a fully adjusted model stratified by gender, race/ethnicity, and age

	Unfavorable SDoH Quartile	No long COVID *N* (Weighted %)	Long COVID *N* (Weighted %)	OR (95% CI)	*P* value	*P* for interaction
Gender						0.056
Male	Q2	2079 (36.2)	336 (31.8)	1.25 (1.02, 1.54)	0.034	
	Q3	973 (18.0)	239 (23.8)	1.88 (1.47, 2.41)	< 0.001	
	Q4	673 (12.1)	219 (20.7)	2.23 (1.64, 3.03)	< 0.001	
	P for trend				< 0.001	
Female	Q2	2799 (35.7)	626 (30.3)	1.46 (1.22, 1.73)	0.040	
	Q3	1638 (21.9)	481 (22.1)	1.64 (1.36, 1.98)	< 0.001	
	Q4	1314 (17.6)	687 (33.7)	2.70 (2.21, 3.29)	< 0.001	
	P for trend				< 0.001	
Race and ethnicity						0.265
NH White	Q2	3566 (36.4)	715 (32.3)	1.33 (1.15, 1.54)	0.034	
	Q3	1694 (18.2)	496 (21.6)	1.70 (1.43, 2.03)	< 0.001	
	Q4	1132 (12.2)	566 (25.3)	2.51 (2.07, 3.05)	< 0.001	
	P for trend				< 0.001	
NH Black	Q2	365 (33.7)	72 (27.5)	1.67 (0.93, 3.00)	0.084	
	Q3	284 (24.1)	61 (24.1)	1.95 (1.06, 3.61)	0.033	
	Q4	285 (23.7)	118 (39.7)	3.33 (1.82, 6.09)	< 0.001	
	P for trend				< 0.001	
Hispanic	Q2	585 (33.5)	116 (25.3)	0.96 (0.62, 1.48)	0.860	
	Q3	466 (28.5)	119 (25.8)	1.15 (0.77, 1.72)	0.492	
	Q4	433 (24.3)	175 (39.1)	1.85 (1.20, 2.86)	0.006	
	P for trend				< 0.001	
Asian/other races	Q2	362 (38.7)	59 (35.1)	0.92 (0.63, 1.37)	0.694	
	Q3	167 (16.2)	44 (25.0)	1.34 (0.95, 1.87)	0.092	
	Q4	137 (13.8)	47 (30.3)	1.77 (1.23, 2.53)	0.002	
	P for trend				< 0.001	
Age category						0.537
18–44 y	Q2	1774 (35.5)	303 (26.8)	1.22 (0.96, 1.54)	< 0.001	
	Q3	1189 (25.0)	300 (25.0)	1.53 (1.20, 1.94)	< 0.001	
	Q4	999 (19.7)	421 (36.5)	2.38 (1.84, 3.08)	< 0.001	
	P for trend				< 0.001	
45–64 y	Q2	1606 (36.1)	373 (32.7)	1.46 (1.19, 1.80)	< 0.001	
	Q3	753 (16.4)	251 (21.6)	1.97 (1.53, 2.55)	< 0.001	
	Q4	648 (13.2)	332 (26.1)	2.53 (1.94, 3.28)	< 0.001	
	P for trend				< 0.001	
65 y or above	Q2	1498 (36.4)	286 (36.4)	1.42 (1.13, 1.79)	0.003	
	Q3	669 (15.9)	169 (19.6)	1.64 (1.25, 2.14)	< 0.001	
	Q4	340 (8.6)	153 (18.3)	2.52 (1.76, 3.62)	< 0.001	
	P for trend				< 0.001	

Subgroup analyses using interaction effects testing were conducted to assess the impact of cumulative social disadvantage on long COVID across various categories, including age, gender, and race/ethnicity

Abbreviations: *OR* Odds ratio, *CI* Confidence interval, *NH* Non-Hispanic

[31, 32]. Racism affects health both directly through economic deprivation and indirectly through chronic stress and pre-existing health conditions [33].

These findings align with our research, which demonstrates that financial strain, food insecurity, housing instability, and limited access to healthcare resources are strongly associated with the report of long COVID. This reinforces the detrimental effects of social disadvantage on health outcomes. However, only examining individual SDoH domains is insufficient, as these

factors are typically interconnected and influence health through complex pathways. Thus, evaluating the cumulative effect of multiple social determinants may offer a more thorough understanding. Figueroa et al. proposed the "multiple social risk score" model, which assesses the combined impact of various social conditions on health outcomes, providing a more comprehensive prediction of individual health risks [14]. Building on this model, our study employs an integrated social disadvantage scoring system that captures both the individual and cumulative effects of social factors.

In this study, we found that the impact of social disadvantage on long COVID may vary by gender, with women showing a higher odds ratio. Occupational exposures may help explain the observed gender disparity. Women are disproportionately represented in occupations like healthcare, education, and service industries, where close contact increases the likelihood of repeated COVID-19 infections [34, 35]. And social-economic disadvantage further restricts their access to health care [36, 37]. Although occupational data were not included in our analysis, this pathway aligns with prior studies showing higher rates of long COVID in these industries. Biological differences suggest that women's immune systems may sustain chronic inflammation for longer periods, which further elevates their risk of developing long COVID [38, 39]. As a result, the interaction of economic burdens, mental health challenges, and biological differences collectively heightens their risk of long COVID.

It is also important to note that the influence of social disadvantage varies across racial and ethnic groups. Non-Hispanic Whites and non-Hispanic Blacks in the highest social disadvantage groups exhibit the greatest likelihood of long COVID. The odds ratio for Hispanic individuals is also elevated, although the magnitude varies. The stronger association among non-Hispanic Black groups reflects systemic inequalities beyond socioeconomic status. Black communities are often concentrated in areas with limited healthcare access, environmental pollution, and food insecurity, factors all linked to chronic inflammation and impaired recovery [40, 41]. Additionally, experiences of racial discrimination can induce chronic stress, further exacerbating post-COVID-19 syndrome. For Hispanic populations, language barriers, immigrant fears, and cultural mistrust of the healthcare system may contribute to delays in the diagnosis and treatment of long COVID.

The mechanisms through which cumulative social disadvantage affects long COVID are complex, involving inflammatory responses, oxidative stress, metabolic dysfunction, microvascular damage, and the interaction of multiple factors. Chronic psychological stress from social disadvantage triggers inflammation, weakening immune function and prolonging recovery [42, 43]. Furthermore, social disadvantage is often associated with environmental pollution, unhealthy diets, and physical inactivity, all of which contribute to oxidative stress through the overproduction of free radicals [44–46]. This oxidative stress damages cells and tissues, particularly in the lungs and cardiovascular system, the primary sites affected by COVID-19 [47]. Social disadvantage also correlates with unhealthy lifestyle and restricted access to healthcare, increasing the incidence of metabolic diseases, including obesity, diabetes, and hypertension. These metabolic conditions impair overall health and heighten the risk of developing long COVID after infection [48]. Studies have shown that COVID-19 patients often experience microvascular damage and thrombosis, conditions closely associated with metabolic syndrome and cardiovascular diseases [49]. Poor chronic disease management, exacerbated by social disadvantage, increases the risk of microvascular damage and coagulation disorders. Notably, long COVID is characterized by unpredictable symptoms, such as fluctuating fatigue, cognitive dysfunction, and post-exertional discomfort [4]. For patients with these symptoms, social disadvantage presents a complex challenge. Individuals without paid sick leave or flexible work arrangements face greater income loss. Limited access to telemedicine and digital literacy gaps further delay diagnosis and treatment. Additionally, marginalized populations often reside in areas with high pollution or overcrowded housing, which can worsen the respiratory symptoms of long COVID.

Our findings reaffirm the necessity of addressing non-medical determinants of health and highlight the importance of integrating both medical and non-medical factors in multifaceted intervention studies. In clinical practice, healthcare providers must adopt a holistic approach, especially when caring for socially disadvantaged groups during the post-COVID recovery phase [50]. Routine care should incorporate systematic screening for SDoH to identify high-risk populations and offer timely interventions to mitigate long-term impacts. For instance, ensuring access to essential healthcare services and mental health support can significantly improve recovery outcomes. From a public health perspective, the policy implications of this study extend beyond general public health interventions. First, targeted medical support should be provided for socially disadvantaged groups affected by COVID-19. This includes the establishment of long COVID screening and rehabilitation services in high-disadvantage areas, offering virtual healthcare to address access barriers, and integrating psychological counseling into rehabilitation plans.

Second, efforts must be made to break the vicious cycle between long COVID and social disadvantage. Such as offering temporary income support and job retraining for those who lose employment or face wage reductions due to long COVID. Our sensitivity analyses revealed that economic barriers and mental health difficulties are primary drivers of the observed association. These findings suggest that interventions addressing these factors could have significant public health benefits.

Strengths and limitations

Our research has several key strengths. First, this is the first study to examine the relationship between cumulative social disadvantages and long COVID, shedding light on the social determinants driving long COVID. It also expands our understanding of other chronic diseases, reinforcing the critical role of social determinants in this area. Another strength of this research is the use of a nationally representative sample of U.S. adults, ensuring the broad applicability of the findings. The large sample size enabled us to conduct robust statistical analyses and explore associations among different populations. Moreover, the research employed a multidimensional approach to measure social determinants, encompassing multiple aspects such as economic stability, access to healthcare, education, and the physical environment. We also applied multi-variable logistic regression models, controlling for potential confounding factors, and accounted for complex sampling designs. Many U.S. hospitals have already integrated SDoH data into Electronic Health Records (EHR), offering a more comprehensive patient profile [51]. This scoring system could be adapted for clinical use by incorporating EHR data on social disadvantage. However, the inclusion of multiple variables presents challenges for full implementation in clinical practice. Future research should focus on simplifying the scoring system, emphasizing key factors like socioeconomic status, healthcare access, and mental health. Policymakers can use this framework to assess the equity of interventions targeting long COVID recovery.

We recognize several limitations in this study. First, as a cross-sectional study, it cannot establish causality. A potential bidirectional relationship exists, where long COVID may exacerbate social disadvantages, rather than social disadvantage solely influencing long COVID. Second, due to variations in the data collection, our score includes fewer indicators than the 38 used by Javed et al., limiting its ability to fully capture cumulative social disadvantages. Third, excluding participants with missing data may have introduced selection bias. Excluded individuals tend to have fewer functional disabilities or comorbidities, potentially leading to an underestimation of the true association. We recommend caution while generalizing the conclusions to the broader population. Future large-scale prospective studies with minimal missing data are needed to further confirm our results. Fourth, the dual role of mental health factors in cumulative social disadvantage and long COVID requires careful consideration. Additionally, although many covariates were controlled for, unmeasured confounders, such as genetic predispositions or undiagnosed health conditions, may still affect the association with long COVID. Our analysis also did not account for occupational exposures or systemic inequalities. Future studies should further clarify the pathways linking social disadvantage to long COVID disparities.

Given the interview-based nature of the NHIS, the self-reported data are subject to recall and social desirability biases. Future research should compare these findings with clinical diagnostic data from other sources and incorporate objective medical records or biomarker data. Notably, long COVID is defined as self-reported symptoms lasting three months or more, but it is not possible to determine whether these symptoms persist or have improved. This definition may lead to an overestimation of the long COVID burden, underscoring the need for longitudinal studies to track symptom persistence.

Conclusions

Overall, the findings of this cross-sectional study indicated that cumulative social disadvantage significantly increases the risk of long COVID among U.S. adults. The association demonstrates cumulative effects across various SDoH domains and may vary across demographic groups. To mitigate the adverse health impacts of long COVID, public health interventions should focus more on addressing social disadvantage by adopting multidimensional and sustainable policies.

Abbreviations

AOR	Adjusted Odds Ratio
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
COVID-19	Coronavirus Disease 2019
HER	Electronic Health Records
KFF	Kaiser Family Foundation
NHIS	National Health Interview Survey
SDoH	Social Determinants of Health
SE	Standard Errors

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12916-025-04039-5.

Additional file 1: Tables S1-S9. Table S1. Common Social Determinants of Health (SDoH) components between the 2023 and 2022 cycles. Table S2. Distinct Social Determinants of Health (SDoH) components between the 2023 and 2022 cycles. Table S3. Distribution of cumulative social disadvantage components in included and excluded samples for sensitivity analysis. Table S4. Detailed definitions and classifications of covariates.

Table S5. Covariate distribution in included and excluded samples for sensitivity analysis. Table S6. Logistic regression analysis of the association between cumulative social disadvantage and long COVID (excluding mental health factors). Table S7. The association between cumulative social disadvantage, barriers to access to care and long COVID-19 in 2022 cycle. Table S8. The association between cumulative social disadvantage, housing affordability, experiences of discrimination, and language use at home and long COVID in 2023 cycle. Table S9. Logistic regression analysis of the association between cumulative social disadvantage and long COVID (excluding cost-related medication non-adherence).

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Authors' contributions
J.X. and R.C. conceptualized the study. J.X. conducted formal analysis, developed the methodology, wrote the original draft, and contributed to reviewing and editing the manuscript. H.Z. was responsible for software development, validation, visualization, and reviewing and editing the manuscript. Y.C. handled data curation, visualization, validation, and investigation. S.C. contributed to methodology development, visualization, and validation. Y.W. supervised the project, provided project administration, and contributed to reviewing and editing the manuscript. R.C. acquired funding, led project administration, wrote the original draft, and contributed to reviewing and editing the manuscript. All authors reviewed and approved the final manuscript.

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Data availability
The data supporting this study's findings are available in NHIS at https://www.cdc.gov/nchs/nhis/index.html.

Declarations

Ethics approval and consent to participate
This study involves human subjects. Given the de-identified nature and public availability of the data, institutional review board approval is not required for this work. All research conducted adheres to the principles of the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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