Iran J Public Health, Vol. 51, No.11, Nov 2022, pp.2458-2471

Review Article

Impact of Social Deprivation on Hospitalization and Intensive Care Unit Admission among COVID-19 Patients: A Systematic Review and Meta-Analysis

Yang-Jie Zhu [1], Kang Tang [1], Fang-Jie Zhao [1], Bo-Yang Yu [1,2], Tong-Tong Liu [1,3], *Lu-Lu Zhang [1]

1. *Department of Military Health Management, College of Health Service, Naval Medical University, Shanghai 200433, China*
2. *Department of Medical Health Service, General Hospital of Northern Theater Command of PLA, Shenyang 110016, China*
3. *Department of Medical Health Service, 969th Hospital of PLA Joint Logistics Support Forces, Hohhot 010051, China*

***Corresponding Author:** Email: zllrmit@163.com

(Received 22 Jun 2022; accepted 17 Aug 2022)

Abstract

Background: The coronavirus disease 2019 (COVID-19) pandemic has disproportionately affected socially disadvantaged groups; however, the association between socioeconomic status and healthcare utilization among COVID-19 patients remains unclear. Therefore, a systematic review and meta-analysis was conducted to assess the association between socioeconomic status and hospitalization and intensive care unit admission among COVID-19 patients.

Methods: PubMed, Embase, and the Cochrane Register of Controlled Trials were searched for relevant literature (updated to Jun 2022). Studies that investigated the association of social deprivation with hospitalization and intensive care unit admission in COVID-19 patients were included. The primary outcomes included risk of hospitalization and intensive care unit admission, measured by odds ratio.

Results: Eleven studies covering 2,423,095 patients were included in the meta-analysis. Socially disadvantaged patients had higher odds of hospitalization in comparison to socially advantaged patients (odds ratio 1.25, 95% confidence interval: 1.14 to 1.38; $P<0.01$). The odds of intensive care unit admission among more deprived patients was not significantly different from that of less deprived patients (odds ratio 1.03, 95% confidence interval: 0.78 to 1.35; $P=0.85$). These findings were proven robust through subgroup and sensitivity analyses.

Conclusion: Socially disadvantaged populations have higher odds of hospitalization if they become infected with COVID-19. More effective medical support and interventions for these vulnerable populations are required to reduce inequity in healthcare utilization and alleviate the burden on healthcare systems.

Keywords: COVID-19; Socioeconomic status; Social deprivation; Healthcare utilization; Meta-analysis

Introduction

Currently, there have been approximately 490 million confirmed cases of coronavirus disease 2019 (COVID-19), including more than 6 million deaths (1). The ongoing COVID-19 pandemic has placed enormous pressure on healthcare systems, disproportionately affected specific popula-

tion groups and undermined health equity (2). Health equity, in which all people have a fair and just opportunity to be healthy, necessitates the removal of obstacles to health, such as poverty, racial discrimination, and limited access to healthcare. Social determinants of health (SDH) are some of the most important contributors to health equity. These include five indicators: economic stability, education, social and community context, health and health care, and neighborhood and built environment (3). For example, living in deprived neighborhoods with poorer availability of exercise equipment for physical activity and limited access to healthcare increases an individual's risk of chronic disease, associated with poor outcomes for COVID-19 patients (4). To improve outcomes for COVID-19 patients and reduce health inequity, it is critical to identify vulnerable populations with higher odds of hospitalization and intensive care unit (ICU) admission.

Many studies have confirmed the association between racial and ethnic minority status and adverse COVID-19-related outcomes, including hospitalization, ICU admission, and mortality (5, 6). These detrimental effects of racial disparities can be amplified by socioeconomic status, quantitatively measured by various social deprivation indices, such as the social deprivation index (SDI), area deprivation index (ADI), and New Zealand deprivation index (NZDI). The SDI is assessed via 7 factors, namely poverty, education, employment, household overcrowding, non-home ownership, family structure, and transportation (7). The ADI uses 17 indicators in its construction, including poverty, education, housing, and employment status (8). The NZDI is calculated based on 10 variables, including social assistance, income, education, housing, family structure and employment status (9). Higher scores of these indices suggest higher level of social deprivation.

Socially deprived populations with limited access to health care services are more vulnerable to COVID-19, and it is critically important to explore the association between social deprivation and healthcare utilization (10, 11). However, this association remains controversial. Some studies have indicated that patients with greater deprivation scores are at a higher risk of hospitalization and ICU admission (12, 13), while other studies have found no association between social deprivation and hospitalization (14, 15).

We therefore conducted this systematic review and meta-analysis to evaluate the impact of socioeconomic status on hospitalization and ICU admission among COVID-19 patients.

Materials and Methods

The guidelines of the Cochrane Handbook for Systematic Reviews of Interventions and the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) were followed during all stages of the design, implementation and reporting of this meta-analysis (16, 17).

The protocol was registered in the PROSPERO database (trial registration: CRD42022319667).

Search strategy

Two authors independently searched for relevant literature in PubMed, Embase, and the Cochrane Register of Controlled Trials (updated to Jun 2022). The search strategy combined terms related to COVID-19, social deprivation, hospitalization, and ICU admission. Reference lists of previously identified literature were also consulted to retrieve additional relevant studies.

Study selection

Two independent reviewers (YJZ and KT) screened all papers using pre-designed eligibility forms. Disagreements were resolved through discussion with a third reviewer (TTL). Because different indicators are involved in the construction of various social deprivation indices, we assessed the impact of social deprivation on healthcare utilization by quantiles rather than in continuous, indexed form. Social deprivation score was categorized into quintiles, where quintile 1 represented the lowest deprivation level and quintile 5 represented the highest deprivation level. Patients in quintile 1 were socially advantaged, and patients

in quintiles 2-5 were socially disadvantaged. Studies were included if they met the following criteria: 1) participants: patients with confirmed COVID-19 infection; 2) intervention: social disadvantage (quintile 2-5 of social deprivation index); 3) comparison: social advantage (quintile 1 of social deprivation index); 4) outcome: hospitalization or ICU admission after COVID-19; 5) study design: observational studies. Studies that met the following criteria were excluded: 1) studies reporting on animals; 2) studies without quantifiable data regarding the association of social deprivation with hospitalization and ICU admission; 3) article types including reviews, letters, comments, conferences, and case reports; 4) studies using social deprivation as a continuous variable to measure the effect size estimates.

Data extraction

Two reviewers independently extracted the data from each study using a Microsoft Excel-based pre-designed electronic data collection form. The extracted data included the first author, publication year, region, study design, recruitment window, age, sample size, social deprivation assessment (ADI; SDI; index of multiple deprivation, IMD; NZDI; Townsend deprivation index, TDI; health improvement index, HII; Pampalon material deprivation index, PMDI), effect measures, effect size of the association between social deprivation scales and hospitalization/ICU admission, adjustment model, and outcomes. A third reviewer examined the extracted data, and any discrepancy was resolved through consensus. Authors of included papers were contacted via e-mail to obtain additional information when required.

Risk of bias assessment

Two reviewers (YJZ and KT) independently assessed the risk of bias, and any discrepancy was resolved by consensus. The risk of bias was assessed using the Newcastle-Ottawa Scale, used to determine the quality of non-randomized studies in the meta-analysis. This scale included three broad perspectives: 1) the selection of the study group, 2) the comparability of the groups, and 3) the ascertainment of the outcome of interest. The total score of the Newcastle-Ottawa Scale ranged from 0 to 9 points, with ≥ 8 points classified as high quality, 5-7 points as moderate quality, and < 5 points as low quality.

Statistical analyses

The statistical analysis was conducted using STATA version 16.0 (StataCorp, College Station, TX, USA). We estimated the odds ratio (OR) with 95% confidence interval (CI) to examine the association of social deprivation with hospitalization and ICU admission. The effects were pooled using a random-effects model to provide a more conservative estimate, allowing for any heterogeneity between studies (18). The heterogeneity was quantified through the I^2 statistic, and $I^2 \geq 50\%$ indicated significant heterogeneity.

To identify potential sources of heterogeneity, subgroup analyses were conducted based on region (USA, UK, or other countries), social deprivation assessment (ADI, IMD, or other deprivation indexes), study quality (high quality versus low-moderate quality), and adjustment model (adjusted or unadjusted). Sensitivity analysis was performed by omitting studies one by one to investigate each study's influence on the overall pooled estimate. The publication bias was assessed using funnel plots and the Egger test. The results were considered statistically significant with a $P<0.05$.

Systematic Review Registration: https://www.crd.york.ac.uk/PROSPERO/#recordDetails, identifier: CRD 42022319667.

Results

Study selection

Overall, 1,163 articles were retrieved, and 54 studies were reviewed in full text after the title and abstract screening. Ultimately, 11 papers with 2,423,095 patients were included in the meta-analysis (Fig. 1) (19-29). The characteristics of the included studies are shown in Table 1. Four studies were conducted in the USA (19, 21, 24, 27), five in the UK (22, 23, 26, 28, 29), one in New

Zealand (20), and one in Canada (25). The sample sizes ranged from 964 (conducted in Canada) to 2,311,282 (conducted in UK) (25, 26). Four studies used the IMD to assess social deprivation (22, 26, 28, 29), two studies used the ADI (19, 27), and five studies used other assessment tools, including the NZDI, HII, PMDI, TDI, and SDI (20, 21, 23-25).

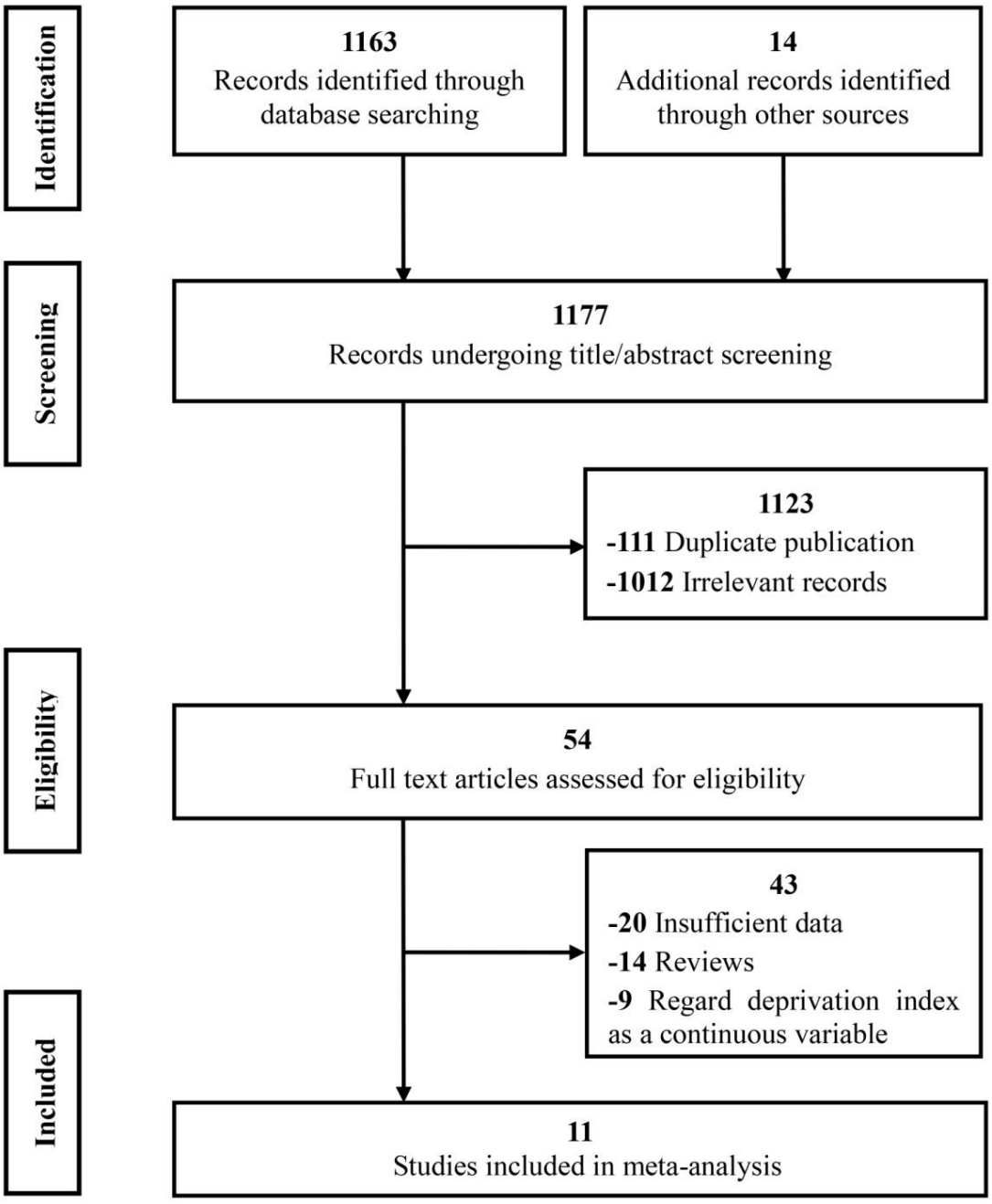

Fig. 1: Flow diagram of literature search and selection

Table 1: Characteristics of included studies

Study	*Publication year*	*Country*	*Recruitment window*	*Age/years*	*Sample size*	*Deprivation index*	*Effect measures*	*Outcome assessed*
Ingraham NE (19)	2020	USA	March 2020-August 2020	44(27-62)	5:577	ADI	OR	Hospitalization
Jefferies S (20)	2020	New Zealand	February 2020-May 2020	NA	1:153	NZDI	OR	Hospitalization
Lewis NM (21)	2020	USA	March 2020-July 2020	NA	28:148	HII	OR	Hospitalization
Cummins L (22)	2021	UK	February 2020-June 2020	≥16	1:781	IMD	OR	Hospitalization ICU admission
Saatci D (23)	2021	UK	January 2020-October 2020	14(9-17)	26:322	TDI	OR	Hospitalization ICU admission
Zhang Y (24)	2021	USA	March 2020-June 2020	54(38-68)	23:300	SDI	OR	Hospitalization ICU admission
Abda A (25)	2022	Canada	March 2020-May 2021	≤17	964	PMDI	OR	Hospitalization
Beaney T (26)	2022	UK	October 2020-April 2021	44.3(17.1)	2:311:282	IMD	OR	Hospitalization
Walls M (27)	2022	USA	March 2020-August 2020	NA	12:956	ADI	OR	Hospitalization ICU admission
Wan YI (28)	2022	UK	September 2020-February 2021	NA	5:533	IMD	OR	ICU admission
Ward JL (29)	2022	UK	February 2020-January 2021	≤18	6:079	IMD	OR	ICU admission

NA: not available; ADI: area deprivation index; NZDI: New Zealand deprivation index; HII: health improvement index; IMD: index of multiple deprivation; TDI: Townsend deprivation index; SDI: social deprivation index; Pampalon material deprivation index: PMDI; HR: hazard ratio; OR: odds ratio; ICU: intensive care unit.

Quality assessment

The quality of the included studies is shown in Table 2. Six studies were of high quality (≥8), while the others were of low-moderate quality according to the criteria of the Newcastle-Ottawa Scale.

Table 2: Results of Newcastle-Ottawa Scale quality assessment

Study	***Selection (4)***				***Compa-rability (2)***	***Outcome (3)***			***Qua lity (9)***
	Repre-senta-tiveness of the exposed cohort	Selection of the non-exposed cohort	Ascer-tainment of expo-sure	Demon-stration that out-come of interest was not present at start of study	Compara-bility of cohort on the basis of the design or analysis	Assess-ment of outcome	Was fol-low-up long enough for out-come to occur	Adequa-cy of follow up of co-horts	
Ingraham NE (19)	1	1	1	1	2	1	0	1	8
Jefferies S (20)	1	1	1	1	0	1	0	1	6
Lewis NM (21)	0	1	1	1	1	0	0	1	5
Cum-mins L (22)	0	1	1	1	2	1	1	1	8
Saatci D (23)	1	1	1	1	2	1	1	1	9
Zhang Y (24)	1	1	1	1	0	1	1	1	7
Abda A (25)	0	1	1	1	1	1	0	1	6
Beaney T (26)	1	1	1	1	2	1	1	1	9
Walls M (27)	1	1	1	1	2	1	1	1	9
Wan YI (28)	1	1	1	1	2	1	1	1	9
Ward JL (29)	0	1	1	1	0	1	0	1	5

Meta-analysis of the effects of social deprivation on hospitalization among COVID-19 patients

Nine studies provided information on the association between social deprivation and hospitalization. Socially disadvantaged patients had higher odds of hospitalization in comparison to socially advantaged patients (OR 1.25, 95% CI: 1.14 to 1.38; $P<0.01$, $I^2=76\%$). Significant heterogeneity was observed among included studies ($P<0.01$; Fig. 2).

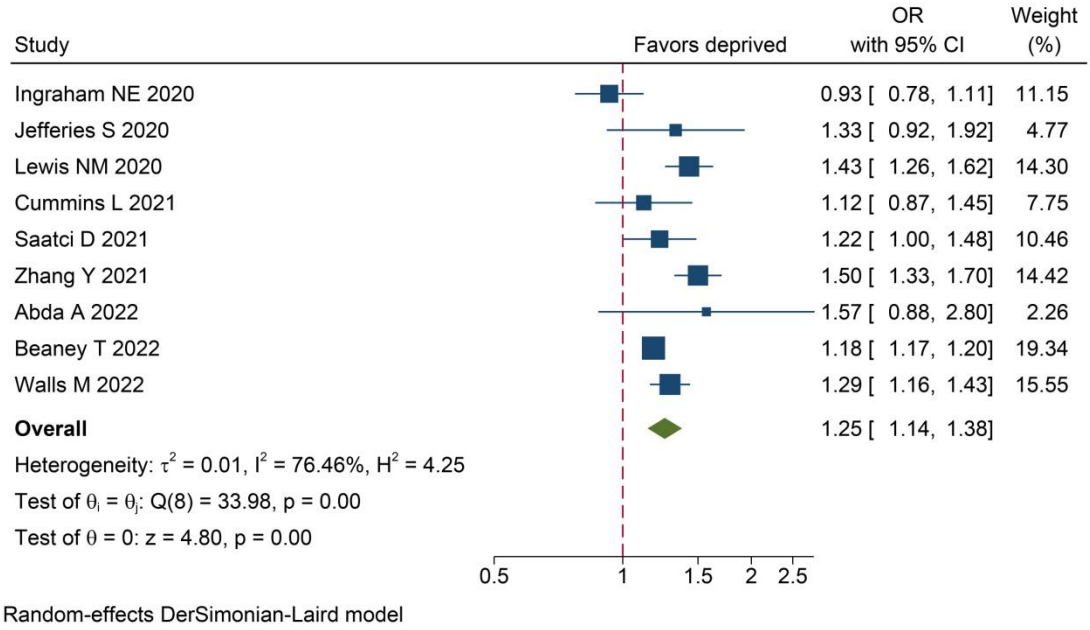

Fig. 2: Forest plot of the effects of social deprivation on hospitalization among COVID-19 patients

Meta-analysis of the effects of social deprivation on ICU admission among hospitalized COVID -19 patients

Six studies reported data on the association between social deprivation and ICU admission. The pooled OR value among the more deprived patients was not significantly different from the less deprived patients (OR 1.03, 95% CI: 0.78 to 1.35; P=0.85, I^2 =86%). A high level of heterogeneity was found in this meta-analysis (P<0.01; Fig. 3).

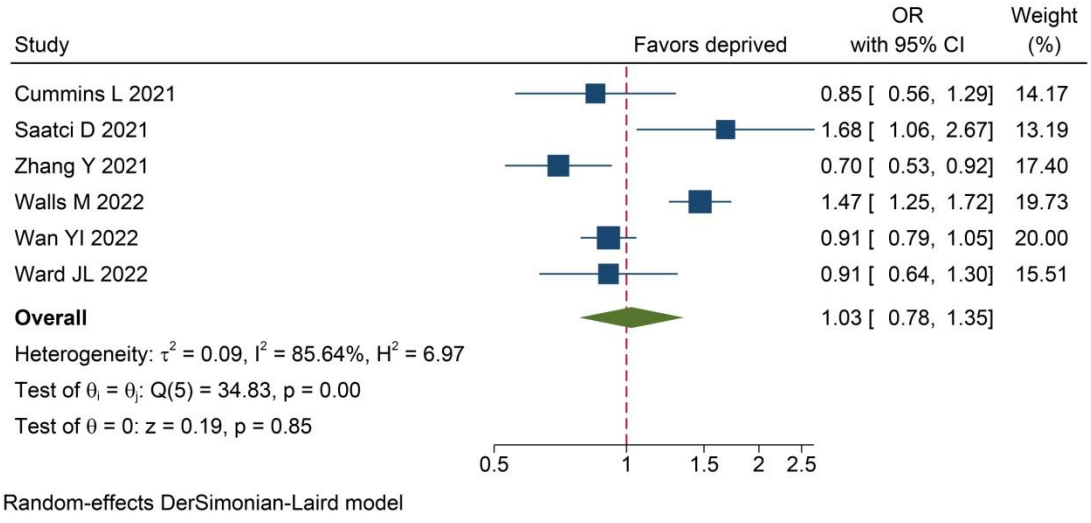

Fig. 3: Forest plot of the effects of social deprivation on ICU admission among COVID-19 patients

Subgroup analysis

For hospitalization, significant interaction was observed between the different deprivation assessments, and larger effects were found in studies that used other deprivation indices (P<0.01). There was also significant interaction between the different levels of study quality, and larger effects were found in studies of low-moderate

quality (P<0.01). Concurrently, heterogeneity declined in the subgroup analyses based on study quality and adjustment model (Fig. 4). In the subgroup analysis by adjustment model, socially deprived patients were less likely to be admitted to the ICU (OR 0.78, 95% CI: 0.60 to 1.00; I^2 =23%) in the unadjusted model, whereas no significant increase in the odds of ICU admission among deprived patients was observed in the adjusted model (OR 1.17, 95% CI: 0.83 to 1.63; I^2 =87%; Fig. 5).

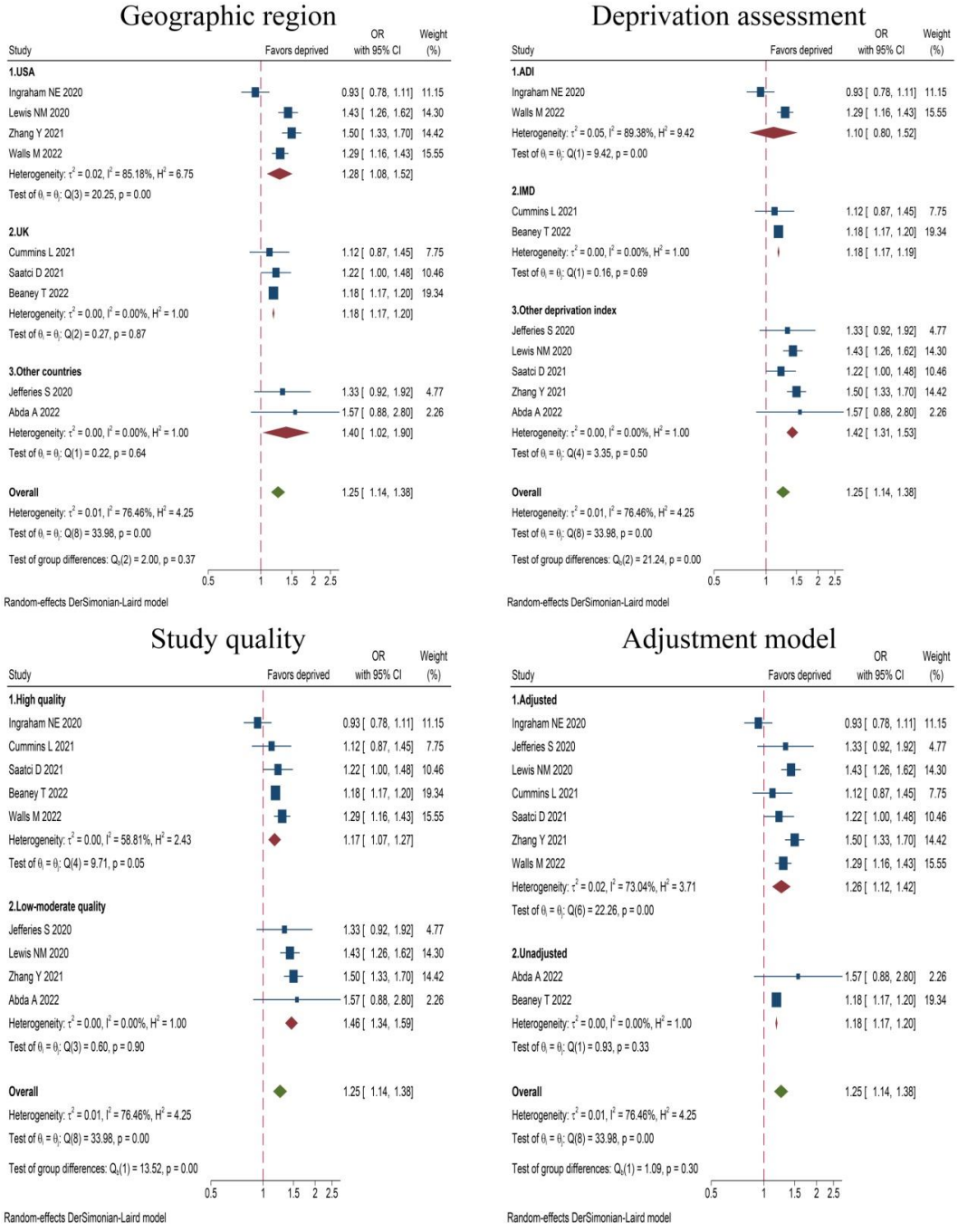

Fig. 4: Forest plot of subgroup analysis of the effects of social deprivation on hospitalization

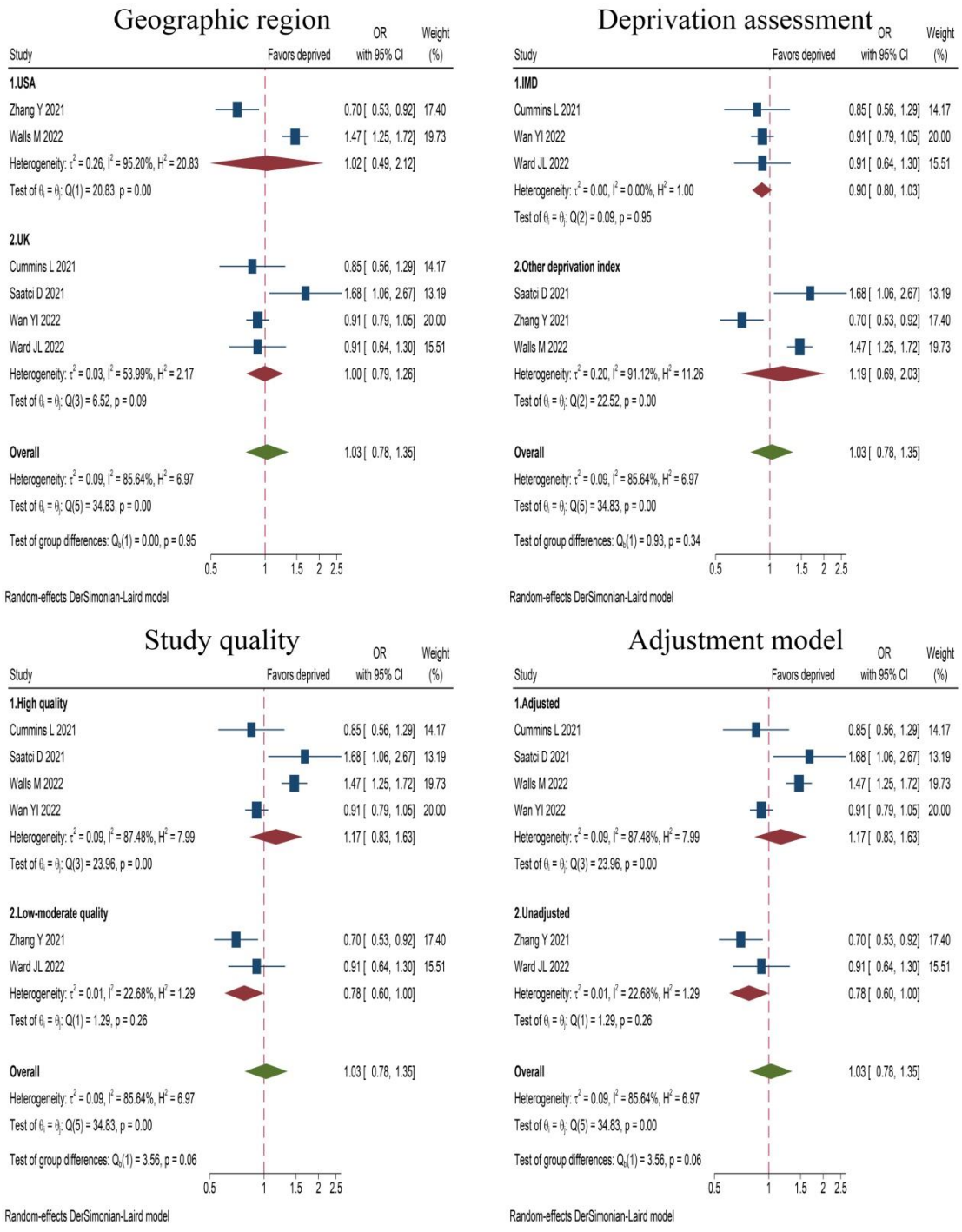

Fig. 5: Forest plot of subgroup analysis of the effects of social deprivation on ICU admission

Sensitivity analysis

For hospitalization, the sensitivity analysis showed that pooled OR values ranged from 1.22 (95% CI: 1.12 to 1.33) to 1.30 (95% CI: 1.19 to 1.43), consistent with the meta-analysis results. For ICU admission, pooled OR values ranged

from 0.92 (95% CI: 0.74 to 1.15) to 1.11 (95% CI: 0.84 to 1.48), implying that omitted studies resulted in only a small variation from the overall estimate (Table 3 and Table 4).

Table 3: Sensitivity analysis of the association between social deprivation and hospitalization

Study omitted	*Odds Ratio*	*95% Confidence Interval*		*Model*
Ingraham NE 2020	1.30	1.19	1.43	Random model
Jefferies S 2020	1.25	1.14	1.38	Random model
Lewis NM 2020	1.23	1.11	1.35	Random model
Cummins L 2021	1.27	1.15	1.4	Random model
Saatci D 2021	1.26	1.14	1.39	Random model
Zhang Y 2021	1.22	1.12	1.33	Random model
Abda A 2022	1.25	1.14	1.37	Random model
Beaney T 2022	1.27	1.13	1.43	Random model
Walls M 2022	1.25	1.12	1.39	Random model

Table 4: Sensitivity analysis of the association between social deprivation and ICU admission

Study omitted	*Odds Ratio*	*95% Confidence Interval*		*Model*
Cummins L 2021	1.06	0.78	1.44	Random model
Saatci D 2021	0.95	0.71	1.27	Random model
Zhang Y 2021	1.11	0.84	1.48	Random model
Walls M 2022	0.92	0.74	1.15	Random model
Wan YI 2022	1.06	0.74	1.51	Random model
Ward JL 2022	1.05	0.77	1.44	Random model

ICU, intensive care unit.

Publication bias assessment

Visual examination of the funnel plots for hospitalization and ICU admission indicated both were symmetrically distributed, suggesting that publication bias was unlikely to have influenced the pooled effect size. Moreover, the values of Egger's test were 0.829 and 0.904, respectively, indicating that there was no significant publication bias.

Discussion

The present meta-analysis identified disparities in healthcare utilization among COVID-19 patients with varying degrees of social deprivation. Socially disadvantaged populations were more likely to be hospitalized than those were socially advantaged. However, there was no significant difference in ICU utilization among patients with varying socioeconomic statuses. These results were robust through subgroup and sensitivity analyses.

The rapid increase in COVID-19 cases has overwhelmed global healthcare systems, and socially deprived populations have been disproportionately affected (30, 31). Social deprivation was associated with decreased COVID-19 testing rates, especially during the initial period of the pandemic wherein limited testing resources were predominately used for seriously ill populations, which resulted in poor outcomes for vulnerable individuals (32). Despite socially deprived populations being less likely to be tested, they were more likely to be COVID-19 positive, and they experienced increased barriers to healthcare access, such as lack of insurance, limited transportation, or fewer neighborhood medical resources (33-35). Such barriers led to delays in receiving medical care until the disease progressed, contributing to increased risk of hospitalization.

Differences in healthcare-seeking behaviors were also associated with the risk of hospitalization. The observed disparity in hospitalization rates

may be partially attributed to the fact that the socially advantaged individuals could obtain early outpatient services and prevent disease progression, resulting in a reduced need for inpatient services (36). In contrast, socially disadvantaged patients living in more deprived communities with fewer sources of supports and limited access to primary healthcare were more likely to receive initial medical care in emergency departments rather than ambulatory clinics, further increasing their risk of hospitalization (24).

Compared to socially advantaged groups, socially disadvantaged populations had more underlying health conditions, which placed them at higher risk for severe cases of COVID-19 (37, 38). These disparities in baseline health status may be attributed to socioeconomic determinants of health inequities (39, 40). For example, populations with low socioeconomic status experience unhealthier working environments and had more sedentary lifestyles as they lived in neighborhoods with few physical activity facilities. This increased their risk of cardiovascular disease (41, 42). Patients with pre-existing conditions, including but not limited to diabetes, obesity, dementia, and cardiovascular diseases, were at higher risk for progression to severe COVID-19 requiring hospital admission and intensive care (43).

In contrast to hospital service utilization, no significant association between social deprivation and ICU admission was observed in our meta-analysis. Moreover, three included studies in the subgroup analysis of the unadjusted model showed that social deprivation decreased the risk of ICU admission. However, income was negatively correlated with the risk of ICU admission (44). There are two possible reasons for these seemingly paradoxical results. First, factors other than income, such as employment, housing, and education, comprised the social deprivation index and might affect the risk of ICU admission. Second, the unadjusted model may have overestimated the pooled estimates of social deprivation and overlooked the effects of other risk factors, including older age, comorbidities, male sex, race, and ethnicity (45).

Given these findings, it is critically important to take measures to alleviate the identified burden on overwhelmed healthcare systems and reduce the social gradient during the COVID-19 pandemic. Providing at-home test kits and mobile clinics could improve equitable access to healthcare services, as transportation is often the major barrier to underserved populations (46, 47). Furthermore, primary prevention to reduce incidence and prevalence of underlying comorbidities and prioritization of vulnerable populations for vaccinations also play an important role in mitigating strain on healthcare systems (48, 49).

The present study had several strengths, including the application of rigorous Cochrane methodology to assess the pooled effect size. In addition, we performed a range of subgroups analyses to explore potential heterogeneity and conducted sensitivity analyses to examine the robustness of our findings. Despite these strengths, there were still limitations. First, four studies did not provide adjusted OR values of the association of social deprivation with hospitalization and ICU admission. Therefore, the pooled estimates might have been overestimated due to potential confounding factors. Second, significant heterogeneity was observed in our results. Although we conducted subgroup analyses by geographic region, deprivation assessment, and adjustment model, heterogeneity was still high in most subgroup analyses. The heterogeneity might reduce the generalizability and statistical power of the meta-analysis. Larger and more robust studies are needed to delineate the external validity our findings. Third, studies using social deprivation as a continuous variable to measure the effect size were excluded, and thus some relevant information may have been overlooked. Finally, most of the included studies were performed in the USA or UK. Therefore, caution should be used in applying these results to other regions.

Conclusion

COVID-19 has disproportionately affected socially deprived populations in that these popula-

tions have faced higher odds of hospitalization. However, no significant association was observed between social deprivation and ICU admission. The evidence from this meta-analysis has identified vulnerable populations at risk and it highlights the pressing need for healthcare services among socially disadvantaged populations. These findings should be considered in the implementation of public health interventions that aim to alleviate the burden on healthcare systems and reduce health inequity during the COVID-19 pandemic.

Journalism Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Funding

This work was supported by a grant from the National Natural Science Foundation of China (No. 72174204) and the Military Dual Construction Project (No. 03).

Acknowledgements

The authors would like to acknowledge the National Natural Science Foundation of China and the Military Dual Construction Project.

Conflict of interest

The authors declare that there is no conflict of interest.

References

1. Abbott S, Parretti HM, Hazlehurst J, et al. (2021). Socio-demographic predictors of uptake of a virtual group weight management program during the COVID-19 pandemic. *J Hum Nutr Diet*,34(3):480-4.
2. Mathur R, Rentsch CT, Morton CE, et al. (2021). Ethnic differences in SARS-CoV-2 infection and COVID-19-related hospitalisation, intensive care unit admission, and death in 17 million adults in England: an observational cohort study using the OpenSAFELY platform. *Lancet*, 397(10286):1711-24.
3. Gomez CA, Kleinman DV, Pronk N, et al. (2021). Addressing Health Equity and Social Determinants of Health Through Healthy People 2030. *J Public Health Manag Pract*,27(Suppl 6):S249-S57.
4. Grosicki GJ, Bunsawat K, Jeong S, et al. (2022). Racial and ethnic disparities in cardiometabolic disease and COVID-19 outcomes in White, Black/African American, and Latinx populations: Social determinants of health. *Prog Cardiovasc Dis*, 71:11-19.
5. Ogedegbe G, Ravenell J, Adhikari S, et al. (2020). Assessment of Racial/Ethnic Disparities in Hospitalization and Mortality in Patients With COVID-19 in New York City. *JAMA Netw Open*,3(12):e2026881.
6. Mude W, Oguoma VM, Nyanhanda T, et al. (2021). Racial disparities in COVID-19 pandemic cases, hospitalisations, and deaths: A systematic review and meta-analysis. *J Glob Health*,11:05015.
7. Liaw W, Krist AH, Tong ST, et al. (2018). Living in "Cold Spot" Communities Is Associated with Poor Health and Health Quality. *J Am Board Fam Med*,31(3):342-50.
8. Kind AJ, Jencks S, Brock J, et al. (2014). Neighborhood socioeconomic disadvantage and 30-day rehospitalization: a retrospective cohort study. *Ann Intern Med*,161(11):765-74.
9. Salmond C, Crampton P, Sutton F (1998). NZDep91: A New Zealand index of deprivation. *Aust N Z J Public Health*,22(7):835-7.
10. Zhang Y, Ancker JS, Hall J, et al. (2020). Association Between Residential Neighborhood Social Conditions and Health Care Utilization and Costs. *Med Care*,58(7):586-93.
11. Bray I, Gibson A, White J (2020). Coronavirus disease 2019 mortality: a multivariate ecological analysis in relation to ethnicity, population density, obesity, deprivation and pollution. *Public Health*,185:261-3.

12. Gu T, Mack JA, Salvatore M, et al. (2020). Characteristics Associated With Racial/Ethnic Disparities in COVID-19 Outcomes in an Academic Health Care System. *JAMA Netw Open*,3(10):e2025197.
13. Patel AP, Paranjpe MD, Kathiresan NP, et al. (2020). Race, socioeconomic deprivation, and hospitalization for COVID-19 in English participants of a national biobank. *Int J Equity Health*,19(1):114.
14. Beaumont AL, Vignes D, Sterpu R, et al. (2022). Factors associated with hospital admission and adverse outcome for COVID-19: Role of social factors and medical care. *Infect Dis Now*, 52(3):130-137.
15. Escobar GJ, Adams AS, Liu VX, et al. (2021). Racial Disparities in COVID-19 Testing and Outcomes: Retrospective Cohort Study in an Integrated Health System. *Ann Intern Med*,174(6):786-93.
16. Moher D, Liberati A, Tetzlaff J, et al. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*,339:b2535.
17. Higgins J (2011). Cochrane handbook for systematic reviews of interventions. Version 5.1. 0 (updated March 2011). The Cochrane Collaboration. https://handbook-5-1.cochrane.org/
18. DerSimonian R, Laird N (2015). Meta-analysis in clinical trials revisited. *Contemp Clin Trials*,45(Pt A):139-45.
19. Ingraham NE, Purcell LN, Karam BS, et al. (2020). Racial and Ethnic Disparities in Hospital Admissions from COVID-19: Determining the Impact of Neighborhood Deprivation and Primary Language. *J Gen Intern Med*,36(11):3462-70.
20. Jefferies S, French N, Gilkison C, et al. (2020). COVID-19 in New Zealand and the impact of the national response: a descriptive epidemiological study. *The Lancet Public Health*,5(11):e612-e23.
21. Lewis NM, Friedrichs M, Wagstaff S, et al. (2020). Disparities in COVID-19 Incidence, Hospitalizations, and Testing, by Area-Level Deprivation - Utah, March 3-July 9, 2020. *MMWR Morbidity and Mortality Weekly Report*,69(38):1369-73.
22. Cummins L, Ebyarimpa I, Cheetham N, et al. (2021). Factors associated with COVID-19 related hospitalisation, critical care admission and mortality using linked primary and secondary care data. *Influenza Other Respir Viruses*,15(5):577-88.
23. Saatci D, Ranger TA, Garriga C, et al. (2021). Association Between Race and COVID-19 Outcomes Among 2.6 Million Children in England. *JAMA Pediatrics*,175(9):928-38.
24. Zhang Y, Khullar D, Wang F, et al. (2021). Socioeconomic variation in characteristics, outcomes, and healthcare utilization of COVID-19 patients in New York City. *PLoS ONE*,16(7):e0255171.
25. Abda A, Del Giorgio F, Gauvin L, et al. (2022). Association between area-level material deprivation and incidence of hospitalization among children with SARS-CoV-2 in Montreal. *Paediatr Child Health*,27(Suppl 1):S27-S32.
26. Beaney T, Neves AL, Alboksmaty A, et al. (2022). Trends and associated factors for Covid-19 hospitalisation and fatality risk in 2.3 million adults in England. *Nat Commun*,13(1):2356.
27. Walls M, Priem JS, Mayfield CA, et al. (2022). Disparities in Level of Care and Outcomes Among Patients with COVID-19: Associations Between Race/Ethnicity, Social Determinants of Health and Virtual Hospitalization, Inpatient Hospitalization, Intensive Care, and Mortality. *J Racial Ethn Health Disparities*, 15:1-11.
28. Wan YI, Apea VJ, Dhairyawan R, et al. (2022). Ethnic disparities in hospitalisation and hospital-outcomes during the second wave of COVID-19 infection in east London. *Scientific Reports*, 12(1):3721.
29. Ward JL, Harwood R, Smith C, et al. (2022). Risk factors for PICU admission and death among children and young people hospitalized with COVID-19 and PIMS-TS in England during the first pandemic year. *Nature Med*,28(1):193-200.
30. Iacobucci G (2020). Covid-19: Deprived areas have the highest death rates in England and Wales. *BMJ*,369:m1810.
31. Williamson EJ, Walker AJ, Bhaskaran K, et al. (2020). Factors associated with COVID-19-related death using OpenSAFELY. *Nature*,584(7821):430-6.

32. Vandentorren S, Smaili S, Chatignoux E, et al. (2022). The effect of social deprivation on the dynamic of SARS-CoV-2 infection in France: a population-based analysis. *The Lancet Public Health*,7(3):e240-e9.
33. Ossimetha A, Ossimetha A, Kosar CM, et al. (2021). Socioeconomic Disparities in Community Mobility Reduction and COVID-19 Growth. *Mayo Clin Proc*,96(1):78-85.
34. K CM, Oral E, Straif-Bourgeois S, et al. (2020). The effect of area deprivation on COVID-19 risk in Louisiana. *PLoS ONE*,15(12):e0243028.
35. Paremoer L, Nandi S, Serag H, et al. (2021). Covid-19 pandemic and the social determinants of health. *BMJ*,372:n129.
36. Dei V, Sebastian MS (2018). Is healthcare really equal for all? Assessing the horizontal and vertical equity in healthcare utilisation among older Ghanaians. *Int J Equity Health*,17(1):86.
37. Arasteh K (2021). Prevalence of Comorbidities and Risks Associated with COVID-19 Among Black and Hispanic Populations in New York City: an Examination of the 2018 New York City Community Health Survey. *J Racial Ethn Health Disparities*,8(4):863-9.
38. Clark A, Jit M, Warren-Gash C, et al. (2020). Global, regional, and national estimates of the population at increased risk of severe COVID-19 due to underlying health conditions in 2020: a modelling study. *The Lancet Global Health*,8(8):e1003-e17.
39. Ferdinand KC, Nasser SA (2020). African-American COVID-19 Mortality: A Sentinel Event. *J Am Coll Cardiol*,75(21):2746-8.
40. Abuelgasim E, Saw LJ, Shirke M, et al. (2020). COVID-19: Unique public health issues facing Black, Asian and minority ethnic communities. *Curr Probl Cardiol*,45(8):100621.
41. Kivimaki M, Kawachi I (2015). Work Stress as a Risk Factor for Cardiovascular Disease. *Curr Cardiol Rep*,17(9):630.
42. Sallis JF, Glanz K (2006). The role of built environments in physical activity, eating, and obesity in childhood. *Future Child*,16(1):89-108.
43. Treskova-Schwarzbach M, Haas L, Reda S, et al. (2021). Pre-existing health conditions and severe COVID-19 outcomes: an umbrella review approach and meta-analysis of global evidence. *BMC Med*,19(1):212.
44. Magesh S, John D, Li WT, et al. (2021). Disparities in COVID-19 Outcomes by Race, Ethnicity, and Socioeconomic Status: A Systematic-Review and Meta-analysis. *JAMA Netw Open*,4(11):e2134147.
45. Grasselli G, Greco M, Zanella A, et al. (2020). Risk Factors Associated With Mortality Among Patients With COVID-19 in Intensive Care Units in Lombardy, Italy. *JAMA Intern Med*,180(10):1345-55.
46. Rader B, Gertz A, Iuliano AD, et al. (2022). Use of At-Home COVID-19 Tests - United States, August 23, 2021-March 12, 2022. *MMWR Morbidity and Mortality Weekly Report*,71(13):489-94.
47. Shukla S, Fressin F, Un M, et al. (2022). Optimizing vaccine distribution via mobile clinics: a case study on COVID-19 vaccine distribution to long-term care facilities. *Vaccine*,40(5):734-41.
48. Sellner J, Jenkins TM, von Oertzen TJ, et al. (2021). Primary prevention of COVID-19: Advocacy for vaccination from a neurological perspective. *Eur J Neurol*,28(10):3226-9.
49. Hoven H, Dragano N, Angerer P, et al. (2022). Striving for Health Equity: The Importance of Social Determinants of Health and Ethical Considerations in Pandemic Preparedness Planning. *Int J Public Health*,67:1604542.