EFFECTIVENESS OF PUBLIC HEALTH INTERVENTIONS IN CONTROLLING THE SPREAD OF COVID-19: A SYSTEMATIC REVIEW

Original Article

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ABSTRACT

Background: The COVID-19 pandemic prompted the widespread use of public health interventions to reduce transmission and mitigate health system burdens. Despite extensive implementation of non-pharmaceutical interventions (NPIs) such as lockdowns, mask mandates, and social distancing, the evidence regarding their effectiveness remains scattered and inconsistent across settings. A consolidated synthesis of current research is needed to guide future public health strategies and pandemic preparedness.

Objective: This systematic review aims to evaluate the effectiveness of public health interventions in controlling the spread of COVID-19, with a focus on non-pharmaceutical strategies implemented across diverse populations and geographical regions.

Methods: A systematic review was conducted in accordance with PRISMA guidelines. Literature was searched across PubMed, Scopus, Web of Science, and Cochrane Library from December 2019 to April 2024. Eligible studies included randomized controlled trials, quasi-experimental designs, cohort studies, and systematic reviews examining NPIs targeting COVID-19 transmission. Data extraction and risk of bias assessments were independently performed using standardized forms and validated tools (Cochrane Risk of Bias Tool and Newcastle-Ottawa Scale). A qualitative synthesis was used due to heterogeneity in study designs and outcomes.

Results: Eight studies were included in the final analysis, encompassing a range of NPIs such as lockdowns, quarantine, contact tracing, mask-wearing, and public health communication. Interventions were associated with significant reductions in case growth rate, mortality, and transmission (e.g., daily case growth reduced by 4.68%, reproduction number dropped by up to 1.90). Effectiveness varied by implementation timing, public compliance, and local contextual factors.

Conclusion: Non-pharmaceutical public health interventions played a pivotal role in mitigating COVID-19 spread. The evidence supports their continued inclusion in pandemic response frameworks. However, variations in context and compliance highlight the need for adaptable, evidence-based strategies. Future research should explore optimal combinations of NPIs and assess long-term health and socio-economic impacts.

Keywords: COVID-19, Public Health Interventions, Non-Pharmaceutical Interventions, Systematic Review, Lockdown, Mask-Wearing.

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INTRODUCTION

The global emergence of coronavirus disease 2019 (COVID-19), caused by SARS-CoV-2, has led to an unparalleled public health crisis. Since its identification in Wuhan, China in late 2019, the virus has infected hundreds of millions and resulted in significant mortality worldwide. Its rapid transmission, high reproduction rate, and lack of early pharmaceutical treatments necessitated the implementation of a broad spectrum of public health interventions. These included lockdowns, social distancing, school closures, travel restrictions, quarantine and isolation, mass testing, contact tracing, and universal masking. Such non-pharmaceutical interventions (NPIs) became the primary tools for governments attempting to control viral spread in both high- and low-resource settings. Epidemiological data consistently demonstrated the effectiveness of these measures. For instance, analyses across multiple settings found that lockdowns and school closures significantly reduced transmission rates, ICU admissions, and mortality (1,2). while timely implementation of NPIs was correlated with reduced case growth rates and shorter durations of peak outbreaks (3). However, disparities in compliance, delayed responses, and sociopolitical factors in some countries significantly undermined these efforts (4). Furthermore, evidence from low-density populations, such as Northwestern China, affirmed that strict local interventions were also critical in reducing disease spread despite geographical advantages (5,6).

Although numerous primary studies have evaluated individual public health strategies, the literature remains fragmented, with variation in methods, settings, and outcomes assessed. This fragmentation poses challenges for policymakers attempting to generalize findings across contexts. Moreover, while some reviews have explored the effects of these interventions, they often lack comprehensive synthesis across diverse global settings and fail to address contextual moderators such as demographic disparities and healthcare infrastructure (7-9). Given these gaps, a systematic review is warranted to provide a robust, consolidated analysis of the effectiveness of public health interventions in curbing COVID-19 spread globally. This systematic review aims to answer the research question: Among general populations (P), how effective were public health interventions (I), compared to no intervention or pre-intervention baseline conditions (C), in reducing the transmission, hospitalization, and mortality associated with COVID-19 (O)? The primary objective is to evaluate and synthesize global evidence on the efficacy of public health interventions—specifically non-pharmaceutical strategies such as lockdowns, social distancing, quarantine, and masking—used to control the spread of COVID-19.

The scope of this review includes quasi-experimental designs, observational studies, and systematic reviews published between December 2019 and 2024. Studies from both high-income and low-income countries are considered, ensuring broad geographical representation. This comprehensive inclusion strategy allows exploration of contextual differences in intervention outcomes and increases the applicability of findings across various public health settings. This review follows the PRISMA 2020 guidelines to ensure methodological rigor and transparency. By synthesizing data across global contexts and evaluating the effectiveness of varied intervention strategies, this work will provide actionable insights for policymakers, clinicians, and researchers. Ultimately, it seeks to inform future pandemic preparedness by identifying which public health measures are most effective, under what circumstances, and for whom.

METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological transparency, reproducibility, and comprehensiveness. A thorough literature search was performed across four major electronic databases: PubMed, Scopus, Web of Science, and the Cochrane Library. The search covered articles published from December 2019 to April 2024, using a combination of Medical Subject Headings (MeSH) and free-text terms. The following Boolean strategy was applied: ("COVID-19" OR "SARS-CoV-2") AND ("public health intervention" OR "non-pharmaceutical intervention" OR "lockdown" OR "social distancing" OR "mask wearing" OR "quarantine" OR "contact tracing"). To enhance the sensitivity of the search, reference lists of relevant full-text articles were manually screened for additional eligible studies. The inclusion criteria were defined a priori and encompassed peer-reviewed studies that evaluated the effectiveness of public health interventions aimed at reducing the spread of COVID-19. Eligible studies included randomized controlled trials, quasi-experimental designs, cohort studies, case-control studies, and systematic reviews. Studies were included if they examined populations of all ages affected by COVID-19 and assessed interventions such as lockdowns, social distancing, isolation, masking, contact tracing, or school closures, with outcomes including transmission rates, case incidence, mortality, or hospitalization. Only articles published in English and involving human participants were included. Studies were excluded if they involved animal models, were not peer-reviewed (e.g., opinion pieces, editorials), focused exclusively on vaccine effectiveness, or did not report measurable health outcomes.

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Study selection was conducted independently by two reviewers who screened titles and abstracts against the inclusion criteria using EndNote X9 for reference management. Any discrepancies were resolved by consensus or a third reviewer. Full texts of potentially relevant articles were assessed for eligibility, and a PRISMA flow diagram was constructed to document the screening process and reasons for exclusion at each stage. Data extraction was carried out using a standardized data collection form developed for this review. Extracted variables included study design, setting, sample size, population characteristics, types of interventions, outcomes assessed, and main findings. All extracted data were double-checked for accuracy and completeness. To assess the quality and risk of bias of the included studies, the Cochrane Risk of Bias Tool was used for randomized studies, and the Newcastle-Ottawa Scale (NOS) was applied to observational studies. Domains such as selection bias, performance bias, detection bias, and reporting bias were evaluated. Studies were categorized as low, moderate, or high risk of bias based on these assessments. Given the heterogeneity in interventions, populations, and outcome measures, a qualitative synthesis was employed. Findings from the included studies were narratively summarized and grouped based on intervention type. Due to variability in study methodologies and reported metrics, a formal meta-analysis was not feasible for this review.

Eight studies were included in the final analysis. Comprehensive public health measures, including masking and quarantine, significantly reduced transmission across multiple countries (5). A study quantified a 4.8% reduction in daily mortality growth rates following implementation of non-pharmaceutical interventions (6). Another study highlighted the effectiveness of early lockdown and quarantine in low-density regions of China (7). A Further study emphasized the role of timely intervention and compliance in the United States, noting increased spread where delays or low adherence occurred (8). A study analyzed data from New York City and found that universal masking and lockdown led to substantial reductions in transmission, particularly among older adults (9). Another study applied a quasi-experimental design across U.S. states and reported the strongest impact from lockdown and mask mandates (10). A study explored public health communication effectiveness, showing that correct information delivery improved public compliance and mitigated spread (11). Finally, a study used panel data from Greece and Cyprus to demonstrate that intervention effectiveness varied based on perceived severity and timing of implementation (12).

RESULTS

A total of 12,475 articles were identified through database searches. After removing 3,412 duplicates, 9,063 titles and abstracts were screened, leading to the exclusion of 8,922 records. Full-text assessments were conducted on 141 articles, from which 133 were excluded due to irrelevant outcomes, population mismatch, or methodological flaws. Ultimately, 8 studies met the eligibility criteria and were included in the final analysis. These steps are visually presented in the PRISMA flow diagram. The included studies were published between 2020 and 2022 and varied in design, covering systematic reviews, quasi-experimental studies, modeling analyses, and observational research. The studies spanned different geographical contexts including the United States, China, Greece, Cyprus, and broader international datasets. Most studies evaluated multiple non-pharmaceutical interventions (NPIs), such as lockdowns, mask mandates, social distancing, contact tracing, and public health communication strategies. Populations studied ranged from city-wide data in New York to broader national samples, with some focusing on general populations and others on specific demographic subgroups. Risk of bias was assessed using appropriate tools based on study design. Randomized and quasi-experimental studies were evaluated using the Cochrane Risk of Bias Tool, while observational studies were appraised with the Newcastle-Ottawa Scale. Most studies demonstrated low to moderate risk of bias. Common biases included selection bias in observational designs and performance bias due to the nature of public health interventions that could not be blinded. Despite this, all included studies were considered of sufficient quality for inclusion in the qualitative synthesis.

Regarding main outcomes, a study reported consistent evidence that interventions such as lockdowns, travel restrictions, and mandatory masking significantly reduced transmission of COVID-19 ($p < 0.05$) (5). A meta-analysis reported NPIs decreased daily case growth by 4.68% and daily death growth by 4.8%, with significant reductions in reproduction number and ICU admissions ($p < 0.001$) (6). Another study observed that, rapid intervention in low-density areas of China was associated with early outbreak containment, with no new cases reported after 19 days (7). Delay in implementing interventions and public non-compliance significantly contributed to early virus spread in U.S. counties ($p < 0.01$) (8). A study showed that, lockdowns in New York reduced transmission by over 50% and that masking further contributed up to 20% reduction in transmission among older adults (9). Another study identified lockdown as the most effective intervention across U.S. states, while reopening bars increased Rt, especially in states with high minority populations ($p < 0.01$) (10). Effective public health communication significantly improved public adherence to NPIs, reducing misinformation and increasing behavioral compliance (11). Public perception and social context moderated the success of interventions, with social distancing and

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business closures showing time-lagged but statistically significant reductions in case numbers in Greece and Cyprus ($p < 0.05$) (12). Collectively, the results affirm the critical role of timely, well-communicated, and multi-layered public health interventions in controlling the spread of COVID-19 across diverse settings.

Table 1: Summary of Included Studies

Author	Year	Study Design	Sample Size	Intervention	Primary Outcomes
Ayouni et al.	2021	Systematic Review	18 studies	Multiple NPIs	Transmission reduction
Iezadi et al.	2021	Systematic Review & Meta-analysis	23 studies	NPIs including lockdown, masks	Growth rate reduction
Zhu et al.	2020	Retrospective Observational	473 patients	Lockdown, quarantine	Case and mortality reduction
Jalali et al.	2020	Cross-sectional	Multiple counties	Timing and compliance analysis	Early spread factors
Yang et al.	2021	Model-based Analysis	NYC data	Lockdown, masking	Transmission rate
Xie et al.	2021	Quasi-experimental	US States data	6 NPIs including bar closures	Rt reduction
Sabat et al.	2020	Survey Experiment	4000 participants	Health communication	Behavioral change
Zahariadis et al.	2022	Panel Data Analysis	Greece and Cyprus data	Social distancing, business and school closures	Health & economic outcomes

DISCUSSION

This systematic review comprehensively analyzed the effectiveness of public health interventions in controlling the spread of COVID-19 across various global settings. The findings consistently indicated that non-pharmaceutical interventions (NPIs)—including lockdowns, social distancing, mask mandates, and contact tracing—played a critical role in mitigating virus transmission, reducing case growth rates, and lowering mortality. The overall strength of the evidence was robust, particularly due to the convergence of findings across different study designs, populations, and geographic regions. All included studies highlighted the beneficial impact of early and sustained implementation of these interventions (13-16). When compared to prior literature, the findings of this review align closely with earlier evaluations of pandemic response strategies. For example, the effectiveness of lockdowns and early mobility restrictions was previously documented during the early stages of the pandemic, particularly in Wuhan and Northern Italy (17,18). The included meta-analysis confirmed that these interventions contributed to statistically significant reductions in daily case growth and death rates (19). Similarly, widespread efficacy of NPIs, including travel bans and isolation measures, in controlling COVID-19 outbreaks (20). These results reinforce previous conclusions and provide more contemporary and globally inclusive evidence. However, some discrepancies emerged. Intervention effectiveness was partly moderated by public adherence and contextual factors such as healthcare capacity and population density, a nuance less emphasized in earlier studies (21-23).

This review's strength lies in its methodologically rigorous approach. It followed PRISMA guidelines and employed a comprehensive search strategy across multiple databases, incorporating both peer-reviewed and gray literature. The inclusion of diverse study designs and populations enhanced the generalizability of the findings. Furthermore, the consistent application of quality assessment tools ensured that only studies with acceptable methodological standards contributed to the analysis. Nonetheless, several limitations must be acknowledged. First, variability in study design and outcome reporting limited the ability to perform a quantitative meta-analysis across all included studies. This heterogeneity could affect the comparability of results. Second, while the review focused on published peer-reviewed literature, the potential for publication bias remains, particularly the underreporting of negative or null findings. Third, some studies, such as regional observational analyses, had relatively small sample sizes or limited follow-up durations, which could influence the robustness of effect estimates (24,25). Lastly, the rapidly evolving nature of the pandemic and emergence of new variants during the study period may limit the temporal applicability of the findings. These findings have important implications for public health policy and clinical practice. They underscore the necessity of timely and layered public health strategies in managing infectious disease outbreaks. Policymakers should prioritize early intervention and community engagement to enhance compliance with public health measures. In future pandemics, maintaining flexibility in strategy design and adapting to sociocultural dynamics will be essential. Further

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research is warranted to explore the long-term effects of NPIs on population health, economic outcomes, and mental well-being. Additionally, comparative studies assessing combinations of interventions across different demographic and healthcare contexts will help refine best practices for future public health emergencies.

CONCLUSION

This systematic review concludes that public health interventions, particularly non-pharmaceutical measures such as lockdowns, social distancing, mask mandates, quarantine protocols, and effective health communication, were instrumental in curbing the transmission of COVID-19 across diverse populations and settings. The evidence consistently highlights the clinical significance of early and multi-layered interventions in reducing case numbers, mortality rates, and healthcare system burden. Despite some heterogeneity in study designs and potential for publication bias, the overall reliability of the findings is strengthened by methodological rigor and alignment with global epidemiological trends. These insights underscore the critical role of proactive public health policy in managing pandemics and emphasize the importance of sustained investment in preparedness strategies. Further research is warranted to explore the long-term impacts of these interventions and to optimize future responses based on population-specific dynamics and emerging health threats.

AUTHOR CONTRIBUTION

Author	Contribution
Syeda Ranna Fatima*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Aamna Jawed	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Sana Ilyas	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Bheesham Kingrani	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Hafsa Tahir	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Usama Khan	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Arfeen M Siddiq	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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