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Abstract

Healthcare worker resilience is essential to building effective, functional, and crisis-ready health systems. This systematic map aimed to provide a comprehensive overview of the global evidence and identify gaps in resilience interventions for healthcare workers. A framework of interventions and outcomes was prepared with the help of advisory group members. The protocol was registered with the Open Science Framework. The search results records were deduplicated and subjected to two levels of screening. We mapped 587 studies in the intervention-outcome framework. Most studies were conducted in high-income countries (473,80.58%) and among nurses (284 studies,48.38%), followed by other categories of health care workers. The most frequently included interventions were resilience training (240,40.89%) and training and mentorship in the workplace (236,40.20%). Artificial Intelligence-based or systems-thinking interventions (31,5.28%) and herbal/traditional or conventional pharmacological interventions (4,0.68%) were the least studied. Psychological outcomes were the domain of outcomes assessed most frequently (521,88.76%). Patient safety (7,1.19%), systems/ policy level outcomes (16,2.73%), and performance/ presenteeism (20, 3.41%) were the least measured outcomes. Overall, this systematic map provides evidence and gaps in resilience interventions for healthcare workers and can be used for planning and conducting future primary studies or systematic reviews.

Keywords: systematic map, evidence map, resilience of healthcare worker, intervention for improving resilience

1. Introduction

Resilience is the ability of an individual, community, or system to adapt or withstand hardships, thrive despite adversity, and recover from stressors (1). Healthcare workers (HCW) resilience and their psychosocial and economic wellbeing significantly influence their performance, as well as the quality of healthcare. This, in turn, affects the system's capacity to withstand shocks and crises and maintain service continuity (2–5). An effective health workforce, capable of sustaining the core functions of a health system, is essential to achieve the goals of the system (6,7).

Despite the global prioritization of safeguarding the mental health and well-being of healthcare workforce (8), HCW continue to face a combination of psychosocial, organizational, lifestyle, and sociocultural challenges. These challenges compromise their performance and overall health in stable (9) as well as in fragile, conflict- or crisis-affected environments (10–12). These challenges are not isolated; their persistent cross-cutting impacts across the entire socio-ecological system present further complexities. HCW (or the individual) is situated at the center of reciprocal, multi-level interactions ranging from immediate personal relationships to broad cultural and policy contexts in the socio-ecological model (13). Research shows that HCW face several challenges, including burnout, moral injury, emotional exhaustion, and interpersonal conflict (13–15). These challenges are exacerbated by systemic factors such as understaffing, resource shortages, heavy workloads, and lack of organizational support (16), as well as sociocultural determinants such as stigma and systemic inequities.

In response, interventions have been developed at multiple levels of socio-ecological context to improve HCW resilience. At the individual (or micro) level, mental health and psychosocial support services reduce stress and prevent burnout, while training programs strengthen their coping skills and stress management capacities (17–22). At the organizational (or meso) level, strategies such as improving workplace climate, reducing workload, promoting wellbeing, and supporting professional development are recommended (9,23–26). At community (or meso) level, peer and community-based psychosocial support networks, human resources for health associations alongside advocacy efforts for HCW, contribute to building resilience (27–29).

However, existing interventions are often context-specific, with limited evidence of transferability across diverse health systems (or macro level) (30,31). Evidence on the effectiveness and applicability of these interventions in low and middle-income countries (LMICs) remains scarce (32,33). Moreover, there is a lack of high-quality evidence on organizational-level interventions and innovative interventions (4,34), as well as interventions tailored for crisis situations such as the COVID-19 disease outbreak, conflict situations or climate-related hazards (35,36). With recent HCW strikes, protests, migration (37), and World Health Organization's (WHO) alerts on global HCW shortages (38), including recent episodes of health crisis, the urgency to sustain HCW wellbeing is intensified, which underscores the need

for stronger evidence on resilience and wellbeing interventions (39–43). Figure 1 presents the conceptual framework for this systematic map.

This study uses systematic mapping:

- To map the global evidence and gaps on interventions designed to improve resilience of healthcare workers from 2004-2025
- To map the global interventions focusing on building resilience by improving mental health and wellbeing of healthcare workers from 2004-2025
- To compare the nature of evidence for building resilience of healthcare workers in pre- and post-pandemic scenario

Unlike systematic reviews that evaluate effectiveness, systematic mapping enables the identification, categorization, and analysis of the breadth of existing evidence, thereby highlighting the strengths and exposing critical knowledge gaps (44). By mapping interventions and outcomes into a matrix based on the socio-ecological framework, we can see more clearly how the system functions in its entirety. To our knowledge, this is the first review to systematically map resilience and wellbeing intervention categories for the global healthcare workforce.

2. Methods

The review follows a transparent and reproducible framework aligned with evidence mapping standards. The methodology for this systematic map followed the mapping review approaches (44,45), along with the PRISMA guidelines (46) for conducting and reporting reviews. The protocol (DOI 10.17605/OSF.IO/9V8P5) was registered with the Open Science Framework database (47). The list of abbreviations and the PRISMA-ScR checklist is provided in Supplementary File 1.

2.1 Eligibility criteria

Population: In this systematic map, included studies conducted globally on institution- and community-based health and healthcare workers. Health and healthcare work included any role that involved direct contact (e.g., providing care at an institution or outreach), indirect contact (e.g., managing a care team), or potential contact (e.g., working in the same ward) with population to improve health (35). Health workers from all levels of care (preventive, promotive, curative, and rehabilitative), as well as studies on students from nursing, medical or paramedical colleges. Studies conducted in non-healthcare study streams and studies on health care providers from the informal sectors, the general population or patients were excluded. However, if the general population had a subgroup of healthcare workers (medical, paramedical, or clinical services), such studies were also included.

2.2 Framework: The framework for this map is a matrix of interventions (rows) and outcomes (columns). The categorization of information in this framework relates to categories of data extraction and stratification for data presentation. Studies are mapped at the intersection of interventions and outcomes. The systematic map filters were country classification of economies by World Bank (48). The filters were study type, study design, status of the study, COVID-19 context, COVID-19 period, war and conflict settings, WHO region, setting, resilience focus, population, gender, additional qualifiers for HCW, mode of delivering intervention, socio-ecological model level, publication type, comparison, funding, and conflict of interest. Categorization of interventions: The intervention is any treatment, procedure, program, initiative, or other action taken to prevent or treat mental health issues and improve resilience among HCW (49). The resilience and wellbeing interventions were broadly classified under psychological support interventions, workplace interventions, interventions to support a healthy lifestyle, socio-cultural interventions, pharmacological interventions, and innovative interventions and other type of interventions. This classification was created by the team of authors and finalized after discussion with the advisory group. In the case of multifaceted interventions which combined two or more of the above stated intervention categories, we checked if the effect of the co-interventions was assessed separately (and it was mapped under the individual intervention it is related to) or together (it was mapped under other or combined interventions). The code and code descriptions are presented in the data extraction section. Categorization of outcomes: Psychological outcomes, professional outcomes, work-life balance outcomes, patient care outcomes, and outcomes at meso- or macro-level were included. This classification was based on the socio-ecological model categories, refined with input from the stakeholders and extensive discussion within the author team.

2.3 Publications: Systematic or rapid reviews, narrative reviews, impact evaluations, economic evaluations, modelling studies, qualitative, quantitative, mixed-methods studies describing or evaluating resilience interventions were included. Journal articles, technical reports, theses, dissertations, scientific blogs, and research briefs were included in this review. For the study types, case reports, case series, and observational studies which did not describe any intervention were excluded. Additionally, conference abstracts, letters to the editor, informal online content (e.g., casual blogs, vlogs) and opinion papers were also excluded.

2.4 Search and search strategy- The search strategy was structured around three core concepts: [A] healthcare workers; [B] resilience and related constructs; and [C] resilience-related interventions. The studies were restricted to English-language publications from 2004-2025 (50). **Electronic databases:** Relevant keywords were identified for each of the concepts, and a search strategy was built using Boolean operators. A trained team member (PP) designed the search strategy, which was reviewed by another team member (SNP). The search was conducted in January 2025 on several databases, including MEDLINE, Scopus, Web of Science, CINAHL, PsycINFO and CENTRAL accessed through PubMed, Elsevier, Clarivate Analytics, EBSCO,

OVID, and Cochrane Library interfaces respectively. The PubMed search strategy is provided in Supplementary File 2. Searches in additional sources: Websites of various organizations were explored, and grey literature was identified. The names of websites and organizations are presented in Figure 2.

2.5 Screening: The results of the search yield were imported into EPPI Reviewer (51), and duplicates were removed using both automated and manual methods. A screening tool was created for title and abstract screening, and pilot title and abstract screening were carried out to refine the screening codes. The title and abstract screening tool are provided in Supplementary file 3A. Screening of titles and abstracts was carried out independently by three researchers (PP, SNP, SS) and one trainee (AM1) according to the inclusion and exclusion criteria listed in the screening protocol. The discrepancies in the decisions were resolved by a senior reviewer (AM). The abstracts meeting the eligibility criteria were subjected to full text retrieval. The full text screening was carried out by independently by five researchers (PP, SA, SS1, SS3, SNP) and one trainee (AM1) using the screening tool developed by the authors (Supplementary file 3B), and the discrepancies were resolved by a senior reviewer (AM). We documented the reasons for exclusion and reported them in the PRISMA 2020 flow diagram (Figure 2).

2.6 Data extraction: was conducted using a customized data extraction form that comprised the items given in Supplementary file 4, finalized after pilot testing the tool independently for five studies by the extractors. Data extraction was performed independently by reviewers for the first 20% of the studies (BS, MB, PP, SA, SNP, SS, SS1, SS2). Any discrepancies in extracted data were resolved through mutual discussion between both extractors. The remaining 80% of the data coding was carried out by a single reviewer (BS, MB, SA, SNP, SS, SS1, SS3) in alignment with the prespecified template and cross-checked by a second reviewer (AM, IS, and PP). The senior reviewer reviewed 100% of the included studies for all codes by generating coding reports. If there were any missing or incorrect entries, reports were generated and reviewed for those codes, and the necessary corrections were made. Data from the systematic reviews and empirical studies was extracted using the same data extraction form. The difference in data from reviews and empirical studies was mainly in the region as reviews were focused on larger geographical regions, and had higher number of interventions and outcomes than primary studies.

2.7 Data analysis and map presentation: The visual and interactive map was created using EPPI Reviewer 6 (51) and EPPI Mapper (version 2.4.5). Descriptive statistics were presented as frequencies and percentages, and cross-tabulations were carried out to find interlinkages among the concepts. A narrative summary was prepared for the data from the included studies for the variables of interest.

2.8 Study quality and ethical considerations: Study quality was not appraised for this systematic map, due to the diverse study designs and the primary focus was on mapping the existing evidence. Ethical approval was not applicable to this systematic map, as it relied solely on data extracted from publicly available sources and did not involve direct interaction with human participants.

2.9 Stakeholder engagement was a significant feature of this systematic map. Experts in the domains of mental health, resilience, and evidence synthesis were included from the protocol writing stage to the data analysis and presentation of findings stage. The initial framework (created by the core team) was subjected to multiple rounds of review with stakeholder feedback. Edits were made in the framework, based on the comments and feedback by the stakeholders. All communications were carried out through email correspondence.

3. Results

3.1 Study selection and characteristics

The database searches led to 11,817 hits, and we searched 1,302 additional records from websites and organizations. A total of 587 studies were included in our systematic map after completion of the full text screening stage. The PRISMA flow diagram for study selection is presented in Figure 2.

Out of the 587 studies, 490 studies (83.48%) focused on resilience, 82 studies (13.97%) were on other related concepts, and 15 studies (2.56%) were unclear. The characteristics of included studies (n=587) are provided in Supplementary File 5.

3.2 Yearly publication trends

The search was carried out from the year 2004, but the included studies in the map covered the period from January 2008 to January 2025, as no eligible studies were found between 2004 and 2008. In Figure 3, the publication trend showed a gradual rise from 2008 to 2018, followed by a sharp surge in literature after 2019. The highest number of studies were recorded in 2023 (97,16.52%), closely followed by studies in 2024 (95, 16.18%).

3.3 Funding status and conflict of interest

Of the 587 studies, 307 (52.30%) were funded, 143 (24.36%) were not funded, and 137 (23.34%) studies did not report their funding status. Most authors declared no competing interests (416, 70.87%). However, authors of 48 (8.18%) studies reported existing conflicts of interest, and 123 (20.95%) studies had no statement on authors' conflicts of interest.

3.4 Categories of interventions

Psychological support interventions were the most studied and featured in 485 (82.62%) of the included 587 papers. There were 320 (54.51%) articles that studied workplace interventions, 269 (45.83%) studied interventions to support healthy lifestyles, and 172 (29.30%) studied sociocultural interventions. In comparison, there were relatively few studies focused on innovative artificial intelligence-based or systems-thinking interventions (31, 5.28%). Herbal/traditional or conventional pharmacological interventions (4, 0.68%) were the least studied interventions.

Within psychological interventions, studies assessed the impacts of resilience training (240, 40.89%), meditation and relaxation techniques (150, 25.55%), mixed psychological interventions (149, 25.38%), mindfulness-based stress reduction (MBSR) (143, 24.36%), other activity-based therapies (93, 15.84%), and cognitive behavior therapy or other psychotherapy (93, 15.84%).

Workplace interventions included training and mentorship (236, 40.20%), organizational support (164, 27.94%) and mixed intervention (43, 7.33%). Flexible work arrangements (14, 2.39%) were the least examined workplace interventions.

Interventions supporting healthy lifestyles were most frequently focused on mindfulness (183, 31.18%). Fewer interventions included components of physical health (66, 11.24%), mixed healthy lifestyle interventions (63, 10.73%), journaling or record-maintaining (50, 8.52%), or holistic lifestyle programs (46, 7.84%).

Socio-cultural interventions were primarily based on emotional and social support (151, 2.72%). Globally, only a few studies focused on community wellbeing initiatives (31, 5.28%) or combined socio-cultural aspects (32, 5.45%). The 'other' category included interventions such as auriculotherapy, experiential exercises with animals, aromatherapy, compassion-based feedback, self-directed training, films, neurofeedback via an electroencephalography device, and communication skills.

3.5 Socio-Ecological Model (SEM) classification of interventions

Most interventions were implemented at the individual (micro) level (529, 90.12%). At the meso level, there were 278 (47.36%) organizational interventions and 42 (7.16%) community interventions. Only a small number of interventions centered around systems-level 18 (3.07%). Additionally, 38 (6.47%) had interventions categorized as 'cross-cutting'.

Across the included studies, interventions at the individual (micro) level and organizational (meso) level are mainly focused at psychological (440, 74.96%, 232, 39.52%) workplace (272, 46.35%; 206, 35.09%), healthy lifestyle (241, 41.09%; 124, 21.12%), and socio-cultural (136, 23.16%; 102, 17.38%) respectively. Whereas at a community (meso) level, a smaller number of interventions on psychological (32, 5.45%), workplace (33, 5.62%) was found. A similar trend was also observed at the systems (macro) level, with very few psychological (16, 2.73%), workplace (15, 2.55%) interventions identified. The classification of interventions and outcomes across the SEM model is provided in Table 1.

3.6 Types of studies and publications

Almost all included studies were published as journal articles (575, 97.96%). The remaining records were theses/dissertations (5, 0.85%), reports (5, 0.85%), one case study (0.17%), and one intervention development paper describing the creation of a toolkit which was presented as a journal article (0.17%).

3.7 Distribution and categories of interventions across WHO regional classification of countries

Across WHO regions, most studies were conducted in Region of the Americas (including United States of America; 330, 56.22%), followed by the European Region (183, 31.18%), the Western Pacific Region (136, 23.17%), the Eastern Mediterranean Region (80, 13.63%), the South-East Asia Region (39, 6.64%), and the African Region (33, 5.62%). There were 48 (8.18%) studies that either did not report the country of study of which six studies were conducted in Taiwan (which is not classified under WHO regional groupings).

Figure 4 presents the distribution of intervention categories across the WHO regions. In the AMR, the most studied interventions were psychological support (279, 47.53%), workplace (182, 31.01%), and healthy lifestyle interventions (171, 29.13%). This trend was consistent across the EMR, EUR, and WPR. Whereas, in SEAR, psychological support interventions were the most studied, followed by healthy lifestyle interventions. Similarly, in AFR, workplace interventions were widely researched. Pharmacological and innovative interventions were minimal across regions.

3.8 Distribution and categories of interventions across country income level

Studies were predominantly conducted in High-Income-Countries (HICs) (473, 80.58%), followed by Upper-Middle-Income Countries (134, 22.83%), LMICs (40, 6.81%), and least (17, 2.90%) studies in Low-income-countries (LICs).

Figure 5 demonstrates that across income categories, psychological support interventions emerged as the most frequently studied category, followed by workplace and healthy lifestyle interventions. While representation declined sharply in lower-income contexts, in contrast, socio-cultural, pharmacological, and innovative interventions remained limited in all income groups. Workplace and healthy lifestyle interventions were also common, especially in HICs (264, 44.97% and 226, 38.50% respectively), while UMICs contributed 75 (12.78%) workplace intervention studies.

3.9 Professional disciplines covered in the studies

The studies covered a broad range of healthcare workers. Nurses were the highest represented category (284 studies, 48.38%), followed by healthcare workers (171, 29.13%), doctors (149, 25.38%), and medical and health science students (136, 23.17%). Represented professionals included surgeons (8, 1.36%), dentists and dental staff (8, 1.36%), and pharmacists (13, 2.21%).

3.10 Distribution of interventions across study settings

A large proportion of the included studies were conducted within healthcare facilities (427, 72.75%), followed by educational institutions related to healthcare (148, 25.21%). A smaller proportion was implemented in community or outreach settings (30, 5.11%).

Figure 6 indicates that psychological (357, 60.82%), workplace (243, 41.40%), healthy lifestyle (195, 33.21%), and socio-cultural (120, 20.44%) interventions were predominantly implemented in healthcare settings. However, in community and outreach settings, psychological (27, 4.60%), workplace (23, 3.92%), healthy lifestyle (14, 2.38%), and socio-cultural (17, 2.90%) interventions were least represented.

3.11 Pattern of interventions based on study designs

Across study designs, non-randomized trials (228, 38.84%) constituted the largest proportion of studies examining interventions to support healthcare workers' wellbeing followed by randomized trials (110, 18.74%).

Non-randomized trials and randomized trials contributed to the largest share of evidence for psychological (182, 31.0%; 92, 15.7%) and workplace interventions (123, 21.0%; 39, 6.6%), respectively.

3.12 Mode of delivery of interventions in included studies

Most of the interventions were delivered offline (in-person) (303, 51.62%), followed by mixed delivery approaches combining online and offline modes (116, 19.76%). Online interventions with a human interface (97, 16.52%) were more frequent than fully digital formats without human interaction (74, 12.61%).

Across intervention categories, psychological support interventions were predominantly delivered offline (242, 41.23%), followed by workplace (178, 30.32%), healthy lifestyle (128, 21.81%), and socio-cultural interventions (98, 16.69%). Mixed modes were also common for psychological (104, 17.72%) and workplace interventions (83, 14.14%). Pharmacological and innovative interventions were least represented across all modes of delivery.

3.13 Interventions studied in the context of COVID-19

Studies in the pre-pandemic period were proportionately high across most of the intervention categories, followed by a noticeable decline in the post-pandemic period. Most of the interventions in the pre-post pandemic period were under psychological support interventions, workplace interventions, and healthy lifestyle interventions, whereas pharmacological and other innovative interventions remained the least explored throughout the timeframe. However, the frequency of socio-cultural and innovative interventions persisted and increased marginally in contrast with other intervention categories in the pre- and during COVID-19 pandemic stages. In the COVID-19 context, psychological support interventions were the most frequently implemented (115, 19.59%), followed by workplace (77, 13.12%) and healthy lifestyle interventions (64, 10.90%).

Figure 7 represents the interventions across the COVID-19 pandemic context. More than half of the included studies were not conducted in the COVID-19 context.

3.14 Aggregate map of interventions and outcomes

The matrix of interventions and outcomes is presented in Table 1. Interventions in studies were coded across multiple outcome domains. The visual and interactive map and information on how to navigate the map is provided in the Supplementary File 6, and the visual and interactive map is provided as an html file (Supplementary File 7)

3.15 Domains of outcomes assessed

Psychological outcomes were most frequently measured (521, 88.76%), covering resilience (367, 62.52%), mental ill-health (333, 56.73%), and emotional wellbeing (317, 54.00%). Professional outcomes were measured in 296 studies (50.43%). Within professional outcomes, burnout (248, 42.25%) and job satisfaction (111, 18.91%) were commonly assessed measures. Fewer studies focused on professional quality of life (ProQOL) (61, 10.39%), turnover intentions (23, 3.92%), and performance/presenteeism (20, 3.41%).

Stress management (147, 25.04%) was the most frequently studied among work-life balance-related outcomes (189, 32.20%). Work engagement (51, 8.69%) and work-life integration (34, 5.79%) were measured less often. There were 138 (23.51%) studies that included meso or macro level outcomes primarily through organizational outcomes (134, 22.83%). There were only 28 studies (4.77%) examining effects at the community or at the systems/policy level (16, 2.73%).

Outcomes related to patient care were the least studied (65, 11.07%), including quality of care (39, 6.64%), patient-worker interactions (37, 6.30%), and patient safety (7, 1.19%).

3.16 Outcomes measured across interventions

Trends among outcomes measured were largely consistent across different intervention categories. Patient-care outcomes were understudied in all intervention categories. Additionally, outcome domains that may have been expected to correspond to certain intervention categories were not reflected in frequencies. For instance, within socio-cultural interventions, meso and macro-level outcomes were measured by less than half (80, 46.78%) of the studies included. Similarly, among studies that included workplace interventions, only 179 (56.29%) studies specifically measured professional outcomes.

Figure 8 depicts a sankey diagram, where 529 interventions focus on the micro layer (both in isolation and in combination with other SEM layers), 320 interventions focus on the meso scope (community layer 42, organization layer 278) of interrelationships for resilience.

4. Discussion

This systematic mapping provides a comprehensive overview of resilience interventions for healthcare workers globally. Given the significant risk to mental health of healthcare workers, this systematic map is of critical importance for both research and practice. This systematic map synthesized 587 studies examining interventions aimed at improving resilience among HCW between 2008 and 2025. The steady rise in publications after 2015 and peaking in 2023 reflects a growing recognition of resilience as an essential determinant of workforce wellbeing, particularly during the COVID-19 pandemic.

Our findings reveal a stark and persisting imbalance in the geographical and economic region distribution of studies. The majority originated from HICs, predominantly from the WHO regions of the Americas (AMR) and Europe (EUR). However, evidence from LMICs remains sparse, particularly from the African and South-East Asian regions. These differences make it hard to generalize the findings everywhere, as contextual differences in health system capacity, work culture, and psychosocial risk factors can shape both the nature and impact of resilience interventions. Similar geographic patterns have been observed in previous evidence on HCW mental wellbeing interventions. We observed a very limited number of studies conducted in institutionally or socially fragile, or conflict-affected settings reveal a significant evidence gap in resilience literature.

Nurses were highly represented, followed by healthcare workers in the included studies, while community health workers (CHW), paramedics, pharmacists, dentists, and midwives were underrepresented. This imbalance reflects the long-standing research emphasis on hospital-based providers (52). Yet, the mental health challenges faced by the community, volunteers/informal and primary-care workers may differ substantially based on multiple factors, including workload, social support, gender, remuneration, personal safety, and systemic constraints. Therefore, to achieve a comprehensive understanding of workforce resilience wellbeing across the health system requires expansion of research by including diverse cadres such as CHW, including health care workers from informal sector (53). In larger institutional settings, the default preferences and decision bias are toward digital interventions. While these are acceptable in institutional settings, their utility and benefits in LMIC settings, complemented by in-person and peer interventions, may need to be examined for adaptability and ownership.

The evidence mapped in this review indicates that resilience interventions for healthcare workers predominantly focused on psychological support consistently prioritized across settings, professional groups, and contexts. The dominance of psychological interventions may reflect both the perceived immediate impact on individual wellbeing as well as the relative feasibility and accessibility. Furthermore, this trend may indicate a gatekeeping tendency among healthcare providers and researchers, who prioritize individual-focused clinical models to maintain professional authority over how stress is managed. By framing stress management as a psychological concern rather than a systemic one, these stakeholders can effectively control the scope of interventions and research within the healthcare sector. In contrast, pharmacological,

innovative and socio-cultural interventions, including digital, artificial-intelligence-driven, or policy-level approaches, received limited attention, suggesting persistent gaps in exploring diverse approaches to resilience. Interventions were largely delivered in-person, though mixed approaches combining online and offline modalities were increasingly employed. There is a paucity in deploying fully digital interventions without human interaction, highlighting potential opportunities to expand scalable, technology-enabled strategies in future resilience-building interventions. Interventions were heavily concentrated at the individual (micro) level, suggesting that research emphasizes individual resilience rather than systemic or structural approaches. Sustainable improvements in healthcare workforce resilience require synergistic interventions across levels.

The effort to seek intervention and outcome learnings from HCW in crisis or fragility contexts yielded limited results. It is likely that there are significant trade-offs between choices for interventional research and in-situ care during crises, and that while facing risks and potential burnout. An implication is that the urgency for timely research evidence and the associated cost of risks from action or inaction remain high. Attending healthcare emergencies as priorities, therefore, implies investing in the learning experiences to after crises period. When faced with limited resources, healthcare workers and researchers in these settings must either rely on available resource buffers or proactively take the lead in developing solutions and gathering necessary evidence. So, while the impact of attention and resource constraints within layers of prevailing crises may limit research action to resourced tertiary institutions, there may be a need to explore how primary and community-based settings are demonstrating bias for learning action that might be contextualized for adaptation.

The interventions were analyzed for their alignment with the SEM. Their distribution across the individual (micro) to systems (macro) level design indicate two broad themes: the design confidence to scope the intervention, across micro to macro and cross-cutting levels is likely rooted in prior evidence considered favorable for: the extent of diagnosed burnout related challenges, and the direct perceived implications on their wellbeing, work and care as well as impacts on peers and team settings as well. On the one hand, these intervention design choices speak of leadership and initiative to examine solutions to burnout, particularly during crises and often at personal risk; they stand to contribute both to science and the practice of readiness. However, they may be limited by the need to identify rapid solutions or protective practices as barriers for individual healthcare workers' benefit, limitations of span of control over study scope, risks during crises, opportunity costs for care work and the trade-off for additional studies and likely resources.

This is significant as resilience has enhanced sustaining properties when healthcare workers are considered part of a community or team and are not isolated or insulated in their responsibility to 'recover' and thrive in their place of work. Therefore, while these interventions were designed and crafted to address: a range of trigger stressors and the positive impact across at least one or

more layer of the SEM for healthcare workers, it is unclear whether the stressor pathways were also examined across the SEM in order to document and distinguish their temporal, lateral and dynamic roots/determinants and vulnerabilities from their symptomatic differences. These might impact the intervention design and may be helpful to evaluate outcome efficacy. This is vital as it implies that in some cases interventions solely address symptoms (interpersonal, care, interaction) on the one hand, and in others address (both intentionally or unintentionally) wider needs across the SEM and trigger spectra, which would be a beneficial/preferable outcome (socio-cultural, quality of life, and quality of care).

While there is an expected spike of interventions reported as implemented during the COVID-19 pandemic, there is a marked dip post-pandemic, both for COVID-specific contexts and war-natural and man-made disaster themes. In terms of settings, the studies based in healthcare facilities and educational institutions had a minor reduction from before the pandemic to its onset. The pattern of studies increasing during the pandemic is unique for LMIC and UMIC, whereas in HIC, there is a dip in studies during and after the pandemic. We intended to examine the distribution of studies across income categories of nations and found that there continues to be a significantly higher skew of studies in favor of HIC, relative to all others.

Similarly, the distribution of funded and unfunded studies reinforces the differences in funding either accessed or available in HIC contexts versus all other income categories. From our study scope, while the number of funded interventions has decreased prior to, during, and post-pandemic, there has been a rise in interventions which have not received funding during the pandemic. This points to unique findings about these in terms of settings. Over 89% (n=69) were either healthcare facilities or educational settings, indicating differential access to resources, support, and decision-making. Most interventions were focused on nurses, followed by health workers and medical students. Institutional initiatives primarily support the staff who do the core work, but the changes tend to fix small, localized problems rather than addressing the larger, systemic issues of the organization. These indicate a greater likelihood of institutional funding available during the pandemic, whereas community outreach efforts may have directed efforts without additional support.

The number of in-person interventions have given way to greater offline and mixed intervention modes during the pandemic. This is likely to have contributed to accelerated response capability and lower funding requirements related to in-person modes. The interventions taper after the pandemic, indicating changes in either healthcare worker or leadership priorities and resource constraints whereby research gaps can continue to persist till there is a shared imperative, urgency and funding emerge, such as a localized or sectoral crisis (54,55).

Further exploration of how and why resilience interventions are designed and who participates in the design will be helpful to consider institutional imperatives and healthcare workers' approaches to the theory and practice of change. There is a need to integrate intervention design

with the nature of stressors and contexts in healthcare settings, in particular, the nature of interactions between stressors, interventions and the mechanisms that worsen and accelerate burnout as well as those that contribute to resilience.

In the non-crisis context, or more specifically in care related interventions contexts, we observed increasing evidence which may point to differences in resourcing, opportunity or even agency to design interventions including socio-cultural interventions covering arts, creative writing, or drama. Further review may be beneficial about whether such interventions needed lower resources or attracted funds more readily, and if there was evidence pointing to relevant local, indigenous and sociocultural, patterns and practices that were worth formally experimenting with. These are becoming contextually, relevant and significant, and therefore merit for examination for their indigenous value and scope of much wider impact beyond micro deployments.

We noticed marked reduction in study numbers post pandemic, particularly for institutional settings - the reasons for which might be helpful to explore further. On the other hand, networked or community outreach settings either continued or increased attention on intervention studies during the pandemic. This indicates either short windows of crisis related opportunities and initiative on the part of the study leads one the one hand or on the other end of the spectrum – extreme amounts of risk and crises that necessitated studies related to survival and resilience. Further exploration of these contexts and the process for intervention designs may be helpful.

For researchers, the map uncovers clear evidence gaps: (i) under-representation of countries from low-resource setting, including fragile and conflict affected regions (ii) limited focus on primary and community care workers, and (iii) a scarcity of system-level or technology-enabled approaches. Future research should aim for methodological diversity, participatory design, participation of primary health workers, expansion of the geographical and institutional scope and longitudinal evaluation to move beyond short-term psychological outcomes toward sustained systemic change.

Additionally, it will be helpful to examine the representation of HCW and CHW in leadership and decision making for intervention design in a way that shifts focus to systems and anticipatory perspectives and integrates lived experience in the framing of challenges persisting in the present and those emerging with the academic and modelling rigor of solutions examined for resilience at individual and team levels, replicable and adaptable across contexts and mirrored at institutional and leadership levels as well.

The strengths of the study lie in its robust methodology and innovative presentation. A comprehensive database search across multiple published and unpublished sources ensured high sensitivity and reduced bias. Double screening by independent reviewers ensured objective study selection, enhancing reliability. We adopted a partial duplicate extraction approach where 20% of full-text records were extracted in duplicate. Data extraction for 80% of full-text records was not

conducted in duplicate, but the senior reviewers performed thorough quality checks of all the records to mitigate data extraction bias. Furthermore, the use of a visual and interactive map significantly improves knowledge translation, making complex evidence accessible to diverse stakeholders. However, the study has a few limitations, including the absence of a formal quality assessment (risk of bias evaluation) of the included studies and the lack of assessment of intervention effectiveness. Also, as only English language publications were included, relevant non-English publications may have been missed. Furthermore, we acknowledge that the inclusion of a diverse range of study designs may have led to potential duplication of evidence. For instance, some primary studies might have been represented within the included reviews. Future research based on the map could examine how minimal clinically important differences in selected outcomes (especially burnout) are determined in experimental and quasi-experimental studies. Another limitation was that the categorization of interventions was mutually exclusive; however, the mixed interventions subcategory may have led to some overlap within a major category of intervention. Also, due to the fluidity of the socio-ecological model, mutual exclusivity could not be maintained in the outcomes.

It is notable that some countries shifted between or out of the classifications in the duration of conducting this systematic map (e.g.: USA moving out of the WHO, or the Israel-Palestinian conflict). To avoid confusion, we retained the classification mentioned in our protocol.

The research focusing on healthcare worker resilience demonstrates a clear geographical bias towards high-income countries, with the majority of studies concentrating on institutionalized nursing and medical staff. This highlights a significant research gap concerning allied health workers and those operating in community settings, necessitating closer examination of these populations. Future investigations are required to address the mental health of healthcare workers within routine and non-crisis settings. In conclusion, this systematic map provides essential evidence to inform stakeholders and direct future efforts toward enhancing healthcare worker resilience and wellbeing.

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Conflict of interest

The authors declare no competing financial or non-financial interests.

Author Contribution

Supervision: AM, PP, VS

Conceptualization: AM, AS, PD, PP, SS, SLM, VS

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Search: PP, SNP

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TiAb screening: AM, AM1, PP, SNP, SS

FT screening: AM, AM1, PP, SA, SNP, SS1, SS3

Source coding: MB, PP, SNP

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Writing first draft: AM, BS, IS, MB, PP, SLM, SNP, SS2, SZ

Reviewing final draft: All authors (AM, AS, BS, IS, MB, PP, PD, SA, SLM, SNP, SS, SS1, SS2, SS3, SZ, VS)

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Figure legends

Figure 1: A framework conceptualizing the systematic map

Figure 2: PRISMA flow diagram for study identification and inclusion

Figure 3: Trends of publication for included studies by year in the systematic map

Figure 4: Distribution of interventions across WHO regional classification of countries

AFR =African Region; AMR = Region of the Americas; EMR = Eastern Mediterranean Region; EUR = European Region; SEAR = South-East Asia Region; WPR = Western Pacific Region

Figure 5: Distribution of interventions across country income level

LIC = Low-Income Countries; LMIC = Lower-Middle-Income Countries; UMIC = Upper-Middle-Income Countries; HIC = High-Income Countries.

Figure 6: Distribution of interventions across study settings

Figure 7: Intervention categories in the COVID-19 context

Figure 8: Sankey diagrams of intervention vs outcomes

Table legends

Table 1: Socio-ecological model categories according to the interventions and outcomes

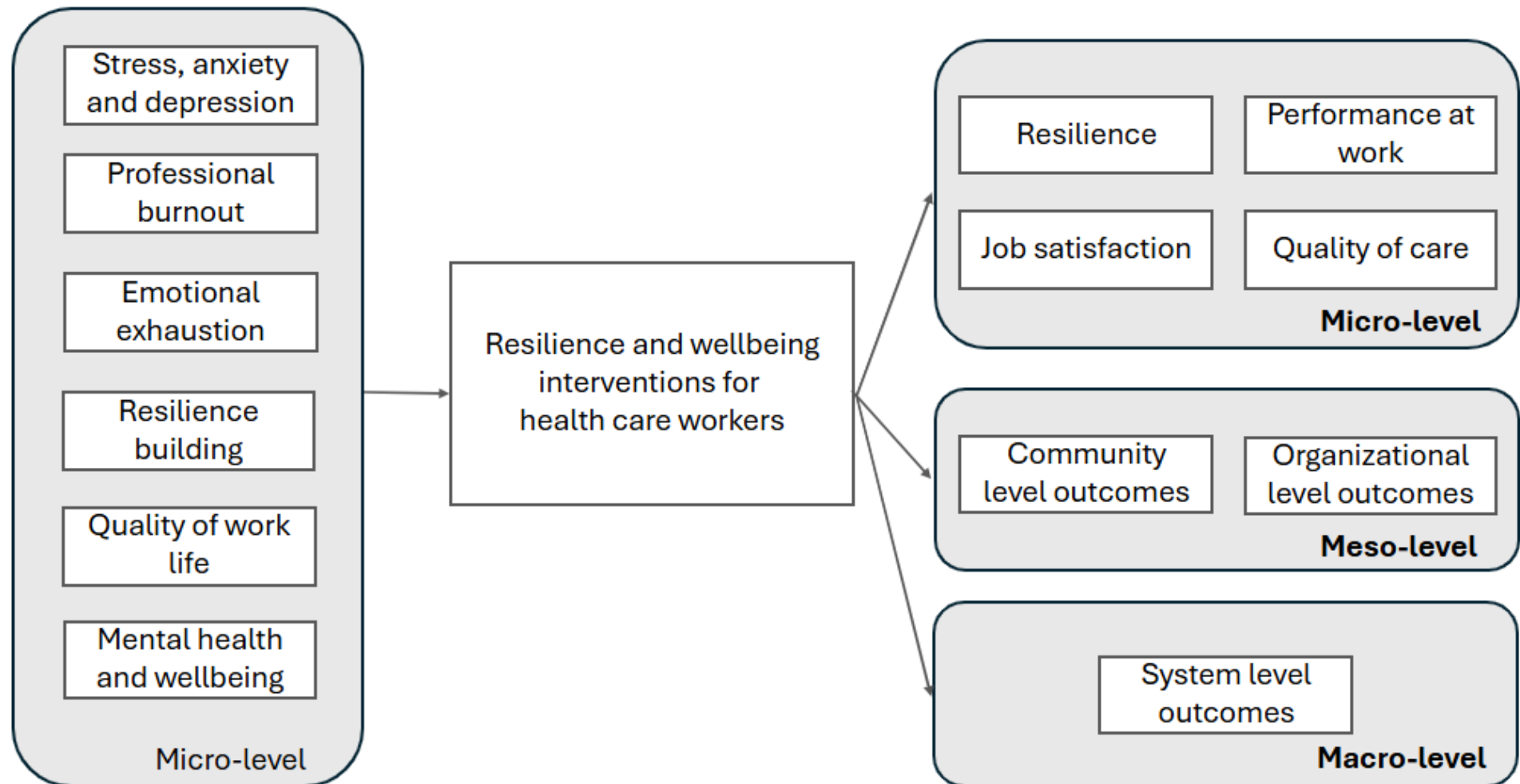
Table 2: Interventions and outcomes in the systematic map

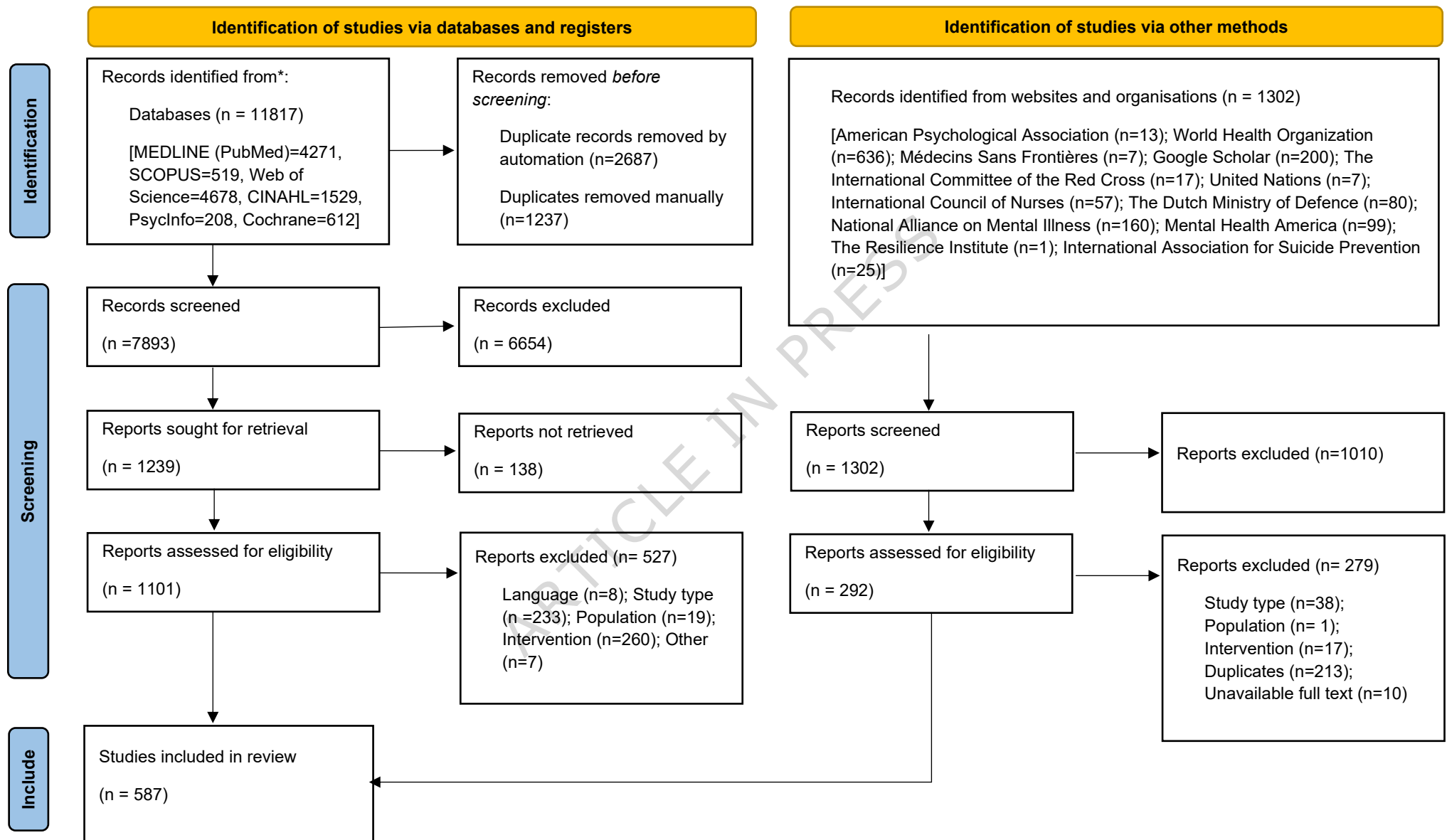
*The values for the outcomes for innovative interventions are low as evidence in this category is emerging. Alternatively, the evidence in pharmacological interventions is low or null as such studies are not carried out due to ethical and feasibility concerns.

SEM layer distribution	Interventions [n (%)]	Outcomes [n (%)]
Micro-level (Individual level)	529 (91.14)	1278 (55.57)
Meso (Organizational, Community)	278 (46.05), 42 (7.71)	133 (5.83), 711 (31.6)
Macro (Systems)	18 (3.28)	51 (2.23)
Cross-cutting	38 (7.32)	117 (5.13)

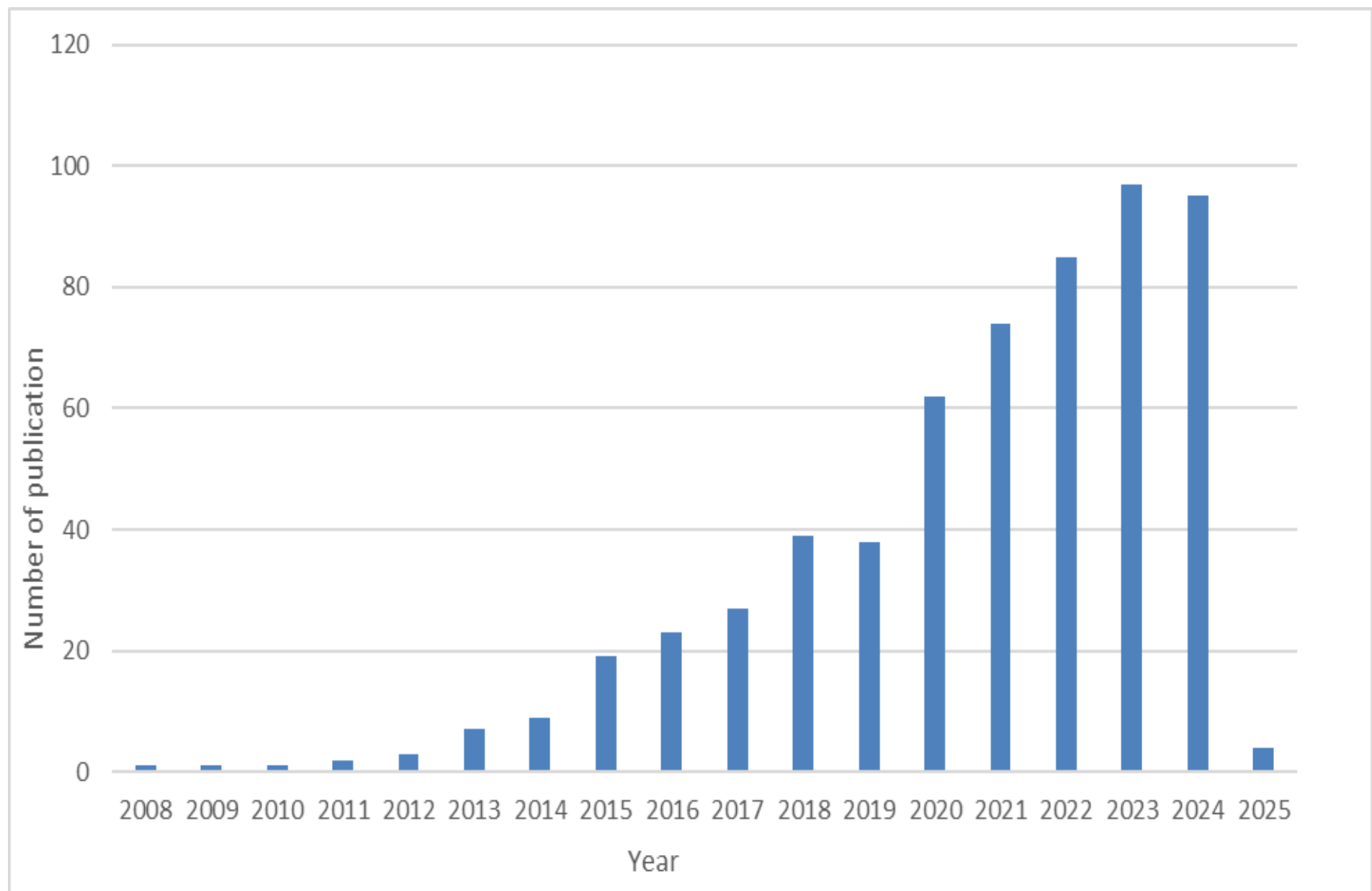
	Outcomes*
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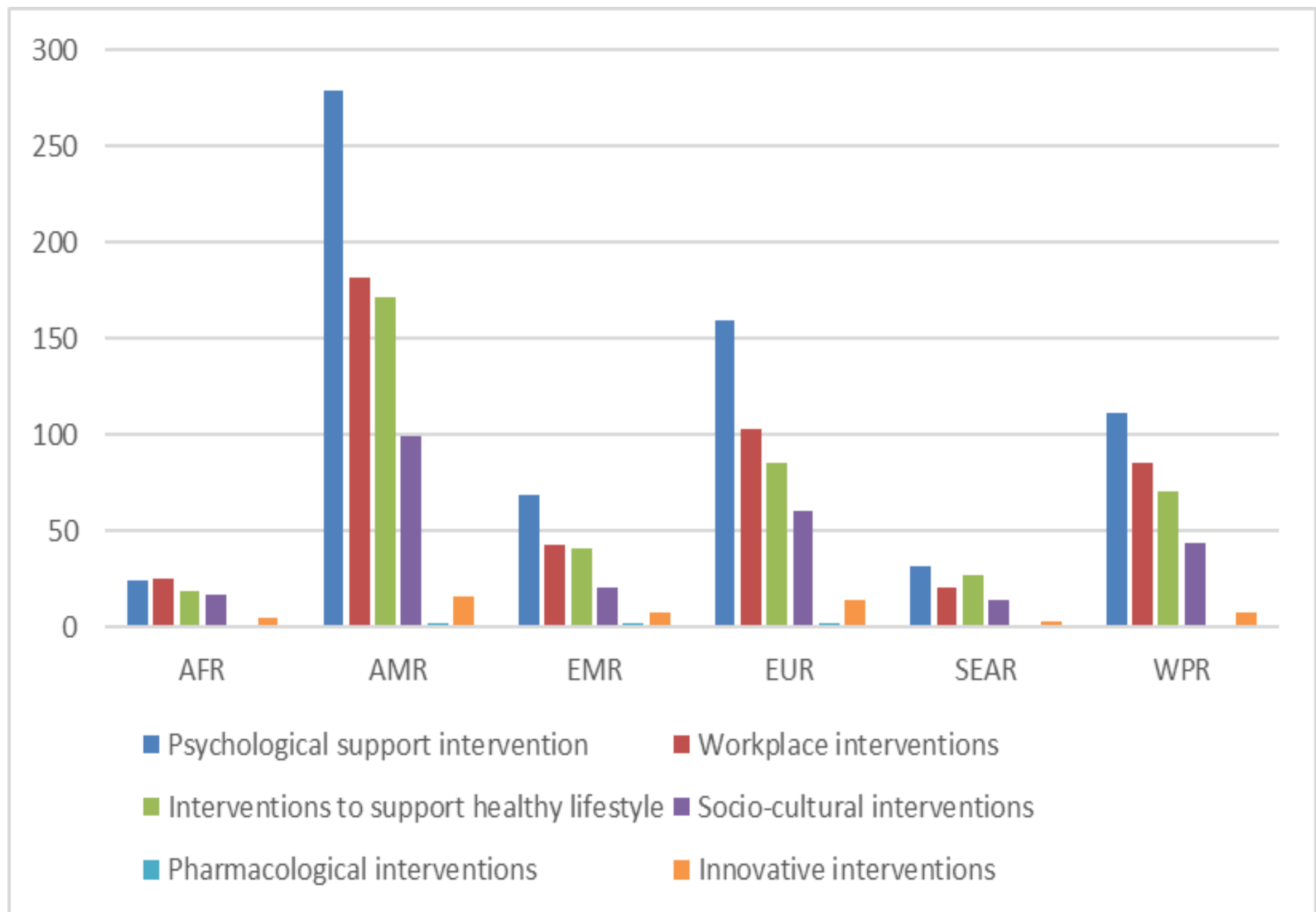
Categories of Intervention (n=587)	Outcomes not assessed	Psychological	Professional	Work-life balance	Patient care	Meso or macro level	Blended interventions	Other
Psychological support	10 (1.70%)	443 (75.46%)	249 (42.41%)	175 (29.81%)	56(9.54%)	121(20.61%)	16 (2.72%)	147 (25.04%)
Workplace	10 (1.70%)	277 (47.18%)	180(30.66%)	126 (21.46%)	44 (7.49%)	115(19.59%)	13 (2.21%)	87 (9.71%)
Support healthy lifestyle	5 (0.85%)	250(42.58%)	162 (27.59%)	115 (19.59%)	41(6.98%)	82 (13.96%)	10 (1.70%)	79 (13.45%)
Socio-cultural	8 (1.36%)	154(26.23%)	96 (16.35%)	81 (13.79%)	28 (4.77%)	80 (13.62%)	12 (2.04%)	38 (6.47%)
Pharmacological	1 (0.17%)	2 (0.34%)	1 (0.17%)	1 (0.17%)	1 (0.17%)	2 (0.34%)	1 (0.17%)	0
Innovative	2 (0.34%)	27 (4.59%)	15 (2.55%)	12 (2.04%)	3 (0.51%)	13 (2.21%)	6 (1.02%)	8 (1.36%)
Other	1 (0.17%)	27 (4.59%)	12 (2.04%)	13 (2.21%)	4 (0.68%)	8 (1.36%)	5 (0.85%)	8(1.36%)

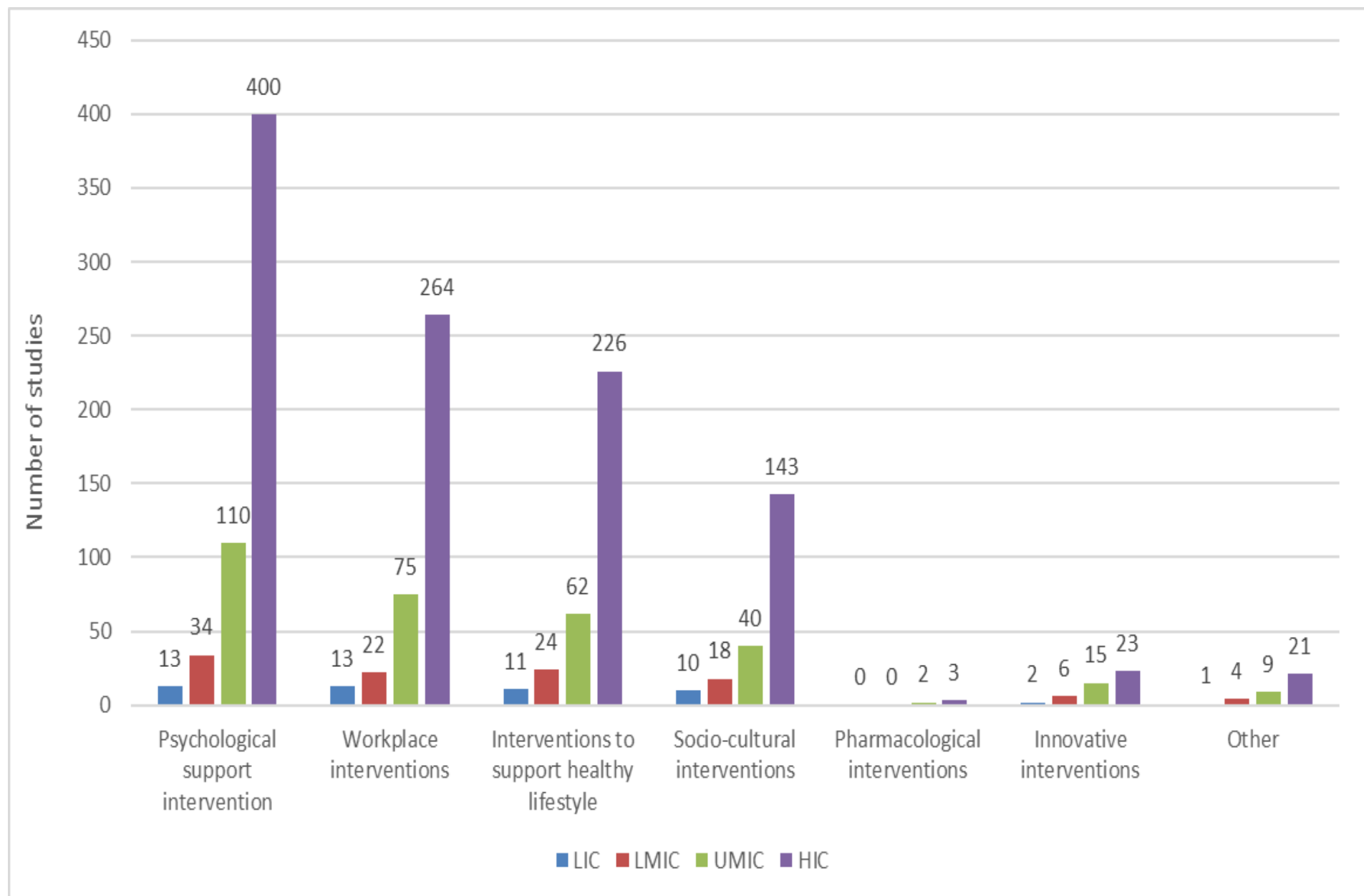


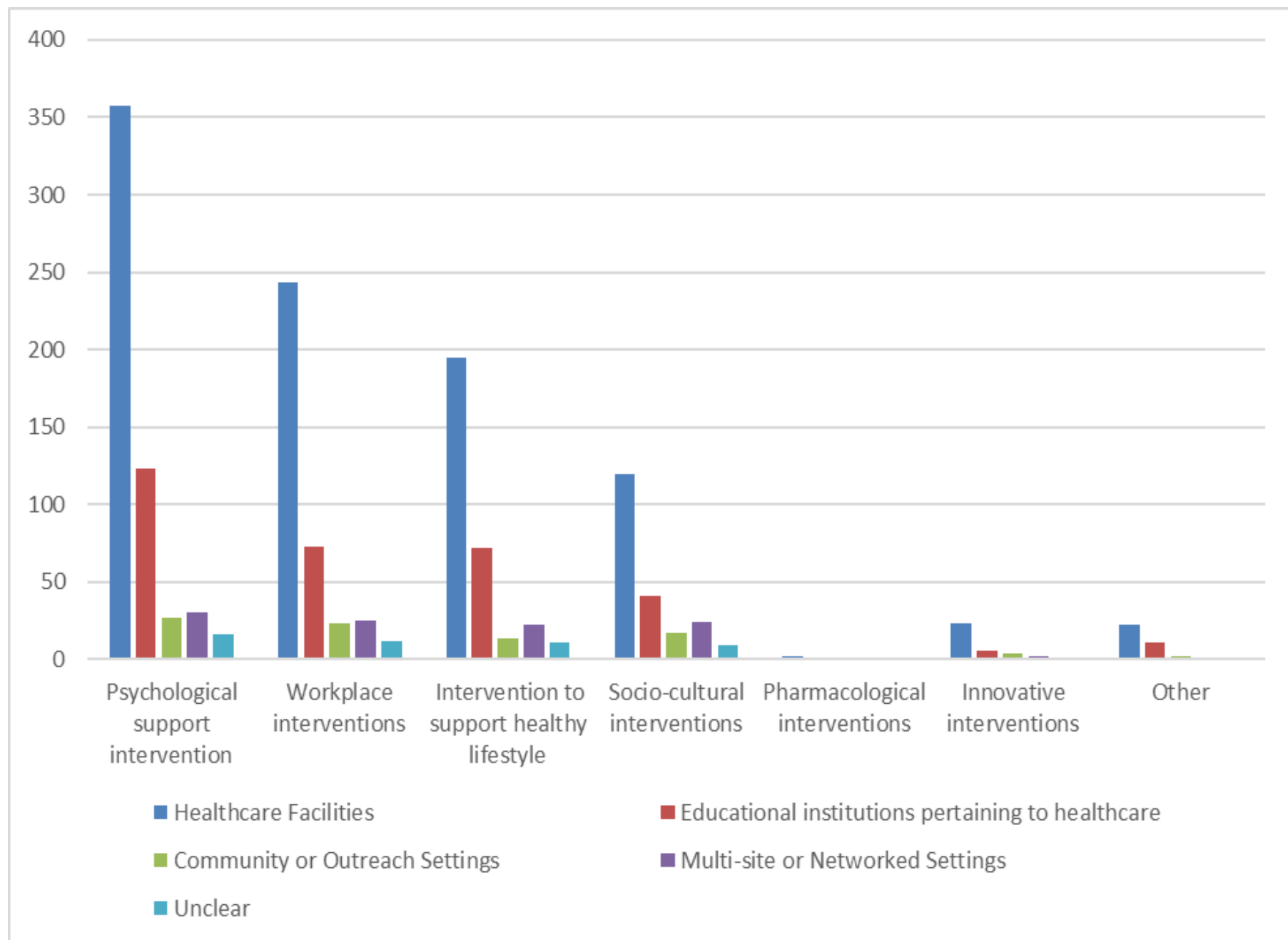


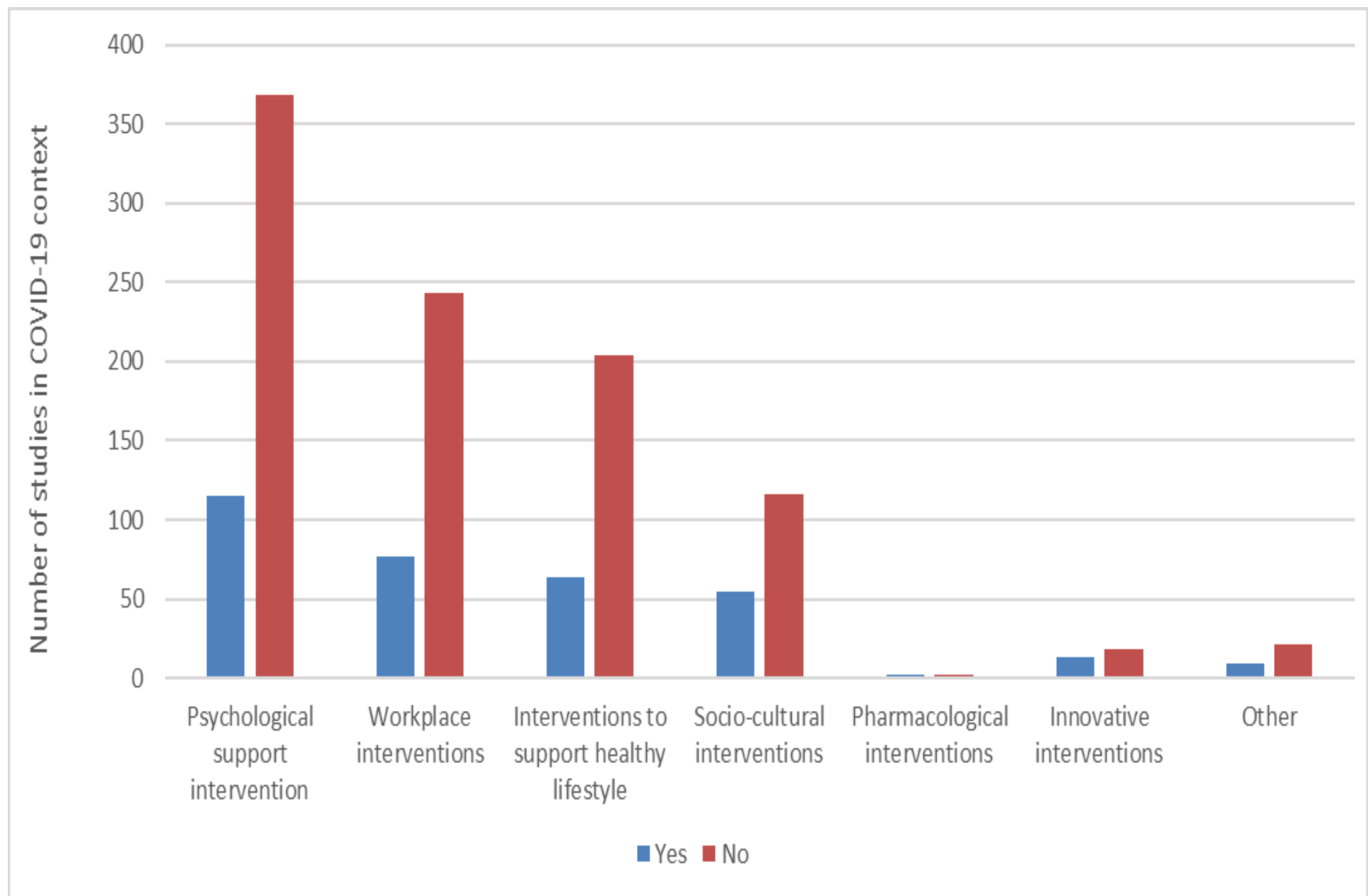
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Intervention to Outcome flows



Intervention to Outcome flows

