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Use of the word "evolution" in the time of a global pandemic

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Introduction: The media can play a vital role in determining to what extent the general public understands scientific concepts. The understanding and acceptance of evolution are often influenced by factors beyond scientific knowledge alone, including education, politics, and media consumption habits. Although discussion of the COVID-19 pandemic and evolution had fixed itself in public discourse on many fronts, the media often avoided the usage of the word "evolve" and showed a preference for alternatives such as "emerge" or "mutate."

Methods: We conducted a systematic analysis to gauge the prominence of the concept of evolution in media discussions across seven English-speaking countries. This involved assessing the frequency of the term "evolve" concerning viral evolution within newspaper articles using electronic databases. Of the 4,951 newspaper articles examined in this study, 11% discussed viral evolution. Out of those articles, 12% explicitly used the word "evolve."

Results: We found that countries did not significantly differ in their "evolve" usage, which may reflect similarities in views about COVID-19 and its evolution across countries or reliance on shared information sources when reporting on COVID-19. We also found that, as the pandemic progressed, the discussion on viral evolution as a topic had increased, but the frequency with which the word "evolve" was explicitly used had decreased.

Discussion: The COVID-19 pandemic has had a substantial impact on science and health news reporting. Although evolution plays a crucial role in the progression of the COVID-19 pandemic, the term "evolve" is not frequently highlighted in COVID-19 news coverage. Our research underscores the significant implications of language choice when describing evolutionary events, particularly in shaping the public's understanding of evolution, both in general and in the context of pandemics and infectious diseases.

KEYWORDS

evolution, COVID-19, SARS-CoV-2, pandemic, SARS

Introduction

Evolution—defined as descent with modification from a common ancestry (Darwin, 1964; Wiles, 2010)—is nearly universally regarded by the scientific community as a foundational concept in biology (Dobzhansky, 1973; Olsen, 2009; Wiles, 2010; Elmesky, 2012). Despite this

general consensus among scientists, understanding and acceptance of evolution can vary greatly among the general public (Miller et al., 2006; Funk et al., 2020b). A 2020 report from the Pew Research Center found that the median public acceptance of evolution across 20 countries was 74% (Funk et al., 2020a). Some of the highest acceptance rates of evolution were observed in Japan (88%) and Spain (87%), while the lowest rates were observed in Malaysia (43%) and Brazil (54%) (Funk et al., 2020b). While levels of acceptance of evolution can vary across countries, multifactorial analyses from the United States (U.S.) and other parts of the world have found that sets of co-dependent factors, such as education level, ideological partisanship, and religiosity, can underlie these differences in acceptance (Deniz et al., 2008; Heddy and Nadelson, 2012; Miller et al., 2022). Other studies have identified that certain factors are more predictive of an individual's acceptance of evolution, such as having an understanding of science (Wiles and Alters, 2011; Dunk et al., 2017; Weisberg et al., 2018, 2021). While there may be multiple factors driving variance in acceptance rates, these findings suggest that a considerable population around the world still may not understand, believe, or readily accept a scientific theory widely accepted by scientists (Miller et al., 2006; Wiles, 2010; Funk et al., 2020a,b; Miller et al., 2022).

Although evolutionary ideas usually have more relevance in scientific discourse, the COVID-19 pandemic provides a relevant, contemporary subject matter to explore how evolution is discussed in popular media. The evolution of SARS-CoV-2, the virus responsible for the COVID-19 pandemic, has direct implications for public health, including vaccine efficacy, disease transmissibility, and virulence, which in turn have widespread social, political, and economic impacts (Cobey et al., 2021; van Oosterhout et al., 2021). At the same time, public attitudes that are resistant to science can have real-world effects (Weisberg et al., 2021). For example, COVID-19, as well as other viral respiratory illnesses such as influenza, necessitate repeated vaccination (Telenti et al., 2021), and yet, unvaccinated individuals report being less likely to change their intention to vaccinate despite incentives or requirements (Sargent et al., 2022). Identifying reasons behind public resistance to science-informed mitigation efforts such as vaccination or masking or lack of understanding of evolution could also offer insights into how scientific communications could be improved. Notably, the COVID-19 pandemic has shown an increased uptake in news media consumption, especially of mass media, print media, and online news sources (Soroya et al., 2021; van Aelst et al., 2021). Because social and political contexts also can shape understanding and acceptance of evolution (Miller et al., 2006), the COVID-19 pandemic presents a unique context to investigate how evolution is described in the popular press.

Observing whether the word "evolve" is used to discuss viral evolution may be a quantifiable way to assess the public's perception of it. The topic of evolution can be polarizing to the public, so the words used to describe it may both reflect and shape how well the public associates the general concept of evolution with viral evolution (Gieryn, 2001). Reasons behind using less scientifically accurate terms may include fraudulent reporting for the purpose of advertising, conflicting responsibilities between scientists and journalists, or a lack of criteria to assess scientific accuracy in the news (Condit, 2004). Thus, the coverage of the pandemic can vary substantially in sensationalism and scientific quality according to the context from which it originates (Mach et al., 2021). Alternative words to "evolve" may have a less specific connotation or avoid distinguishing the subtleties of different evolutionary processes. They also might reflect what Antonovics et al. (2007) have called "simplified phraseology," or the replacement of terms with less controversial or less scientifically accurate ones. However, it is important to note that Antonovics et al. (2007) derived this conclusion from observing scientific journal articles although "simplified phraseology" may also extend to non-scientific media. In our review, we aim to see if language in print newspapers is effectively used to connect the general concept of evolution with viral evolution in COVID-19, which can be important for informing the public to recognize the connections between science and pressing societal needs (Meagher, 1999).

Here, we examine the frequency in which the word "evolve" (or any of its lexemes; e.g., "have evolved," "is evolving," "result of evolution," etc.), as opposed to an alternative, such as "change" or "develop," is used to discuss viral evolution in newspaper articles covering the COVID-19 pandemic. Given that social and epidemiological factors related to both COVID-19 and evolution vary among countries (Silver and Connaughton, 2022), we aim to determine whether usage of the word "evolve" varies by country in the top circulated English-language newspapers of Australia, India, Canada, Nigeria, Guyana, the United Kingdom (U.K.), and the U.S. Additionally, as the context of the pandemic has changed over time, particularly with the evolution of variants and the administration of vaccines, we ask both if COVID-19 evolution is discussed more often and if "evolve" usage also changes over time. Finally, we catalog the full array of alternatives to the word "evolve" used to describe evolution. Through this, we aim to gain a better understanding of the extent to which newspapers directly describe COVID-19 as an evolutionarily driven public health issue and what language is used alternatively when it is not used.

Materials and methods

We focused our study on Australia, Canada, Guyana, India, Nigeria, and the U.K., countries from each continent with English as an official or national language (Central Intelligence Agency, 2023; International Database, 2023). We also included the U.S. as the country with the largest number of English speakers (Worlddata.info, 2023) (Table 1). Many of these countries were shown to already have varying levels of acceptance of evolution and trust in scientists just before the start of the pandemic (Falade, 2019; Funk et al., 2020a). First, we identified the top two newspapers from each country based on circulation (Agility PR Solutions, 2015; Audit Bureau of Circulations, 2019; Walcott, 2020; Abba-Aji et al., 2021; Alliance for Audited Media, 2021; Roy Morgan Research, 2021). For Australia, the one country we focused on where major newspapers no longer reported circulation publicly, we instead chose the top two newspapers based on readership (Roy Morgan Research, 2021). We accessed most newspapers through the electronic databases ProQuest, Factiva, and NexisUni. However, no Guyanese newspapers were accessible via database, so we instead searched for newspaper articles on their publicly available web pages (Kaieteur News, 2023; The Guyana Chronicle, 2023).

Given the frequent reference to the COVID-19 pandemic in articles focused on issues other than viral evolution, such as school and business closures and travel bans and restrictions,

TABLE 1 List of countries and newspapers examined.

Country	Newspaper	Total number of articles read	Number of relevant articles
Australia	The Age	254	27
	The Sydney Morning Herald	238	20
Canada	The Toronto Star	502	37
	The Globe and Mail	352	41
Guyana	Kaieteur News	44	7
	The Guyana Chronicle	65	9
India	The Times of India	997	139
	The Hindu	322	64
Nigeria	The Punch	101	17
	The Nation	96	8
United States	The New York Times	722	71
	The Wall Street Journal	406	47
United Kingdom	Daily Mail	307	37
	The Sun	545	40

Quantities of articles read and relevant articles identified for the top two newspapers from each country. An article is "relevant" if it contains phrase(s) in which it is reasonable to expect the use of the word "evolve" in the context of COVID-19 and viral evolution. Letters to the editor, articles less than 100 words, and repeated articles were excluded.

we explored various Boolean search strings to help restrict our search to articles more likely to discuss evolution in some way. Preliminary searches showed that the inclusion of both "variant" and "strain" in search strings generated results containing articles from all stages of the pandemic, including early coverage of initial outbreaks, as well as outbreaks of COVID-19 variants, that were narrower in focus than searches of "COVID" or "coronavirus" alone. Ultimately, we used the Boolean search string "(covid OR coronavirus OR SARS-CoV-2) AND (variant OR strain)" to search for articles published between December 31, 2019, the date the Wuhan Municipal Health Commission reported a cluster of cases of pneumonia in Wuhan, China to the World Health Organization, and September 1, 2021 (World Health Organization, 2020), the date of our first search. For newspapers accessed via database, we typed the search string as written directly into the search bar and filtered results by date. For the Guyanese articles, we typed the same search string in Google followed by "site:kaieteurnewsonline.com inurl:2020|2021" for Kaieteur News and "site:guyanachronicle.com inurl:2020|2021" for The Guyana Chronicle to search for results on their respective web pages (Kaieteur News, 2023; The Guyana Chronicle, 2023). We manually removed articles published outside of our date range.

Searches yielded 19,821 articles across all newspapers (Figure 1). After generating search results and sorting them in order of ascending date, we selected every fourth article to create a smaller subset of 4,951 articles that we could read in entirety and examine for relevance. We employed a set of relevance and exclusion criteria used in two similar studies by Singh et al. (2016, 2017) that have explored "evolve" usage in newspaper articles on other evolution-driven public health contexts. We considered an article relevant if it contained at least one phrase in which the use of the word "evolve" (or any of its lexemes; e.g., "have evolved," etc.) would be reasonably expected in the context of the viral evolution of SARS-CoV-2 (Supplementary Table S1). Articles discussing COVID-19 generally but lacking any discussion of the evolution of COVID-19 (including any of its variants) were considered irrelevant and excluded. If we encountered duplicate relevant articles, we excluded the shorter of the two. In cases where these duplicate articles were the same length, we excluded the older of the two. Other articles we excluded were letters to the editor and articles less than 100 words. All articles were screened independently by at least one co-author.

For every relevant article, we documented each of the one or more phrases discussing viral evolution and recorded whether or not the word "evolve" (or any of its lexemes) was used (Supplementary Table S2). In phrases that did not use the word "evolve," we documented any alternative word or phrase used to describe evolution, including but not limited to "mutate," "emerge," or "change" (and their lexemes).

Qualitative analysis was used when reading for relevance to detect and distinguish some commonly used alternatives to the word "evolve" that are appropriate in COVID-19-related contexts. For example, "mutate" could be used to appropriately discuss genetic mutation as a driving force of evolution, and "emerge" could be used as an epidemiological term to describe COVID-19 and its variants as emerging infectious diseases. In such cases, multiple co-authors evaluated and discussed the surrounding sentences or phrases to determine whether there was clear discussion of evolution involving the replacement of the word "evolve." We excluded phrases where these alternative words were more appropriate, as it would be more reasonable to expect the alternative than the word "evolve."

We performed analyses in R Statistical Software (v4.1.1; R Core Team, 2023). We first analyzed whether "evolve" usage varied between countries. We considered country as a categorical variable representing the social and epidemiological factors potentially influencing "evolve" usage for three reasons. First, social factors, such as acceptance of evolution, can vary depending on when they were measured, and the methodology used to measure. Second, information on social factors was not available for all of the countries we examined from the same time point using the same measurements (Barnes et al., 2022; Miller et al., 2022). Third, all of the social and epidemiological variables that did have data available from the same time point collected using the same methods covaried with each other and with country. Thus, we deemed country to be the most suitable lens through which we could understand differences in "evolve" usage in the context of COVID-19.

We counted the number of articles for each country that used the word "evolve" at least once in the article to discuss COVID-19 evolution and the number of articles for each country that only used alternative words to describe COVID-19 evolution. With these counts, we conducted a Chi-square test of independence to determine whether the frequency of articles using "evolve" varied significantly between countries. Across all countries, we explored how often COVID-19 evolution was discussed in the news over the course of the pandemic, as well as whether the usage of "evolve" changed as the pandemic progressed. We designated December 18, 2020 as a significant event in COVID-19 evolution,

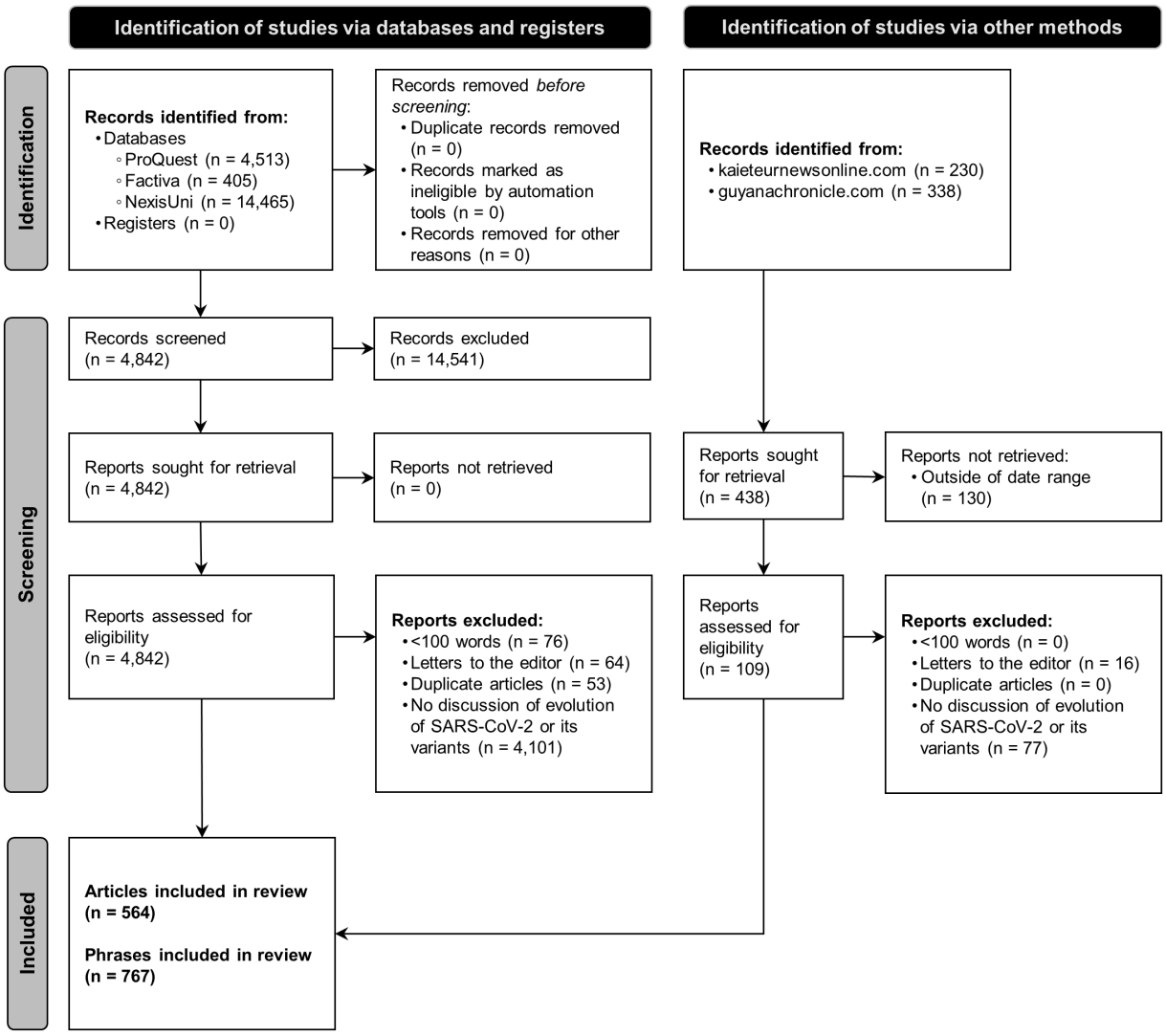

FIGURE 1
PRISMA flow diagram describing study records. The number of articles at each stage of the screening process is shown as a total for all newspapers from all countries (Moher et al., 2009; Page et al., 2021).

since on that day the WHO announced the Alpha variant as the first variant of concern (VOC) (World Health Organization, 2020). Thus, we used that date to divide the time of publication of all relevant articles between two time periods: from December 31, 2019 to December 18, 2020, and from December 19, 2020 to September 1, 2021. Relevant articles were labeled to be from the first or second time period, named "Before" and "After," respectively. Within each label, we counted how often "evolve" was explicitly used during this period. We also distinguished how often an alternative word to "evolve" was used during "Before" and "After."

We used Spearman's rank correlations to examine the relationships between the number of articles discussing COVID-19 evolution and the month of the pandemic, as well as the percentage of articles using the word "evolve" and the month of the pandemic. In both analyses, we treated the month of the pandemic as an ordinal variable by counting each month starting with January 2020 as $n = 1$. For our analysis of "evolve" usage with each month of the pandemic, we calculated the percentage of articles using "evolve" as the number of articles in each month that used the word "evolve" at least once divided by the total number of articles discussing COVID-19 evolution that month times 100.

Results

Relevant articles

Of the 4,951 COVID-19 articles evaluated, 564, or 11%, of articles contained at least one relevant phrase discussing viral evolution, regardless of whether they specifically used the word "evolve" or its lexemes (Figure 1). The number of relevant articles varied widely across newspapers and countries (Table 1). We identified the fewest relevant articles in Guyanese publications, while we identified the most relevant articles in Indian publications, with 16 and 203 relevant articles, respectively.

"Evolve" usage across countries

In the United States, the usage of "evolve" declined from 29% before the event to 18% after. Canada saw a drop from 25 to 7%, and the United Kingdom showed a decrease from 31 to 13%. In Guyana, the percentage remained consistent at 13% both before and after the event. Similarly, Nigeria showed stability with 13% before and 12% after. India experienced a decrease from 27 to 6%, and Australia showed a marked decline from 50 to 9%." However, the proportion of articles using the word "evolve" did not differ significantly by country ($\chi^2 = 10.9$, df = 6, $p = 0.091$).

"Evolve" usage over time

During the stage of the pandemic before the announcement of the first VOC, the number of relevant articles was relatively low. From January 2020 to November 2020, fewer than 10 articles per month discussed COVID-19 evolution across all publications and countries, but we observed a large increase after December 2020. All countries had an appreciable increase in the number of relevant articles after the announcement of the first VOC (Figure 2). Across all months, we saw an average of 28 relevant articles per month across all publications, with 78 as the highest number of articles found in a single month during January 2021 (Figure 3A). We saw a positive correlation between the number of articles discussing COVID-19 evolution and months into the pandemic ($\rho = 0.63$, $p = 0.003$). Despite this, we found a negative correlation between the percentage of articles using the word "evolve" and months into the pandemic ($\rho = -0.60$, $p = 0.005$; Figure 3B). As the pandemic progressed, the percentage of articles using the word "evolve" decreased despite the increase in the number of articles discussing COVID-19 evolution.

Alternatives for the word "evolve"

Across all relevant articles, we identified 42 unique words or phrases used instead of "evolve" to discuss the evolution of COVID-19 and its variants. "Emerge" and "mutate" (and their lexemes) were the most often used alternatives for "evolve," appearing in 36 and 34% of phrases discussing evolution, respectively (Figure 4). Although the two words have similar overall counts, "emerge" was used less frequently in the "Before" stage of the pandemic compared to "mutate." "Evolve" itself was the third most frequently used term to discuss COVID-19 evolution, appearing in 12% of all phrases. Numerous alternatives were used less than 1% of the time to replace the word "evolve," such as "transform," "upgrade," "pop up," "spawn," "appear," and "turn into."

Discussion

"Evolve" usage across countries

Our findings show that only 12% of popular press articles about COVID-19 mention the word "evolve" when discussing its evolution. We initially hypothesized that varying social and epidemiological factors between countries might lead them to also differ in "evolve" usage in COVID-19 news (Heddy and Nadelson, 2012; Funk et al., 2020b). For example, we predicted that differences in views on evolution between countries would influence their "evolve" usage. We also posited that countries where VOCs were first documented might be more likely to use the word "evolve" because they would be more likely to report on COVID-19 evolution firsthand, rather than summarizing reports from other parts of the world. Surprisingly, however, "evolve" usage in the context of COVID-19 did not differ significantly between countries. This indicates that the concept of evolution in the context of COVID-19 is being discussed in a similar proportion of articles globally, potentially reflecting a common understanding and narrative in the worldwide discourse on the pandemic. However, studies have shown that acceptance of evolution can vary between concepts of microevolution, macroevolution, and human evolution, so it is possible that general views on evolution for a given country do not reflect a country's acceptance of COVID-19 evolution (Nadelson and Southerland, 2012; Nadelson and Hardy, 2015).

We also speculated that public attitudes towards science in general might be associated with "evolve" usage in newspapers (Falade and Bauer, 2018; Funk et al., 2020a). Given the reliance of journalists on experts to interpret the substance and significance of new scientific findings, trust in scientists may play a role in how the scientific knowledge of journalists is constructed and reported (Conrad, 1999). Inaccurate, sensationalist, or unbalanced science reporting also can potentially influence the public's perception of science (Geller et al., 2005). Five out of the seven countries included in our study reported generally high trust in scientists (Funk et al., 2020b), which we believe might correlate with more accurate scientific reporting. However, we observed low "evolve" usage across all countries, and one possible explanation for this pattern could be that people exhibit information avoidance behaviors when engaging with controversial or polarizing issues, such as COVID-19 or the concept of evolution (Soroya et al., 2021). Thus, the similarly infrequent use of the word "evolve" across countries might indicate a shared avoidance of controversial science terms like "evolution" in news sources people rely on and trust for health and science knowledge (Tao et al., 2020; Soroya et al., 2021; van Aelst et al., 2021).

Previous studies have explored "evolve" usage in newspapers in other evolution-driven public health contexts and found that "evolve" usage of the term varied significantly between countries (Singh et al., 2016, 2017), adding another reason why we initially believed that our findings would follow this pattern. For example, one study that reviewed English-language newspaper articles (from Australia, Canada, India, the U.S., and the U.K.) found that the U.K. used the word "evolve" to describe evolution of antibiotic resistance significantly more often than India, which used it the least (Singh et al., 2016). They also found that 18% of newspaper articles used the word "evolve" in this context (Singh et al., 2016). In another study on the same countries, "evolve" was used to discuss evolution in only 6.6% of articles on HIV drug resistance and 3.9% of articles on cancer tumor drug resistance (Singh et al., 2017). In all contexts, "evolve" usage was low. These studies have also shown that not only did "evolve" usage vary across countries in news on a single subject, but usage can also vary within a country depending on the news subject.

Acceptance of evolution, trust in scientists, first reporting of variants, and numerous other social and epidemiological factors could potentially be influencing "evolve" usage in ways we were unable to

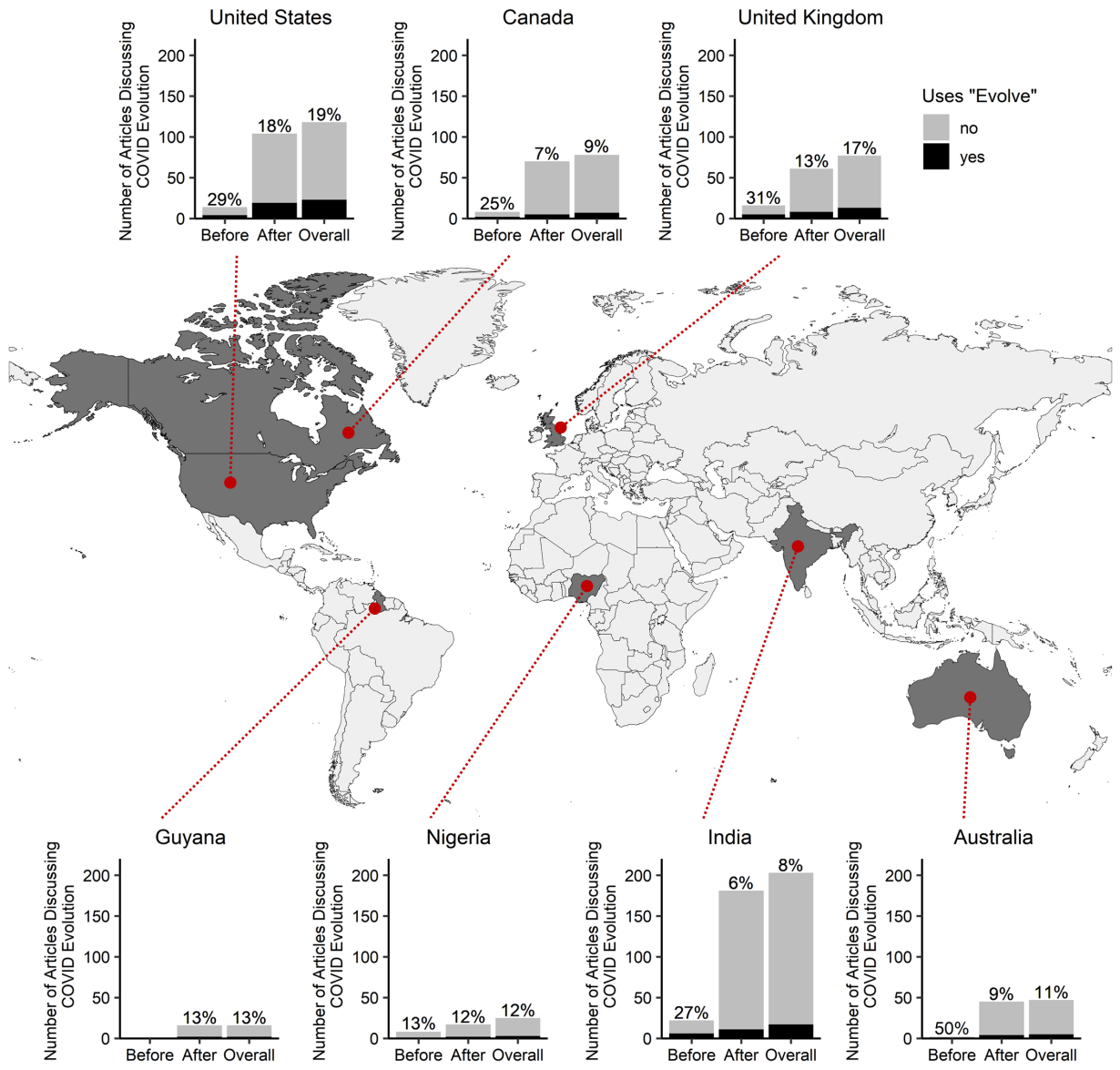

FIGURE 2
COVID-19 "evolve" usage in different countries and stages of the pandemic. All countries for which newspapers were examined are highlighted on our map with bar graphs showing the number of articles discussing COVID-19 evolution. Bars show the total number of articles from the top two newspapers in each country as the sum of articles that use the word "evolve" at least once (black) and articles that only use alternative words or phrases (gray) when discussing COVID evolution for different evolutionarily relevant stages of the pandemic. "Before" represents all relevant articles published between December 31, 2019 and December 18, 2020, the date the World Health Organization designated the Alpha variant as the first variant of concern (VOC) (World Health Organization, 2020, 2023; Carvalho et al., 2021). "After" represents all relevant articles published after the designation of the Alpha variant as the first VOC through September 1, 2021. "Overall" represents all relevant articles published between December 31, 2019, and September 1, 2021. The labels above each bar indicate the percentage of total articles that use the word "evolve" to discuss COVID evolution in each country and stage of the pandemic. "Evolve" usage did not vary significantly among countries ($\chi^2 = 10.9$, df = 6, $p = 0.091$). This figure was made using mapchart.net (MapChart, 2023).

detect in our analysis. For example, we only analyzed articles from the top two newspapers by circulation or readership from each country. Most of these newspapers were based in major cities, which might indicate they have more urban-based journalists and/or intend to reach more urban audiences. For countries where social factors can vary greatly between urban and rural communities, the top two newspapers are likely not representative of the average views across the entire country. In the U.S., for example, attitudes towards science and scientists can significantly differ along the urban-rural divide; newspapers based in New York city may not effectively represent views of rural areas or other parts of the country (Krause, 2023). Thus, further analysis of "evolve" usage in COVID-19 articles across a wider variety of newspapers from each country in terms of geographic location and viewpoint might elucidate any potential differences between or even within countries. Additionally, we also recognize that our selection of only seven English-speaking countries limits our ability to draw truly global conclusions. Further investigations of "evolve" usage in COVID-19 news across more countries and in

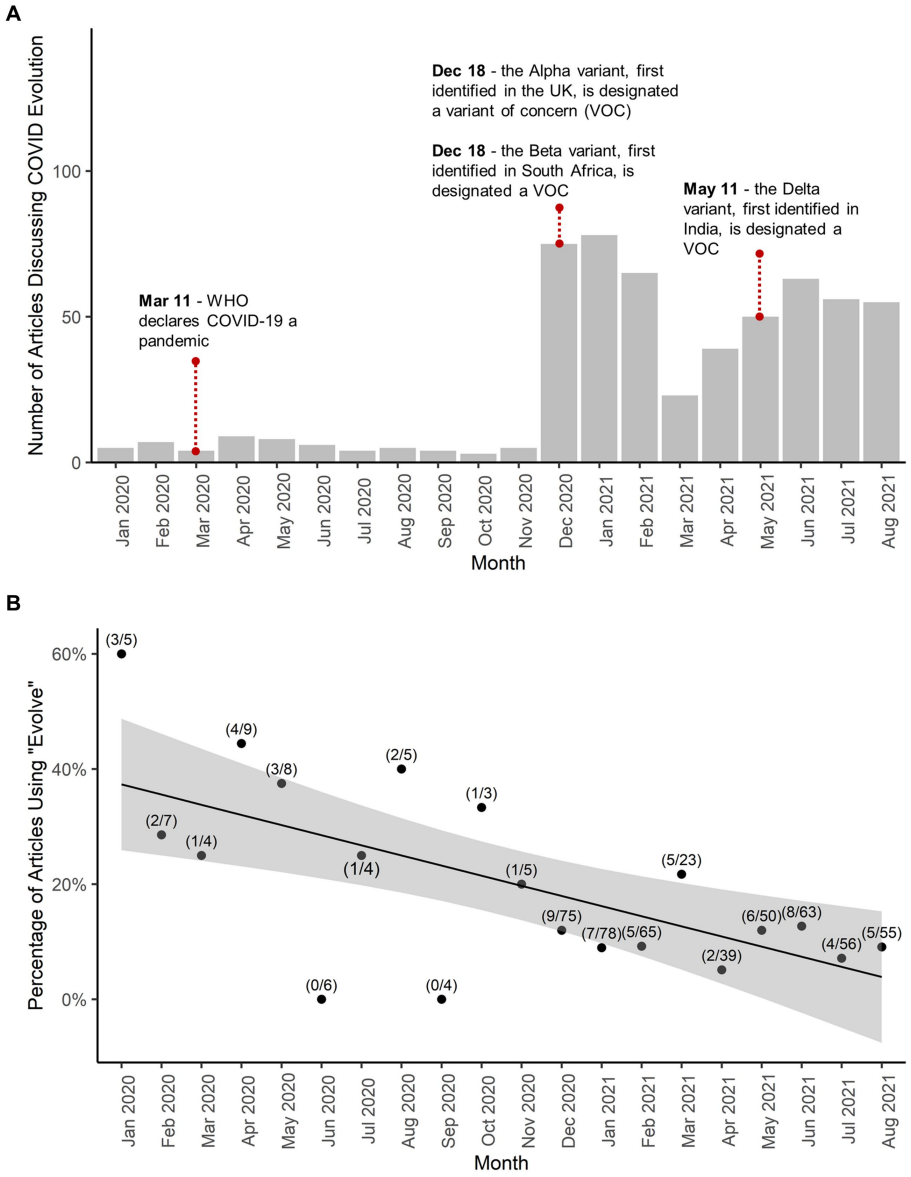

FIGURE 3
"Evolve" usage each month in all countries. **(A)** Number and fraction of articles from the top two newspapers in all countries discussing COVID-19 evolution for each month. Number of articles discussing COVID-19 evolution increased with months into the pandemic (ρ=0.63, p=0.003). Labels above highlight significant events related to the pandemic, including the declaration of the COVID-19 pandemic and declarations of VOC (World Health Organization, 2023). **(B)** Percentage of articles that used the word "evolve" in each month in all countries. "Evolve" usage decreased with months into the pandemic (ρ=−0.60, p=0.005). Parenthetical data labels indicate: (number of relevant articles using "evolve"/total number of articles discussing COVID-19 evolution).

newspapers in more languages may also offer more insight into how COVID-19 evolution is communicated in newspapers worldwide.

In many ways, the complexity, spread, and limited availability of information of the COVID-19 pandemic required a change in how media is produced (Guo and Vargo, 2020; García-Avilés, 2021). With entire newsrooms rather than journalistic specialists reporting on events, travel and social distancing restrictions limiting journalists' ability to talk to trusted sources, and misinformation being spread across social media, news media outlets have often relied on citing one another to disseminate new information about COVID-19 (Mayo-Cubero, 2020; Matsilele et al., 2022; Guo et al., 2023). In an analysis of international flow of COVID-19-related news at the beginning of the pandemic, Guo et al. (2023) found that COVID-19-related international news flow had a complex and unequal pattern, with a few countries and media outlets occupying a prominent place in the network (Guo et al., 2023). If this same pattern of the world news system citing few and shared sources to disseminate COVID-19 health-related information persisted throughout the pandemic, we might expect to also see more shared language used to describe new information, such as the evolution of the virus, in newspaper articles worldwide. Similar "evolve" usage across countries, therefore, may reflect how the global, novel, and urgent nature of the COVID-19 pandemic drove more interconnectedness in news reporting across countries. This could explain why "evolve" usage was similar across

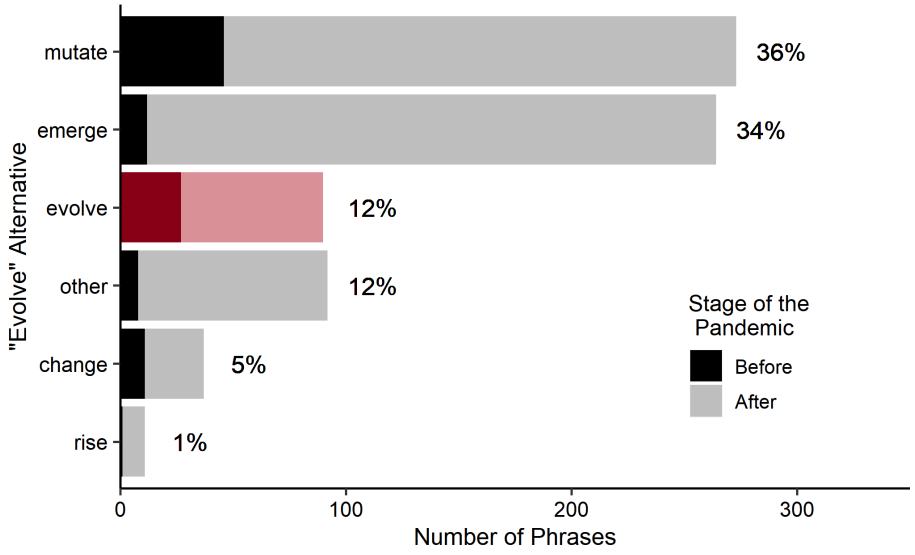

FIGURE 4
Alternative words used to discuss evolution of COVID-19. Frequencies that the word "evolve" or alternative words for "evolve" are used for all relevant phrases examined across all countries. Bars are colored to indicate the time the articles containing the phrases were published, either before (black) or after (gray) the declaration of the Alpha variant as the first VOC. "Other" includes all alternatives used in fewer than 10 phrases. Labels at the end of each bar indicate the percent of total phrases represented by each "evolve" alternative across all relevant articles.

countries despite not only their epidemiological differences, but also their differences in "evolve" usage in other public health contexts less novel and interconnected globally relative to COVID-19 (Singh et al., 2016, 2017).

Ultimately, our observations of similar "evolve" usage across countries coupled with the lack of clear or direct associations between various social and epidemiological factors and the use of the word "evolve" in COVID-19 news suggest that the usage of "evolve" in this context depends on numerous and potentially interacting factors. What is likely key amongst these factors is the context of the global pandemic itself—not only may it have changed the way different countries view COVID-19 and its evolution, but also it may have likely influenced the way the world reports it in the news.

"Evolve" usage over time

In addition to exploring variation in "evolve" usage across countries, we investigated patterns in their collective usage of the word "evolve" when discussing viral evolution over the first 20 months of the pandemic. We observed a significant increase in the number of articles discussing COVID-19 evolution using any terminology as the pandemic progressed. However, we saw a significant decrease in the number of articles using the word "evolve" over time.

The increase in the number of articles discussing evolution could have several explanations. First, there was an apparent jump in the number of relevant articles in December 2020, which coincides with the designation of the Alpha variant as a VOC (Carvalho et al., 2021; World Health Organization, 2023). After a decline in relevant articles following December 2020, there was another jump in May 2021, when the Delta variant was designated a VOC (World Health Organization, 2023). Given that new variants of COVID-19 result from the evolution of the virus, it is reasonable to expect a jump in the number of articles discussing evolution that coincides with the initial reporting of variants. Our inclusion of "(variant OR strain)" in the Boolean search string used to locate articles to consider in this study very likely inflated this jump in the number of relevant articles. However, even if our search string inflated the number of articles discussing COVID-19 evolution later in the pandemic, it is unlikely that this would have impacted our ability to assess the percentage of articles that used the word "evolve." Regardless of a true or possibly inflated increase in overall number of articles discussing COVID-19 evolution, we still observed a significant decrease in "evolve" usage over the first 20 months of the pandemic. Because global scientific knowledge of COVID-19 greatly improved during the timeframe that we analyzed, we anticipated greater scientific understanding of COVID-19 would reflect in a general increase not just in the reporting of evolution of COVID-19 but also in "evolve" usage (Carvalho et al., 2021; Coccia, 2021). This was not what we found. This unexpected decrease could have multiple potential explanations.

We speculate that this rapid acquisition of scientific knowledge may have implications for how quickly and effectively it is disseminated to the public. One possibility is the increasing specificity and technicality of the language used by scientists and journalists as an understanding of the virus increased. The research field of COVID-19 has been characterized by unparalleled velocity and scientific production (Coccia, 2021). The daily growth of the body of COVID-19 research publications is more than double that of related fields (Coccia, 2021). Thus, the increase in the number of articles discussing evolution paired with a decrease in the percentage of articles using the word "evolve" could signal that keeping up on reporting these findings diminishes the quality and/or thoroughness of scientific reporting. Typically, journalists will contact fewer experts when they are on a tight deadline (Conrad, 1999). The experts themselves may also describe COVID-19 evolution using different terminology. Antonovics et al. (2007) found that evolutionary biology

journals used the word "evolve" to describe evolution 65.8% of the time, while medical research journals used it only 2.7% of the time in research articles about antibiotic resistance published in different types of scientific journals. Thus, the type of expert paraphrased or quoted by a journalist in articles describing COVID-19 evolution may also influence "evolve" usage."

In addition, when tasked with disseminating new COVID-19 information quickly, journalists also may prioritize reporting on topics they find more pertinent and digestible to a broad audience than the topic of viral evolution. For instance, journalists writing about a new COVID-19 variant might focus more on thoroughly and accurately describing its epidemiology and impacts than its evolution. The decrease in "evolve" usage despite the increase in discussing the evolution of COVID-19, therefore, could reflect how information discovered by scientists or published in research journals may not be immediately or thoroughly described in newspapers. Further investigating the sources, motivations, and intended audiences of journalists reporting on COVID-19 might offer insight into their usage of the word "evolve" when reporting on viral evolution.

Alternatives for the word "evolve"

We found that in place of "evolve," a wide variety of alternative words were used to describe or discuss COVID-19 evolution. Specifically, we found that "emerge" and "mutate" were the two most frequently used words in place of "evolve." We suggest two main possible explanations for this. First, recurrent usage of "emerge" and "mutate" might be due to their associations with epidemiological or microevolutionary aspects of COVID-19. In collecting our data, we were careful to distinguish "emergence" as a replacement for evolution from "emergence" as an epidemiological term referring to conditions of the novel appearance or rapid spread of an infectious disease, which is often the result of viral evolution and spillover events (World Health Organization, 2014). We also were careful to differentiate "mutation" as a specific mechanism of genetic change from "mutation" as an alternative word for evolution. While we did encounter these words used in their appropriate contexts, "mutate" and "emerge" were still used even more often than the word "evolve" itself in phrases about COVID-19. While use of contextually relevant terms might be indicative of some level of scientific understanding, their frequent use in place of the word "evolve" offers evidence of a failure to understand and communicate many subtle yet important aspects of evolution.

Second, given the immense global impact of the COVID-19 pandemic, we also considered the possibility that different words are used in place of "evolve" to sensationalize the evolution of the virus and its effects. While words like "mutate" can reflect sensationalism or catastrophe discourse in similar evolutionary contexts, such as the evolution of antibiotic resistance (Nerlich, 2009), it seems less likely that such rhetoric is occurring here in the context of COVID-19. While we did not assess how journalists and their audiences perceived the term "evolve" and its alternatives specifically, a content analysis of COVID-19 reporting in major print and online newspapers from the U.S., U.K., and Canada found that across all publications, articles had overall low levels of sensationalism (Mach et al., 2021). The same study found that COVID-19 reporting had only moderate scientific quality, which was potentially implicated in policy failures and failures to alert readers of COVID-19's public-health risks. Thus, although it seems unlikely that use of alternatives to the word "evolve" increased the level of sensationalism in COVID-19 news, it is possible that failing to use the word "evolve" where appropriate could have consequences for public understanding of COVID-19 evolution and its relationship with public health during the pandemic. Further analysis of how journalists and their readers perceive the term "evolve" and its various alternatives might offer more insight into how the choice of terminology both reflects the journalists' intended messaging and reflects audiences' actual receptivity to COVID-19 evolution in the news.

It is important to note the significance of the term "evolution" in the context of COVID-19 and other viral pandemics, as highlighted by recent research. For instance, host RNA editing mechanisms are suggested to partly influence SARS-CoV-2 evolution, crucial for monitoring the virus's transmission between humans and animals (reviewed by Qian et al., 2022). Similarly, the evolutionary plasticity of coronaviruses through mutation and recombination impacts their adaptation, transmissibility, and pathogenicity in zoonotic-originated epidemics such as SARS-CoV-2 (Amoutzias et al., 2022). Additionally, understanding the interconnectedness of human, animal, and environmental health in discussions on viral evolution helps integrate this broader context to address the challenges posed by zoonotic diseases and pandemics (Haroun and Mohammed, 2015).

Conclusion

While evolution has clearly played a role in the progression of the COVID-19 pandemic, the word "evolve" has not been as apparent in COVID-19 news. Quantifying the differences in how often different countries use the word "evolve" offers a unique lens to explore if and how various social and epidemiological factors might be associated with the reporting of evolution in the news, particularly in the unprecedented context of the COVID-19 pandemic. What stands out as more important than these differences, however, is what was observed collectively across countries. Despite COVID-19 evolution becoming more topical in the news over the first 20 months of the pandemic, particularly with the reporting of variants, the word "evolve" was used less frequently.

More nuanced reporting of COVID-19 that uses more specific and exact scientific language that accurately names and describes important concepts of evolution might help readers better connect specific processes and outcomes of evolution to the concept itself. Other scientifically accurate terms related to evolution may include heritability, mutation, recombination, and natural selection. Increased awareness around common linguistic choices or metaphors used in science communication can help scientists or journalists understand what may be limiting public understanding of evolution (Kueffer and Larson, 2014). For example, the infrequent use of the word "evolve" and the choice of alternative words describing it in news reports might portray evolution as an independent force that is not influenced by human culture and behavior. It may also highlight a common misconception about evolution—that it is a process that is imperceptibly slow or requires a large expanse of time to occur (Antonovics et al., 2007; Coccia, 2021). Such a misconception might make it difficult to recognize viral evolution as a process that can occur rapidly or can have salience in our daily lives. For example, influenza viruses responsible for numerous deadly pandemics evolve on a seasonal basis, limiting vaccine effectiveness (Ghedin et al., 2005; Wille and Holmes,

2020). A retrospective study on the language around evolution in previous pandemics may provide further insights on different perceptions of evolution in different contexts or lasting misconceptions about evolution.

The media can have dramatic effects on public acceptance of other scientific concepts. Social media has provided forums for scientific debate—but has also created spaces for misinformation to spread (Wang et al., 2019). As with influenza, different strains of COVID-19 have become epidemiologically significant over time, warranting the development of new vaccines to augment immune response (Yadete et al., 2021). Pre-existing notions about the effectiveness of COVID-19 vaccines from media misinformation, such as the likelihood of dangerous side effects, may impact the likelihood of receiving booster doses to protect oneself from future infection (Yadete et al., 2021). Future analysis of how vaccine hesitancy has changed and will continue to change over the course of the pandemic (with respect to COVID-19 evolution) would reveal how media has impacted public understanding of vaccine effectiveness and evolution. This can also impact policy decisions on vaccines, including willingness by governmental agencies to distribute, authorize, or promote future vaccines for the general population, or ease restrictions on disease monitoring, as has occurred in states like Texas (Matthews et al., 2024). We have witnessed how major stakeholders and policymakers can influence science, in areas such as vaccine hesitancy and climate change. However, knowledge gaps between scientists, policymakers, and the general public still exist and have obscured substantive, evidence-based science policies (West and Bergstrom, 2021). Understanding how this information is communicated is crucial to comprehending patterns of acceptance, identifying gaps in understanding, and clearing misinformation for the general public and policymakers as a whole.

As scientists and health professionals continue to use the popular press to communicate their findings and as the general public continues to consume media to stay informed about public health topics, language will serve as a critical tool to connect scientific concepts with public health realities. In the context of COVID-19 and future public health crises, use of precise and scientifically accurate language, including the word "evolve" where appropriate, might be key to connecting the specific processes and outcomes of evolution with public health consequences.

The potential implications of language choice extend beyond public understanding and may impact public health policies and attitudes toward science. If the public perceives evolution as a slow, irrelevant process, they may be less likely to support or adhere to public health measures designed to combat rapidly evolving pathogens. This could hinder efforts to implement timely interventions, such as vaccination campaigns or travel restrictions, and diminish public trust in scientific recommendations. Science communication that conveys the relevance of viral evolution could foster a more informed and responsive public, ultimately aiding in the implementation of policies that mitigate the spread of infectious diseases.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SB: Funding acquisition, Supervision, Writing – original draft, Writing – review & editing. SF: Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. CX: Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. BL: Writing – original draft, Writing – review & editing. SN: Writing – original draft, Writing – review & editing. MY: Writing – original draft, Writing – review & editing. NL-H: Supervision, Writing – original draft, Writing – review & editing. ED: Supervision, Writing – original draft, Writing – review & editing. PY: Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2024.1427596/full#supplementary-material

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