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Exploring nutritional supplement use for countering respiratory tract infections through an X (formerly Twitter)-based survey

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Abbreviations: COVID-19, Coronavirus disease 2019; MERS, Middle East respiratory syndrome; NAC, N-acetyl cysteine; NER, Named-Entity Recognition; NLP, Natural Language Processing; NLTK, Natural Language Toolkit; QDA, Qualitative Data Analysis; SARS, Severe acute respiratory syndrome; URTIs, Upper respiratory tract infections; VADER, Valence Aware Dictionary and sEntiment Reasoner; WHO, World Health Organization.

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A R T I C L E I N F O

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A B S T R A C T

Background: Respiratory tract infections are a common health issue, driving interest in preventive strategies like nutritional supplements, while evidence on their usage and effectiveness remains limited. In this context, social media platforms, particularly X (formerly Twitter), provide a unique opportunity to gather large-scale public health-related data.

Objectives: In this study, we aimed to survey participants' uses and opinions on nutritional supplements in prevention or treatment of respiratory tract infections, by using X.

Methods: A survey was conducted between 1st and 15th December 2022. A single open-ended question "Which are the best dietary supplements to counteract respiratory infections?" was asked. One week after the start of the survey, a poll was posted to get more relevant information and boost the survey's reach. Total endorsements were calculated for each tweet posted as the total sum of replies, retweets, and likes.

Results: The open-ended question received a total of 118 retweets, 39 quotes, and 371 likes, while the poll received 56 retweets, 13 quotes, and 67 likes. A total of 495 replies, 2,251 retweets, 5,118 likes, and 148 quotes were received for the question and its related tweets. Vitamin D (1,607 endorsements), zinc (1,347 endorsements), vitamin C (803 endorsements), magnesium (694 endorsements), and honey (661 endorsements) were the nutritional supplements that received most endorsements.

Conclusion: Various foods, drinks, and natural ingredients have been suggested as potentially helpful for counteracting respiratory infections. Approximately half of respondents indicated using such supplements for

[1] Both authors have contributed equally and are to be treated as first authors.

themselves. The result of this study supports the idea that the X platform can be used as an effective survey tool to study global health-related behaviours and trends.

Introduction

Respiratory tract infections are a common ailment affecting people of all ages. They cause discomfort and inconvenience and can lead to serious complications, especially in vulnerable populations such as the elderly and immunocompromised individuals (Saleri & Ryan, 2019). Being a very common type of infection and generally with very favorable prognosis, patients may not seek medical help in mild cases and often treat themselves with various modalities of treatment, including home remedies and food supplements (Thota et al., 2020). Several previous studies have found that nutritional supplements like garlic, vitamin D, zinc acetate, and others may be beneficial or have potential benefits in preventing respiratory infections (Abioye et al., 2021; Camargo et al., 2021; Mrityunjaya et al., 2020; Murni et al., 2021; Nantz et al., 2012; Prasad et al., 2008; Trivillin et al., 2022). Over the course of the last two decades, there have been four significant outbreaks of viral infectious diseases, namely Severe Acute Respiratory Syndrome (SARS), Influenza H1N1 (Swine Flu), Middle East Respiratory Syndrome (MERS), and Coronavirus Disease 2019 (COVID-19), resulting in a substantial global mortality toll reaching hundreds of thousands of individuals. These diseases share a common clinical presentation characterized by initial respiratory tract infections affecting both the upper and lower respiratory system (Lombardi et al., 2020).

A respiratory tract infection is a term used to describe any infectious disease affecting either the upper or lower respiratory tract. Upper respiratory tract infections (URTIs) encompass various conditions such as the common cold, laryngitis, pharyngitis/tonsillitis, acute rhinitis, acute rhinosinusitis, and acute otitis media (Heikkinen & Ruuskanen, 2006; Shahan et al., 2019). On the other hand, lower respiratory tract infections comprise ailments like acute bronchitis, bronchiolitis, pneumonia, and tracheitis. In primary care settings, antibiotics are frequently prescribed for both adults and children with respiratory tract infections (Dasaraju & Liu, 1996; Guidelines, 2008).

Natural products offer significant potential as antimicrobial agents due to their diverse chemical structures and bioactive compounds (Raina et al., 2023; Sharma et al., 2023; Singla De, et al., 2023). Echinacea, Cistus, green tea, *Panax quinquefolius*, *Pelargonium sidoides*, *Cyclamen europaeum*, and garlic are only few examples of traditional natural remedies that have been employed since ancient times to alleviate symptoms associated with acute respiratory infections (Langeder et al., 2020).

Nowadays, the integrated approach of study and research networking represents a great challenge (Singla, et al., 2023). Social media has become a valuable tool for health research and communication. Health-related surveys can be conducted on social media platforms like X (formerly Twitter), Facebook, and Instagram. Such surveys can reach a wide range of individuals, including those for whom it may be challenging to get through traditional research methods (Chen & Wang, 2021). However, social media research in the healthcare context has some limitations too. For example, the population reached through social media may not be representative of the general population, and self-reported data may be subject to bias (Ventola, 2014). Additionally, social media survey participants may be more likely to have specific characteristics, such as higher levels of education and income (Thackeray et al., 2013). Despite these limitations, social media can be a valuable tool for conducting health-related surveys, providing a novel approach to gather information about health behaviours, attitudes, and knowledge (S. Mondal et al., 2022; Prieto et al., 2014; Zhou et al., 2018). Along the same lines, crowdsourcing, the process of obtaining ideas or information from a large group of people, has become a popular method for gathering information and generating innovative ideas. Social media platforms, such as X, have emerged as powerful tools for crowdsourcing, providing a vast and diverse range of perspectives and ideas. In the field of health, crowdsourcing from social media platforms has the potential to provide valuable insights and generate new ideas for addressing various health-related issues (Alvaro et al., 2015; H. Mondal et al., 2022; Singla De, et al., 2023). Nevertheless, although social media platforms like X allow for large-scale, real-time data collection, their use particularly in epidemiological research is limited by factors such as self-reported data, the absence of detailed demographic and clinical information, and the potential for response bias. These limitations necessitate caution in interpreting findings and underscore the need for complementary methods to validate results.

In this study, the use of X as a method for gathering information and opinions on nutritional supplements used to prevent and treat respiratory infections is explored. This methodology allows for a large-scale data collection, providing a diverse range of perspectives and real-time insights. It demonstrates the potential of social media platforms for research purposes.

Materials and methods

Type and setting

The present study represented a mixed-method survey study conducted on X, a social media platform with limited text capacity *per* post. The study was conducted from December 1 to December 15, 2022.

Data collection

This study involved the collection of both qualitative and quantitative data with question and pool, respectively. The question and poll with the dates of posting are shown in Fig. 1. The open-ended question collected qualitative textual data, and the poll collected the total responses in “yes” and “no” votes. In addition, retweets, likes, and quotes

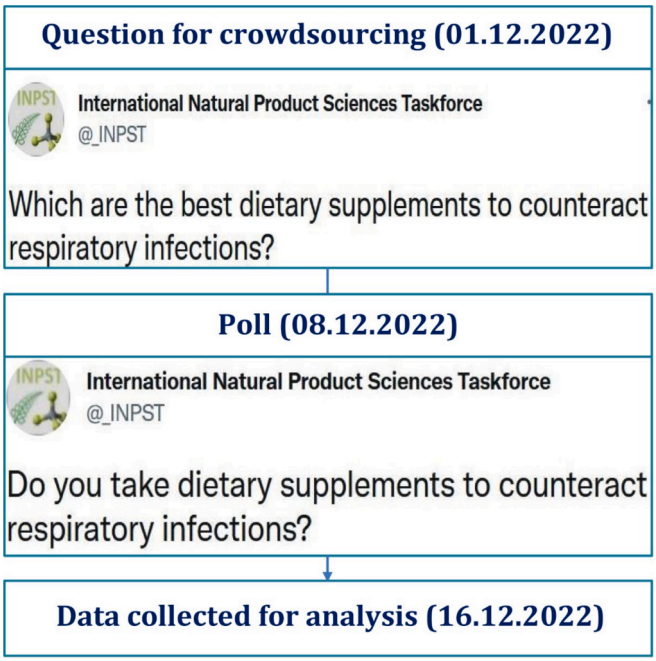

Fig. 1. The survey question and poll with dates of posting on X.

were collected in numbers.

The crowdsourcing survey was done with a single open-ended question: "Which are the best dietary supplements to counteract respiratory infections?". The tweet with the indicated question was posted from the X handle of the International Natural Products Sciences Taskforce (https://twitter.com/_INPST), which had 7,857 followers at the time of posting. After one week, a poll was posted on the same thread to get a closed opinion and boost the tweet's reach. The poll was conducted with the question, "Do you take dietary supplements to counteract respiratory infections?" with "yes" and "no" response options.

For calculating endorsements, we considered each tweet suggesting a specific supplement as one endorsement. If a single tweet included multiple recommendations, each one was recorded and counted separately. For example, in Fig. 2, the displayed representative tweet contains two recommendations (vitamin D and magnesium). If there were X number of retweets, and Y is the number of likes of this tweet, then the total endorsement for each recommended item was calculated as 1 + X + Y.

Importantly, the survey aimed to collect general opinions and self-reported behaviors rather than comprehensive clinical data. Gathering data on variables such as participants' health conditions, pregnancy status, or duration of supplement use were beyond the scope of this exploratory study.

Data analysis

The text responses were collected from X and cleaned from irrelevant inputs. For instance, tweets with only emojis, appraising or thanking were excluded and not evaluated further. The replies posted in languages other than English were translated to English with the help of Google Translate (https://translate.google.co.in) in "Detect language" mode, in order to automatically detects the input language, and converts to English.

The final textual data were first used to generate a word cloud (carried out at https://www.freewordcloudgenerator.com) after removing the following words, i.e., dietary, supplement, counteract, respiratory, tract, infection, following, thank, especially, just, work, treatment, symptoms, please, mg, beneficial, review, research, study, *meta*-analysis, yes, risk, say, high, people, concluded, help, upper, effective, prevent, recommended, effects, use, think, and found. The described filtering was performed to reduce the bulk of less relevant words for the analysis.

The data were further presented according to the occurrence frequency in tabular form. Directly quoted texts were used to represent the result. Qualitative Data Analysis (QDA) Miner Lite was used for the qualitative data analysis of the data collected from the current X-based survey. QDA Miner Lite is a well-recognized tool for qualitative and quantitative data analysis (Bayked et al., 2022; Kurnianto et al., 2023; Mekashaw Bayked et al., 2022; Singla, Joon, et al., 2023). QDA Miner Lite was chosen for its ability to efficiently organize, code, and analyze textual data. This tool allowed the authors to identify patterns, themes, and sentiments within the user responses collected from X. Its intuitive interface and essential analytical features made it well-suited for handling the open-ended textual data, fulfilling the need for an accessible yet robust software solution for this exploratory study. The collected tweets were analyzed to identify patterns of endorsement for specific supplements. The authors applied reasoning to synthesize the most relevant and representative examples from the range of options provided by users. The resulting representative statements are included in Table 1 to illustrate the endorsements and highlight user opinions.

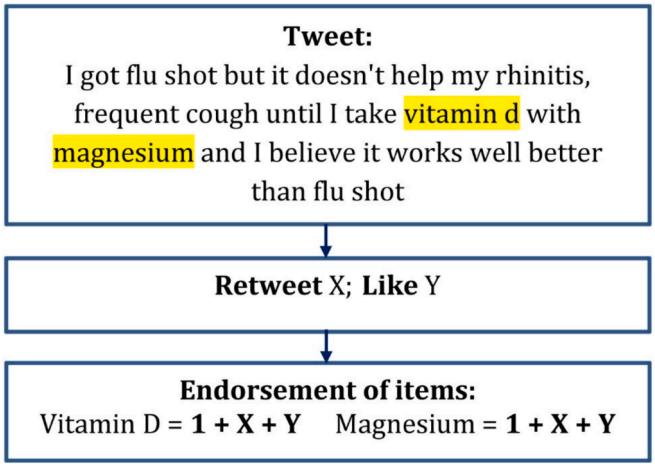

Fig. 2. Calculation of endorsements from a tweet.

Further, the literature search was performed in PubMed on 11.06.2023 and the following search terms were utilized (applying a strategy involving a combination of keywords present in titles/abstracts of papers and Medical Subject Headings (MeSH) terms): (dietary supplement [Title/Abstract] OR Vitamin[Title/Abstract] OR Zinc[Title/Abstract] OR Magnesium[Title/Abstract] OR honey[Title/Abstract] OR ginger[Title/Abstract] OR Garlic[Title/Abstract] OR Turmeric[Title/Abstract] OR probiotic[Title/Abstract] OR Green tea[Title/Abstract] OR elderberry[Title/Abstract] OR flavonoid[Title/Abstract] OR lemon [Title/Abstract] OR basil[Title/Abstract] OR pepper[Title/Abstract]) AND (respiratory infection[MESH]). PubMed data was extracted and

Table 1
Top 20 endorsed nutritional supplements to prevent or treat respiratory infections. Quoted text from X was not curated for grammatical improvement. The specific quoted statements are based on the authors' synthesis reflecting the user-recommendations from the analyzed tweets, representing the most commonly endorsed supplements.

Item	Endorsements	Quoted text example
Vitamin D	1,607	"I take vitamin D with magnesium and I believe it works well better than flu shot"
Zinc	1,347	"Vitamins and zinc may be beneficial dietary supplements to counteract respiratory infections"
Vitamin C	803	"when I have respiratory infections, I take vitamin C (sodium ascorbate)…"
Magnesium	694	"I take vitamin d with magnesium and I believe it works well better than flu shot"
Honey	661	"I usually prefer to take ginger, black pepper, mulethi, tulsi and honey"
Ginger	637	"I usually take ginger"
NAC*	552	"I know the official position, but NAC works for me"
Garlic	472	"I found chewing up raw garlic cloves was the best remedy for the painful sore throat"
Turmeric	450	"the powdered turmeric with luke warm water is very effective"
Probiotics	368	"Probiotics protect against various diseases, including respiratory infections"
Green tea	355	"green tea consumption is effective in the prophylaxis of influenza infections"
Elderberry	322	"Supplementation with elderberry was found to substantially reduce upper respiratory symptoms"
Flavonoids	319	"flavonoid quercetin can ameliorate COVID-19 infection and symptoms"
Multivitamin/s	284	"I think multivitamin with vitamin C as supplement is best"
Vitamin/s B	276	"I think vitamin B12 is also helpful"
Lemon	227	"Taking lemon juice daily might improve immunity against common cold"
Black seed oil	223	"take black seed oil"
Basil	212	"Holi Basil (Tulsi) is an Indian herb utilised for different diseases. The extracts from this plant is used for common cold or respiratory infection"
Pepper	205	"Traditionally, pepper is good for that as well"

* NAC: N-acetyl cysteine; COVID-19: Coronavirus disease 2019; Mulethi: Licorice; Tulsi: Holy basil.

imported for further analysis in VOSviewer, a tool used for bibliometric analysis (Cai et al., 2023; Chai et al., 2023; Su et al., 2023; Vaishya et al., 2023; Wang et al., 2023; Zielinska et al., 2023). VOSviewer extracts key terms from titles and abstracts and visualizes co-occurrence networks based on their frequency and relationships within the analysed data. Terms are grouped into clusters, with the strength of connections between terms represented by the thickness of lines and proximity of nodes. For this study, we input relevant PubMed search results (N = 5,298 articles) and generated keyword and MeSH term co-occurrence maps. A minimum occurrence threshold was set at five to ensure robust and meaningful relationships. The algorithm prioritizes terms based on their relevance and link strength, allowing for the identification of prominent research themes related to dietary supplements and respiratory infections. The minimum occurrence threshold in VOSviewer was set at five to achieve a balance between inclusiveness and relevance. This value was chosen to ensure that frequently occurring terms were captured while minimizing the inclusion of infrequent terms that could introduce noise. Similar thresholds have been commonly used in bibliometric analyses, with values typically ranging from 3 to 10 depending on dataset size and research objectives. Given the exploratory nature of our study and the dataset size (5,298 articles), this threshold was deemed appropriate to generate a meaningful co-occurrence network without compromising interpretability.

The poll result was presented in percentage and evaluated statistically by the binomial two-tailed test where a $p < 0.05$ was considered statistically significant. The test was conducted in GraphPad Prism 7.00 for Windows (GraphPad Software, Inc., USA).

Natural Language Processing (NLP) data analysis tasks – sentiment analysis and Named-Entity Recognition (NER) of entity types "chemical" and "disease" – were performed with the Natural Language Toolkit (NLTK) and ScispaCy libraries in Python (Bird et al., 2009; Neumann et al., 2019). NLTK VADER (Valence Aware Dictionary and sEntiment Reasoner) classifier is a lexicon and rule-based sentiment analyser specifically attuned to sentiments expressed in social media. It's mainstream model for sentiment analysis frequently used in companies and academia. The lexicon dictionary contains around 7,500 sentiment features specifically used in social media. Words not listed in the dictionary are scored as "0: Neutral". After cleaning text from URLs, hashtags, and mentions, text was tokenized and lemmatized, and compound scores were derived with NLTK VADER into the normalized range −1 to 1. Classification into "Positive", "Negative" and "Neutral" was performed with the default rule. NER entity types "chemical" and "disease" were derived with a large pre-trained model of biomedical text. A spaCy NER model en_ner_bc5cdr_md (F1 = 84.23%) trained on the BC5CDR (BioCreative V Chemical Disease Relation) corpus is used for identification of entity types "chemical" and "disease". The BC5CDR corpus consists of 1,500 PubMed articles with 4,409 annotated chemicals, 5,818 diseases, and 3,116 chemical-disease interactions. Entity type "chemical" as supplement have been cross-checked with derived sentiment classes.

The selection of visualization methods, including word clouds and term maps, was guided by their ability to effectively summarize and communicate key findings in an intuitive and accessible manner. Word clouds offer a straightforward representation of frequently mentioned terms, making it easier to identify dominant themes at a glance. Term maps, as generated through VOSviewer, provide a structured depiction of keyword relationships, allowing for the recognition of research clusters and co-occurrence patterns. These approaches align with standard bibliometric and text-mining methodologies, ensuring that the presented data remains interpretable to a broad audience while maintaining analytical rigor, and striking a balance between readability and meaningful representation, which is of particular importance given the exploratory nature of this study.

Results

We have successfully conducted a crowdsourcing survey in 15 days on X, yielding 118 retweets, 39 quotes, and 371 likes on the open-ended question. In addition, 56 retweets, 13 quotes, and 67 likes of the poll were received. A total of 495 replies, 2,251 retweets, 5,118 likes, and 148 quotes were generated on all thread tweets.

Altogether, the thread's tweets contained a total of 9,021 words from the user's inputs. After removing common and terms not useful for the research intended, we generated a word cloud, shown in Fig. 3. The top 10 words were: vitamin (specifically, vitamin D and vitamin C were frequently mentioned; see also Table 1), zinc, honey, garlic, ginger, N-acetyl cysteine (NAC), magnesium, and tea.

Users from around the world indicated that they were using or suggesting various nutritional supplements alone or in combination to counteract/combat respiratory infections. Cumulatively, 14,737 endorsements were received, with the top 20 items contributing to 67.95% of the endorsements. The top 20 recommended nutritional supplements to prevent or treat respiratory infections and their respective numbers of endorsements are shown in Table 1.

The poll received 56 retweets, 13 quotes, and 67 likes. A total of 307 votes were obtained, with 166 (54.07%) in agreement and 141 (45.93%) in disagreement votes on the question, "Do you take dietary supplements to counteract respiratory infections?" Hence, about half of the users take dietary supplements to counteract respiratory infections (binomial two-tailed test, $p = 0.17$).

NLP sentiment analysis with NLTK VADER reveals that most responses had positive (50.3%) or neutral (41.9%) sentiment, with only minor negative (7.8%) sentiments received. User device type distribution follows an equal tendency across all three sentiment classes, with most devices being Web App, Android and iOS. Cross-checking of derived "chemical" NERs and sentiments, associates five most endorsed nutritional supplements, vitamin D, zinc, vitamin C, magnesium and honey, predominantly into positive and neutral sentiments.

We further explored PubMed for the available scientific literature on the obtained X-based recommendations using the search terms "dietary supplement, vitamin, zinc, magnesium, honey, ginger, garlic, turmeric, probiotics, green tea, elderberry, flavonoid, lemon, basil, pepper, and respiratory infection." The indicated search yielded 5,298 results as of June 11, 2023. On processing the PubMed results in VOSviewer, these 5,298 articles resulted in 10,423 keywords, and 1,671 keywords were being repeated in a minimum of 5 publications. The top 15 key terms are given in Table 2. Network interactions between these 1,671 keywords are visualized in Fig. 4. However, when we processed it as *per* the MeSH terms, we found 5,239 MeSH keywords in those 5,298 articles, and there were 1,374 MeSH terms that minimally occurred five times. The top 15 MeSH key terms are given in Table 2. The obtained data (Table 2) further hint at emphasizing vitamin D uptake in the scientific literature related to respiratory tract infections. Network interactions among the identified 1,374 MeSH terms are visualized in Fig. 5. The association of ascorbic acid, flavonoids, flavones, riboflavin, glycine, and ginger with various respiratory tract infections like tuberculosis, pneumonia, COVID-19, and others, was also evident (Fig. 4). At the same time, examination of the MeSH key terms indicated a strong association of dietary supplements such as vitamin D, curcumin, flavonoids, *Lactobacillus*, magnesium, and ergocalciferol with ailments related to the respiratory tract.

Discussion

Findings from the current study highlight the effectiveness of the social media platform, X, for researching to gather insights and opinions from a large and diverse population. The research also indicates the role of different nutritional supplements that are popularly used for preventing and combating respiratory infections. The remedies identified in this study, including vitamins, minerals, and natural products, align

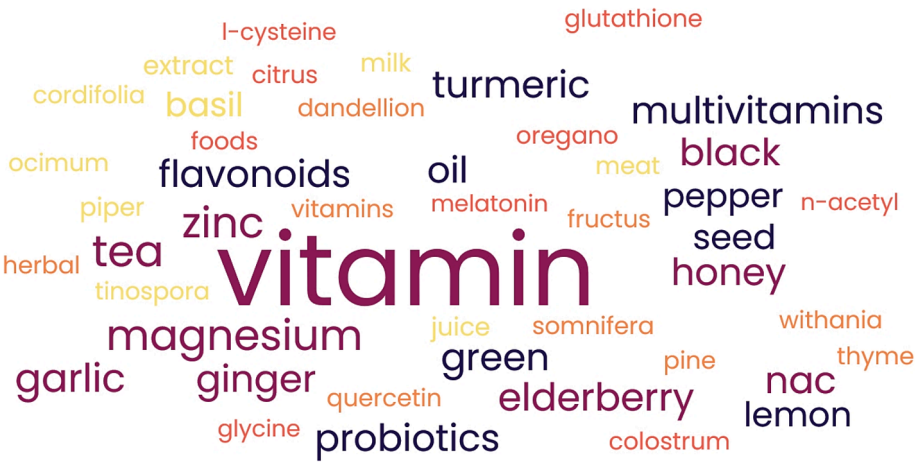

Fig. 3. A word cloud generated through https://www.freewordcloudgenerator.com from the texts after removing words unrelated to the study.

Table 2
Top 15 keywords and MeSH key terms retrieved by VOSviewer from the publications data (related to dietary supplements and related keywords as well as respiratory infections) obtained from PubMed. Keywords are ranked *per* the relevance algorithm of VOSviewer, while MeSH key terms are ranked as *per* the total link strength algorithm of VOSviewer.

Keywords	Occurrences	MeSH Key terms	Occurrences
Humans	4,895	Humans	4,895
Male	1,898	Male	1,898
Female	1,844	Female	1,844
COVID-19	2,118	COVID-19	2,112
SARS-CoV-2	1,538	Adult	1,069
Vitamin D	1,436	SARS-CoV-2	1,472
Adult	1,069	Vitamin D	1,294
Middle-aged	885	Middle-aged	885
Aged	721	Aged	721
Respiratory tract infections	822	Respiratory tract infections	811
Dietary supplements	741	Dietary supplements	736
Vitamin D deficiency	746	Vitamin D deficiency	738
Vitamins	768	Animals	687
Animals	687	Child	641
Pandemics	660	Child, preschool	543

with the concept of self-medication—a common practice for managing minor respiratory conditions. Self-medication, when based on informed decisions and credible recommendations, can empower individuals to address minor ailments effectively and reduce the burden on healthcare systems. However, to harness potential benefits it is essential to ensure that self-medication practices are guided by accurate information to avoid potential risks, such as inappropriate use or interactions with other treatments.

X as a tool for conducting surveys on public health-related topics

X can be a useful platform for crowdsourcing ideas and surveying opinions on health-related topics due to its large user base, engagement features, and real-time feedback option (Choo et al., 2015). Additionally, use of X's hashtags allow users to easily search for and follow specific health-related topics, making it easier to identify ideas and opinions on health-related issues. Previous studies successfully used this social media for crowdsourcing ideas prospectively (running a particular campaign and collecting data prospectively) or retrospectively (collecting ideas from already available posts) (Alvaro et al., 2015; Goncalves & Sanchez, 2014; Harris et al., 2015; H. Mondal et al., 2022). The present study exemplifies the utility of prospectively surveying healthcare-related opinions from a large pool of social media users

However, it is essential to note that surveying opinions on X also has limitations, such as the fact that the collected ideas represent X users only and not the entire population. Therefore, it is essential to curate and analyze the ideas generated on X carefully (Khare et al., 2016). On the other side, the human communities are greatly influenced by mass media, which are characterized by the presence of confusing or conflicting health information. However, research on the influence of mass media as an information source on patient medication adherence is scarce (Im & Huh, 2017).

Vitamins

In the top twenty recommended supplements, we have found the individual vitamins D, C, and B-type vitamins, as well as multivitamins, to be popular among participated X users to combat respiratory infections. It is well-known that vitamin D plays a role in respiratory health and that its low levels are associated with an increased risk of respiratory infections (Anitua et al., 2022; Ganmaa et al., 2021; Hughes & Norton, 2009; Park et al., 2023). Studies have suggested that vitamin D supplementation may benefit populations with low vitamin D levels (Jolliffe et al., 2021; Martineau et al., 2019). Interestingly, vitamin D is the most highly endorsed supplement by the X users (Table 1), and the only specific supplement present in the keywords and MeSH terms of the identified publications on dietary supplements and respiratory tract infections (Table 2). Vitamin C, the third most endorsed supplement in our survey (Table 1), has been associated for long time with preventing and treating respiratory infections, and studies have shown that vitamin C supplementation can reduce the incidence and duration of respiratory infections (Holford et al., 2020; Uddin et al., 2021). However, overall, the evidence for vitamin C's effectiveness in preventing respiratory infections is mixed and needs further evaluation (Hemila, 2003). Other vitamins, such as type B vitamins, have also been suggested to play a role in preventing respiratory infections, although more research is needed to fully understand their impact (Vlieg-Boerstra et al., 2022). Many of the users informed us of their choice to use multivitamins. While the evidence for the role of vitamins in preventing respiratory infections is not always clear-cut, there is a growing recognition of their importance in maintaining overall immune health. Reflecting their importance, vitamin C (ascorbic acid) and vitamin D (colecalciferol, ergocalciferol) along with several other vitamins, have been included in the World Health Organization (WHO) Model List of Essential Medicines (22nd List, 2021) as remedies for respective vitamin deficiencies (Organization, 2021).

Minerals

Minerals are essential for supporting immune function and may help

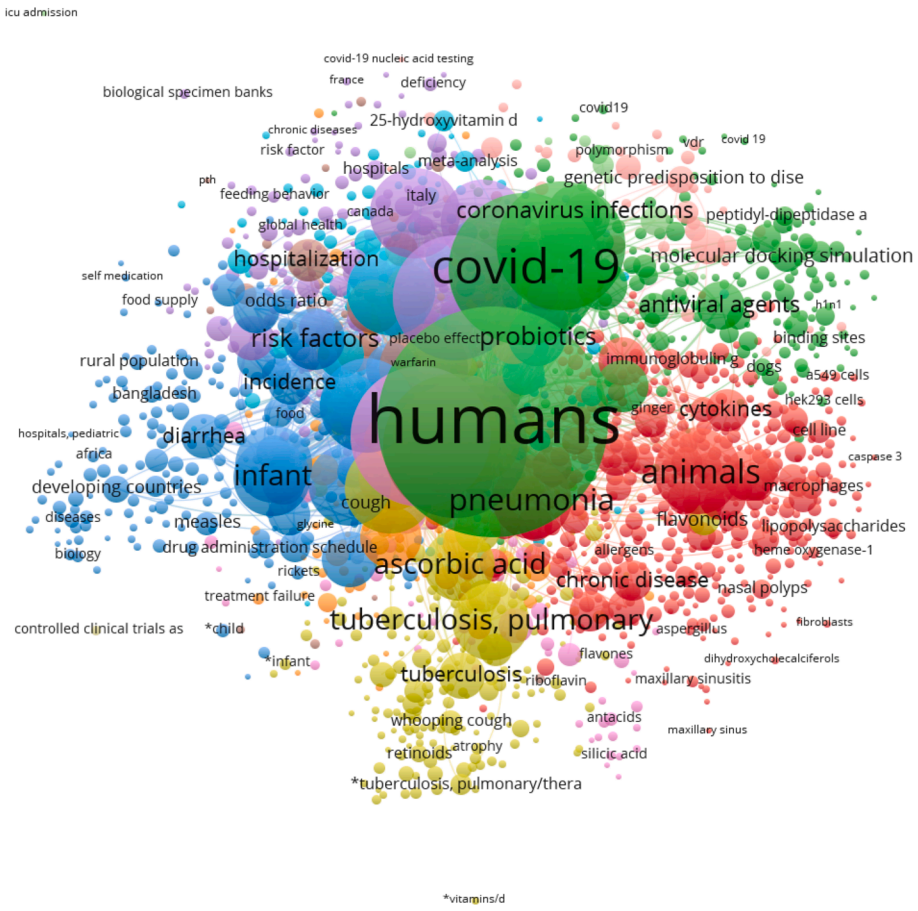

Fig. 4. Term map of the keywords of the identified publications on dietary supplements and respiratory infections based on the data obtained from PubMed on 11th June 2023.

prevent respiratory infections (Pecora et al., 2020; Weyh et al., 2022). Zinc, the second most endorsed supplement in our survey (Table 1), helps to regulate the immune system by supporting the development and function of immune cells (Gammoh & Rink, 2017; Maywald & Rink, 2022; Wessels et al., 2021). It also acts as an antioxidant, which helps to protect the body against harmful free radicals that can damage cells and weak the immune system (Jarosz et al., 2017; Prasad, 2014). Additionally, zinc has been shown to have antiviral properties, which may help to inhibit the replication of viruses causing respiratory infections. Studies have shown that zinc supplementation may reduce the incidence and severity of respiratory infections, including the common cold and pneumonia (Hunter et al., 2021; Luan et al., 2022; Maywald & Rink, 2022). Magnesium, the fourth most endorsed supplement in our survey (Table 1), is another essential mineral that helps maintain overall health, including supporting the immune system and preventing respiratory infections. It would also act as an anti-inflammatory agent, which may help to reduce inflammation in the respiratory system and prevent respiratory infections (Tang et al., 2020).

Functional foods, beverages, spices, medicinal plants, and formulations

In the past and before the discovery of medicines, traditional medicine people often used various herbs to treat diseases based on their experience (Goldman, 2001; Li & Weng, 2017). Research on various phytochemicals and functional foods and their ingredients is ongoing, but more discoveries are needed to realize their full potential for preventing or treating respiratory infections (Emran et al., 2024; Lim & Mohamed, 2016). Functional foods are more easily procurable by consumers than supplements (Eussen et al., 2011; Matin et al., 2024). In addition, various population groups traditionally believe that the use of homemade beverages and spices can be helpful as a support during respiratory infections treatment (Innocent et al., 2022; York et al., 2011). Honey, the eighth most recommended dietary supplement in our survey (Table 1), has been used for centuries as a natural remedy for various health conditions, including respiratory infections (Živanović et al., 2019). Honey has antimicrobial and anti-inflammatory properties, making it an effective aid for respiratory infections, such as coughs and colds (Mandal & Mandal, 2011). Additionally, honey has a soothing effect on the throat and can help to alleviate coughing and irritation. However, a special care should be taken for usage in small children and people with diabetes (Anibasa et al., 2022). Uptake of hot beverages is widely practiced for upper respiratory tract infections (Guppy et al., 2011). Green tea (ranked 11th by X users; Table 1), is rich in antioxidants, particularly catechins, which have been shown have potential antiviral and antibacterial properties (Rawangkan et al., 2021; Zhang et al., 2023). Ginger (*Zingiber officinale* Roscoe), the 6th most endorsed supplement in our survey (Table 1) has anti-inflammatory and antioxidant properties (Pagano et al., 2020), that may help to support immune function and prevent respiratory infections. It also has antibacterial properties that may be also helpful during infections (Chang et al., 2013). Another condiment i.e., garlic (ranked 8th; Table 1), contains compounds such as allicin that have potent antimicrobial properties. It may help prevent respiratory infections (Saastamoinen et al., 2019). Some X users also suggested mushrooms and some homemade tea combinations with various spices to be in their opinion effective in various respiratory infections. Mushrooms indeed have been reported to possess some antiviral and immunomodulatory properties and in the future have chance to be deeper examined in perspective to help fighting

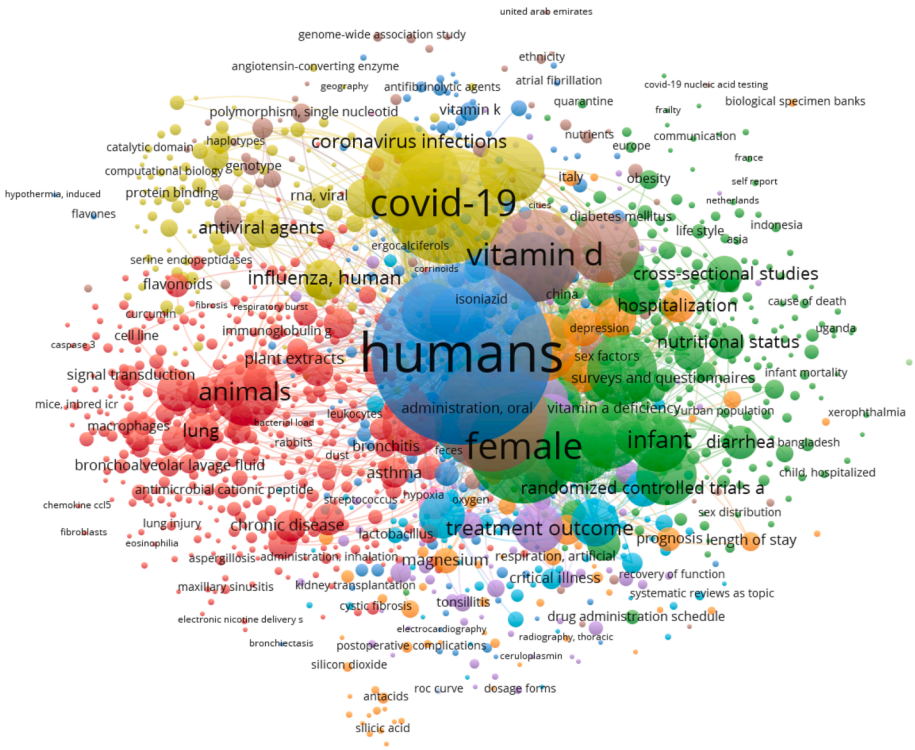

Fig. 5. MeSH key terms map for the identified publications related to dietary supplements and respiratory infections based on the data obtained from PubMed on 11th June 2023.

with infectious diseases (Arunachalam et al., 2022).

NAC, the 7th most endorsed supplement (Table 1), is a precursor to glutathione, a powerful antioxidant crucial in supporting the immune system and reducing inflammation in the respiratory tract. NAC has been shown to help loosen thin mucus in the airways, making it easier to cough up and clear (Sadowska et al., 2006). This can help to alleviate respiratory infection symptoms such as coughing and congestion. Additionally, NAC has been shown to have antiviral properties, which may help to inhibit the replication of viruses that cause respiratory infections (Calverley et al., 2020; Schloss et al., 2020; Zhang et al., 2018). Turmeric (*Curcuma longa* L.), the 9th most endorsed supplement (Table 1), is used as both a medicinal plant and a food component. It contains curcumin, a diarylheptanoid derivative compound, which particularly has both anti-inflammatory and immune-boosting properties. It may help prevent respiratory infections (Babaei et al., 2020; Dhar & Bhattacharjee, 2021; Thimmulappa et al., 2021). Another highly endorsed plant is elderberry (*Sambucus sp.*, Table 1; ranked 12th). It is a plant used for centuries as a natural remedy for various health conditions, including respiratory tract infections. Elderberry has been shown to have antiviral properties, particularly against certain strains of influenza viruses (Hawkins et al., 2019; Mocanu & Amariei, 2022; Pouramini & Asgary, 2022). It contains compounds that may help inhibit the entry of viruses into cells and prevent their replication. Some studies have suggested that elderberries can help reduce the severity and duration of symptoms in viral respiratory infections, such as the flu and the common cold (Krawitz et al., 2011; Mocanu & Amariei, 2022; Wieland et al., 2021). Elderberry may also have immune-boosting effects, although there is no evidence that it over-stimulates the immune system (Kiselova-Kaneva et al., 2023; Mahboubi, 2020; Schön et al., 2021; Wieland et al., 2021; Yuan et al., 2020). Probiotics (ranked 10th, Table 1) are currently researched for numerous benefits such as modifying specific cytokine levels in the bloodstream, enhancing the quality of life, and affecting the frequency and duration of respiratory infections (Cristofori et al., 2021). Such properties of probiotics that are currently under investigation might make them in the future a promising adjunct therapy in respiratory infection diseases such as COVID-19 (Darbandi et al., 2021; La Fata et al., 2017; Manna et al., 2020; Ozen et al., 2014; Zhao et al., 2022). Other recommendations by the X users are lemon (*Citrus limon* (L.) Osbeck), black seed oil (*Nigella sativa* L.), basil (*Ocimum* sp.), and pepper (*Piper nigrum* L.) (Table 1). These are natural remedies that have been traditionally used to treat respiratory tract infections. Lemon is rich in vitamin C, flavonoids and other antioxidants, which can help support the immune system and reduce inflammation (Chen et al., 2020; Merheb et al., 2019). Drinking lemon juice or adding it to hot water with honey can soothe a sore throat and relieve congestion (Lucas et al., 2020; Thaggard et al., 2023; Thota et al., 2020). Black seed oil is derived from the seeds of the *Nigella sativa* L. [Ranunculaceae] plant and has been used for centuries in traditional medicine. It has been found to have antibacterial, antiviral, and anti-inflammatory properties, which may make it helpful in counteracting respiratory infections (Al-Azzawi et al., 2020; Koshak et al., 2020; Kulyar et al., 2021; Mahboubi, 2018; Said et al., 2022). Basil is another herb with anti-inflammatory and antibacterial properties (Eftekhar et al., 2019; Takeuchi et al., 2020). It is treated and referred to as holy basil in many countries, like India, and is broadly used in households. It can be added to teas or soups and is considered a traditional folk remedy for diverse ailments (Aminian et al., 2022; Thota et al., 2020). Pepper, mainly black pepper, has been shown to have antimicrobial properties and may fight with infections (Butt et al., 2013; de Oliveira et al., 2022). It can also help break up mucus and improve coughing (Thota et al., 2020).

Limitations and future research directions

One significant limitation of X surveys is the sample representativeness. X users may not represent the general population, as they often tend to be younger, more educated, and more politically engaged (Mellon & Prosser, 2017). As a result, X-based studies may not accurately reflect the attitudes and behaviours of the wider population, and generalizations based on X data may not apply to other groups. Furthermore, X users may have opinions or interests that differ from the

wider population, which can be reflected in the study results (Guidi et al., 2021; Vicente, 2023). Additionally, X messages have a limited character count, which can lead to oversimplification during discussions of complex topics. Furthermore, recent changes in X due to its ownership change have led to modification of some regulations and practices, which might have implications for the replicability of the outcomes received from our work in future studies (Lordan & Devkota, 2023). X data may also, in general be subject to noise, such as interference from spam or fake accounts, which can negatively impact the validity of the study's results. To counteract the latter limitation, our study relied on manual screening and evaluation of all shared tweets. Another limitation that should be mentioned that while the survey collected international data, was conducted using an English-language survey question. Querying X users with survey questions posted in other languages might provide further insights reflecting different views and experiences. Since X posts are publicly visible, a factor that might peer pressure effects influencing responses should also be considered (with users potentially more likely to give comments that conform to the views of their peers and their online communities). Last but not least, taking into account the need of scientific substantiation of effectiveness of interventions targeting respiratory infections, surveys of experiences in general have constrains related to influencing factors such as cultural traditions or personal believes that can result in placebo effects (Finniss et al., 2010). NLP related sentiment classifier such as NLTK VADER can misclassify sentiments due to not being domain-specific. While NLP techniques offer an interesting direction for large data analysis tasks, they warrant developing and benchmarking supervised, self-learning, and deep learning domain-specific sentiment classifiers for highest accuracies. In respect to the potential effectiveness of the recommended supplements, this study is limited by the self-reported nature of data, lack of demographic and clinical variables, potential response bias, and the representativeness of the X user base. The findings should be interpreted as exploratory and hypothesis-generating rather than definitive.

Taking into consideration that the study's reliance on self-reported data from X limits the ability to account for critical demographic and clinical factors, such as participants' age, health status, or duration of supplement use, future studies could integrate more detailed survey questions or combine social media data with traditional epidemiological methods to address these gaps. Thus, despite the outlined limitations, the findings highlight emerging trends and public perceptions, offering a foundation for more rigorous follow-up studies.

Conclusion

The X survey conducted in this study yielded valuable insights into the utilization and perceptions of nutritional supplements and home remedies in combating respiratory infections. This novel approach complements traditional survey methods and provides a unique perspective on public opinions and behaviours. The substantial engagement observed in response to the open-ended question and poll indicated a notable level of interest in the subject matter. The identification of common themes and sentiment analysis provide a nuanced understanding of the public discourse. Findings demonstrated that a significant proportion of individuals worldwide employ or recommend various vitamins, minerals, food components, teas (with or without specific additives), herbs, and other home remedies to counteract respiratory infections. The poll component of the study revealed that slightly over half of the respondents employ nutritional supplements for this purpose. These findings have implications for healthcare professionals, policymakers, and the development of evidence-based recommendations to prevent respiratory infections. Additionally, they can inform the creation of future public health messaging and campaigns aimed at enhancing respiratory health. Further research is warranted to assess the safety and efficacy of the frequently utilized supplements and home remedies in combating respiratory infections. While this study highlights the potential of social media platforms for gathering health-related insights, it is exploratory in nature and future research should also integrate more robust methodologies to address limitations and provide a comprehensive understanding of public health behaviors.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Authors A.G. Atanasov, Dongdong Wang, Maurizio Battino, Anupam Bishayee, Alejandro Cifuentes, Thomas Efferth, Ilkay Erdogan Orhan, Michael Heinrich, and Gian Luigi Russo are Editorial Board Members of Current Research in Biotechnology but did not participate in the editorial handling and did not have information for the peer-review process of this work].

Data availability

Data will be made available on request.

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