



Research article

Discussion of waterpipe tobacco smoking on reddit

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ABSTRACT

Objectives: This study aimed to examine public discussions of waterpipe tobacco smoking, as well as the potential associations of different waterpipe flavors with health symptoms, using Reddit data.**Study design:** This is an observational infodemiology study.**Methods:** Using keywords such as “waterpipe”, “hookah”, and “shisha”, Reddit posts were extracted from Reddit Archive (pushshift.io) between February 1, 2016, and December 31, 2020. Temporal analysis was used to understand the longitudinal trend of the discussions about waterpipe tobacco smoking. Topic modeling using the Latent Dirichlet Allocation (LDA) model was performed to examine the topics on waterpipe tobacco. We estimated the conditional probability of having each health problem for each given waterpipe flavor.**Results:** The discussion of waterpipe on Reddit was slowly decreasing from 2016 to 2018 and surged until May 2020. The fruit was the most popular waterpipe flavor and the neurological symptom was the most mentioned health category in waterpipe-related Reddit posts. The most popular topics included “Friends spending time together at night with waterpipe smoking”, “Playing games and smoking waterpipe at a hookah bar”, and “Discussing waterpipe flavors and related products”. Some waterpipe flavors were more associated with certain health problems than others. For example, mint/menthol flavor had a high probability to be associated with symptoms related to throat and mouth.**Conclusion:** This study provided longitudinal surveillance of waterpipe tobacco smoking discussed on Reddit. We showed the potential relationship between waterpipe flavors and health symptoms, which provides preliminary evidence about the potential health effects of waterpipe tobacco smoking.

1. Introduction

Waterpipe tobacco smoking (WTS) is a traditional way of smoking that originated in India [1]. It is also known as hookah, shisha, narghile, argileh, and hubble-bubble. The waterpipe apparatus has many configurations but most commonly, it consists of a bowl, a pipe, a water jar, and a saucer that holds the ashes [2]. When in use, shisha tobacco is heated by the charcoal placed above the bowl and the smoke comes down from the holes at the bottom of the head and passes through the pipe of the apparatus to be cooled and humidified by the water in the water jar. The smoker then inhales the smoke from the hose.

WTS has gained its prevalence across the world especially among the young population [2]. In 2017, it is estimated that there were 2.6 million adults WTS users in the US [3], and 4.1% of high school students, as well as 1.2% of middle school students, have used WTS in the past month [4]. Youths are found to have more risk for WTS. A study on Iran high school

students found that 6.0% of the students were WTS users at least once a month and 44.9% of the students have tried WTS [5]. In the US, a survey conducted in 2014 and 2015 showed that college students are more likely to start WTS, and misperception of the harm of WTS was found especially in young population and never smokers [6]. Studies have shown that flavors are one of the major reasons for young people to smoke waterpipe tobaccos [7, 8], and social influence is the other one [9]. The fruit flavor is the preferred flavor among waterpipe tobacco users, and females are found to be more inclined to consume flavored waterpipe products than males [10]. Other commonly seen flavors for waterpipe include sweets, alcohol, and other beverages [2].

The health effects of WTS are often neglected and misperceived by the public. Same as traditional tobacco products, waterpipe tobacco contains nicotine that can be addictive [11]. In addition, the unique way of heating tobacco with charcoal increases the risk of carbon monoxide poisoning. Since the mouthpiece is often shared during the smoking

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session, the spread of infectious disease can be another problem [12]. Flavored waterpipe products can pose different health risks. It has been shown that the melon honeydew flavor had the highest rate of radon gas concentration, while the natural mint flavor had the lowest [13]. Potential health problems related to WTS include cancer, respiratory illness, and periodontal disease [14]. Waterpipe tobacco users have a higher risk of lung cancer and ever using waterpipe tobacco was associated with two-fold risk of lung cancer than tobacco abstainers [15]. Children exposed to waterpipe tobacco or traditional tobacco were 2.3 times more likely to have respiratory diseases than the non-exposed ones [16].

Infodemiology is a science of utilizing online information to inform public health and health policy [17]. Social media has become a common platform where many substance users share their related experiences [18]. Many studies have used social media data to study the usage of waterpipe tobacco and its health risks [19, 20]. A study on Instagram posts related to waterpipe tobacco showed that WTS is associated with night social activities [21]. A semiotic analysis of Twitter data showed that 59% of the tweets about WTS are positive, while only 3% of them are negative with the concern of health risk [20].

In the past decade, Reddit has grown from a small community to one of the most popular social media platforms in the world, and it now has over 52 million daily users who actively post, comment, and vote on the platform. There are more than 100 thousand communities called subreddit, where people with the same interest connect and discuss with each other [22, 23]. Reddit posts usually contain self-reporting user experience and are therefore often used to study people's true experiences and perceptions of various things including tobacco products [24]. Using a *Reddit dataset*, researchers identified the potential association between flavored e-cigarettes and health symptoms [25]. Similarly, a study on JUUL usage using Reddit posts showed that interventions on youth usage such as age restrictions could instead foster youth use [26]. While WTS is widely discussed on Reddit, little study has been done to study WTS using Reddit posts.

In this study, we aimed to provide surveillance on WTS discussions on Reddit by analyzing the trend of WTS discussions. We examined potential associations between different waterpipe tobacco flavors and health symptoms. Our study provides valuable insights into the popularity and potential health problems of WTS.

2. Methods

2.1. Data collection

From Reddit Archive (pushshift.io), we downloaded Reddit posts from February 01, 2016, and December 31, 2020. To obtain the Reddit posts related to waterpipe, a set of keywords were constructed from previous studies [20, 27], including waterpipe, WATERPIPE, Hookah, Shisha, Narghile, Argileh, hubble-bubble, goza, borry, qaylan, chica, mada's, mouassal, jurak, tumbak, hooka, sheesha, and hubblebubble.

To ensure that all the posts are related to waterpipe, the Reddit posts were further filtered to denoise the data. For example, the keyword "shisha" is a common way to refer to waterpipe, while combined with the word "octane", it refers to a car in an xbox game. We developed a rule that eliminated posts that contain keywords "octane", "ps4", and "xbox" so that only the related Reddit posts were kept. Furthermore, we removed promotion posts using keywords such as "sale", "promotion", and "percent off" in the Reddit posts as well as posts with *Reddit usernames* containing "dealer", "waterpipe", and "shisha".

2.2. Waterpipe flavors and potential health symptoms

We have created a flavor and brand dataset for most of the waterpipe tobacco brands on the market (Supplemental Table 1). For each brand, we manually obtained the names of their products and the flavors of the products. Each product's flavor was classified into specific flavor, middle and large flavor categories based on previous e-cigarette flavor

classification methods [28, 29]. The nine large flavor categories include 'mint/menthol', 'fruit', 'mixed', 'beverage', 'sweets', 'tobacco', 'spice', 'alcohol' and 'other'. This dataset was used to obtain waterpipe flavors mentioned in the Reddit posts. We conducted separate filtering for tobacco flavors. Since the word "tobacco" often refers to traditional tobacco products, a filter was designed such that only posts including flavor keywords (e.g., flavor, flavours) and "tobacco" are considered to have tobacco flavor. The tobacco flavor subset was combined with other flavors to construct the flavor subset.

A health symptom dataset was generated to investigate the health problems co-mentioned with waterpipe smoking. The health keyword list included 144 health keywords and eight health categories (neurological, psychological, respiratory, mouth, cardiovascular, throat, digestive, and cancer) used in a previous study on the e-cigarette [25].

We further studied the potential associations between flavors and health problems using the health-flavor subset, which includes posts mentioning only one flavor and health symptoms. For each flavor category, we calculated the conditional possibilities of mentioning health problems for a given flavor category. To obtain the conditional probabilities, we divided the number of posts that mentioned both the health problem and the flavor category by the number of all posts that mentioned the flavor category. The resulting conditional probabilities showed the likelihood of co-mentioning a certain waterpipe tobacco flavor with health symptoms.

Temporal analysis was conducted to show the longitudinal trend of Reddit posts related to waterpipe, the mentions of each flavor category, and health symptoms. The number of related posts in each month from February 2016 to December 2020 was calculated. A trend of each flavor, as well as health symptom category, were shown in percentage for the number of total posts in each month.

2.3. Topic modeling

Topic Modeling using the Latent Dirichlet Allocation (LDA) model was utilized to identify common topics that appear in the Reddit posts of waterpipe tobacco. LDA model is commonly used to find topics in social media platforms including Reddit [25] and Twitter [30]. LDA is a generative statistical model that was applied in machine learning to discover topics in documents. The model regards the document as a distribution of the number of topics and the topics as distributions of words. LDA can be regarded as a three-layer Bayesian model, which gives the probabilities of different words appearing in each topic, where the words, in turn, define the topics. Bigram and trigrams that appears more than five times in the corpus were constructed before training the model so that the vocabulary was enriched. Sentences are transformed to lowercase letters and words and are lemmatized using the spaCy software [31]. To further clean the corpus, we removed stop words (e.g., the, are, you) using the Natural Language Toolkit. The optimal number of topics was chosen based on the maximum coherence score.

3. Results

3.1. Waterpipe related reddit posts

Using the set of waterpipe keywords, we extracted 85,694 waterpipe-related Reddit posts. Further cleaning resulted in 26,449 waterpipe-related Reddit posts, among which 16,968 non-promotion posts were left for further data analyses (Supplemental Figure 1). Using our flavor and brand dataset, we found 6,701 Reddit posts that mentioned at least one flavored product, while 2,173 of them mentioned only one flavor. A health subset containing 1,259 Reddit posts was generated by filtering the waterpipe-related Reddit posts. In addition, a health-flavor subset (containing 257 Reddit posts that co-mention both health symptoms and waterpipe tobacco flavor) was generated by filtering the 2,173 Reddit posts mentioning only one flavor.

3.2. Discussions of waterpipe on reddit over time

To examine the overall trend of waterpipe tobacco discussed on Reddit, we plotted the number of waterpipe-related posts over time (Figure 1). The result showed that the popularity of the waterpipe tobacco discussion on Reddit decreased from 2016 to 2018, and then increased gradually. The discussion of waterpipe peaked at the beginning of 2020 but dropped significantly at the end of 2020.

3.3. Waterpipe flavors mentioned on reddit

To understand the popularity of different waterpipe flavors mentioned on Reddit, we grouped the waterpipe flavors into nine flavor categories and showed their popularity by counting the number of Reddit posts mentioning these flavors. The percentage of posts with each flavor category in all flavor-related posts was shown in the bar chart (Figure 2). We showed that the most frequently mentioned waterpipe flavor was fruit (3035/6701, 45.29%), followed by mint/menthol (662/6701, 9.88%), beverage (647/6701, 9.66%), sweets (621/6701, 9.27%), mixed (527/6701, 7.86%), tobacco (470/6701, 7.01%), spice (233/6701, 3.48%), alcohol (119/6701, 1.78%), and other (387/6701, 5.78%). Despite some variation over time, the fruit flavor remained the most popular flavor over the whole study period while other flavors remained low (Supplemental Figure 2).

3.4. Health symptoms mentioned in waterpipe-related reddit posts

To examine which health symptoms were more likely to be mentioned in waterpipe-related Reddit posts, we grouped the 144 health symptoms into eight categories. Figure 3 showed the percentage of posts mentioning each health category in all health-related posts. In waterpipe-related posts, the most frequently mentioned health category was neurological (319/1259, 25.34%), followed by psychological (214/1259, 17.00%), mouth (202/1259, 11.76%), cardiovascular (145/1259, 11.52%), throat (120/1259, 9.53%), digestive (66/1259, 5.24%). The least mentioned health category was cancer (45/1259, 3.57%).

The longitudinal trends for all eight health symptom categories showed that the most mentioned health category was neurological during the study period (Supplemental Figure 3). The number of posts for each health category fluctuated over time. It is noticeable that the mention of cardiovascular health problems has a peak in January 2019.

3.5. Topics discussed in waterpipe-related reddit posts

To identify topics discussed on Reddit about waterpipe tobacco, topic modeling was performed on the waterpipe-related Reddit posts using the LDA method. We chose three topics as the optimal number of topics since they gave the highest coherence score. As shown in Table 1, the common topics identified in waterpipe-related Reddit posts included “Friends spending time together at night with waterpipe smoking” (40.80%),

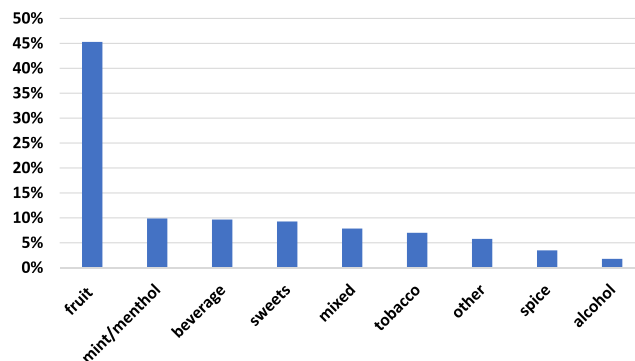


Figure 2. Flavor categories for waterpipe mentioned in Reddit posts.

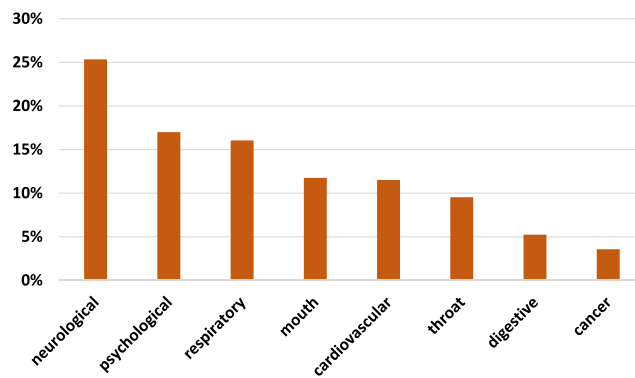


Figure 3. Top health symptoms mentioned in waterpipe-related Reddit posts.

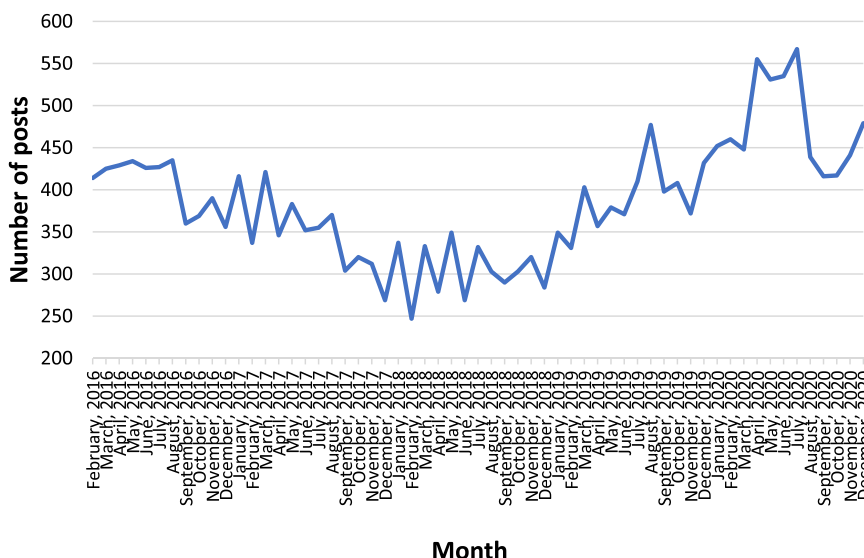


Figure 1. Longitudinal trend of Reddit posts related to waterpipe tobacco.

Table 1. Topics discussed in waterpipe-related Reddit posts.

Topic	Percentage of Tokens	Keywords	Examples
Friends spending time together at night with waterpipe smoking	40.80%	time, feel, friend, day, start, make, thing, back, year, good, night	<ol style="list-style-type: none"> 1. Long nights at my parents' house with laughter, hookah, and coffee are my favorite 2. ... An electronic Shisha passed around And an umbrella in your hand ... and I ask myself what could have been If we'd never said goodbye that day. 3. I'm a 22Yo guy. Had a tiring week so looking for a good time this weekend. Hookah and interesting conversations is a great combo ... 4. Any good places in Minneapolis that play good music and have couches where you can just chill and smoke hookah with people?? 5. ... I've been to hookah lounges before, but it was always with friends and that's when I lived in a city where I had friends. So how can I make friends at a hookah lounge? What should I do or say? How do I meet people?
Playing games and smoking waterpipe at a hookah bar	32.40%	make, bar, people, game, find, play, place, good, post, waterpipe, high	<ol style="list-style-type: none"> 1. ... Beers and thai food, first time trying hookah and played a couple rounds of Killer... 2. ... Topeka Hookah House is hosting their first ever trivia night tonight. BYOB smoke shop and lounge with food, drinks, and great place to relax and smoke or vape... 3. ...hookah and drink and drunk uno tonight who down single females and couples are welcome 4. I currently have a generic hookah with a rotating base. We set it in the middle of the table during our tabletop games and pass the pipe around. It's much more manageable than a normal stationary hookah since we never have to worry about the hose wrapping or the pipe getting pulled over... 5. So I just played my first few games of chess. Went to a hookah bar with few friends and got smashed...
Discussing waterpipe flavors and related products	26.80%	hookah, smoke, shisha, bowl, good, tobacco, buy, flavor, coal, smoking, pipe	<ol style="list-style-type: none"> 1. ... Me and some friends are planning to buy a nice hookah for a friends birthday party. I've been told khalil moon is a nice hookah brand, which got me stranded here, not really sure which one to choose and what the differences are. Came here hoping someone would be able to shed some light on that... 2. Looking for a good mint that cools. What is everyone's opinion on these two? Or even other brands for someone who just started smoking hookah 3. I have been using a cheap heat manager from amazon with naarcoal, all AF or tangiers shisha and it just burns or loses flavor so fast. Back on foil right now and it's better. What are your recommendations for heat mgmt and coal? 4. I've been smoking Al Fahker for quite awhile and my two favorite flavors are Golden Double Apple and Fresh. They've always been great quality and have smoked amazingly. Flavors would last for a couple of hours...So my question for you guys would be is there anything I may be doing wrong or did I get unlucky with my most recent batch? 5. So thought I would give this flavor a shot. It's ok. Strong chocolate taste and a hint of mint in it. <i>I didn't</i> like it. I wish Tangiers would make smaller sample size so I can try different flavors without wasting all that shisha

“Playing games and smoking waterpipe at a hookah bar” (32.40%), and “Discussing waterpipe flavors as well as related products” (26.80%).

3.6. Co-mentioning of waterpipe flavors with health symptoms

To understand if any health symptoms might be more associated with a certain waterpipe flavor, we calculated the conditional probability of mentioning each health category given a certain waterpipe tobacco flavor (Figure 4). The mint/menthol flavor was more likely to be co-mentioned with throat and mouth problems. The beverage was more likely to be co-mentioned with throat and psychological problems. Sweets were more likely to be co-mentioned with respiratory and mouth problems. Tobacco flavor was more likely to be co-mentioned with respiratory and neurological problems. Spice flavor was more likely to be co-mentioned with neurological and digestive problems. Alcohol flavor was more likely to be co-mentioned with respiratory problems.

4. Discussion

Through examining the flavors mentioned in the Reddit posts related to waterpipe, we showed that fruit was the most popular flavor category, followed by mint/menthol, beverage, and sweets. Neurological health symptoms seemed to be the most frequently mentioned health symptoms in the Reddit posts related to waterpipe tobacco. Waterpipe tobacco

smoking was popular in social activities indicated by the top topics discussed on Reddit such as friends spending time together during the night to play games and smoking waterpipe tobacco in a hookah bar. The conditional probabilities of co-mentioning each health category given a certain waterpipe tobacco flavor indicated different associations of waterpipe tobacco flavors with health symptoms.

By analyzing the trend of waterpipe tobacco mentioned on Reddit, we showed that the popularity of WTS decreased from 2016 to 2018 and started to gradually increase afterwards. It had been reported that there were 1.2% of adult waterpipe smokers in the US in 2015, while the number dropped to 1% when the survey was conducted again in 2017 [3, 32], which is aligned with the trend observed in our study. One explanation for this decrease in waterpipe tobacco use over time could be the changes in public perceptions of tobacco products in general, as the uses of traditional cigarettes and e-cigarettes were also dropping during this time period [3]. In our study, we observed that the mentions of WTS had an obvious increase since March 2020 when the COVID-19 pandemic was declared by World Health Organization (WHO) [33]. The increased discussions might be related to the restrictions on social gathering as socialization is one of the major motivations for WTS.

In this study, fruit flavor was identified as the most frequently mentioned waterpipe flavor on Reddit. In a 2009 survey on the favorite waterpipe flavors in the San Diego area, the mint flavor was the most commonly chosen flavor, closely followed by a combination of fruit

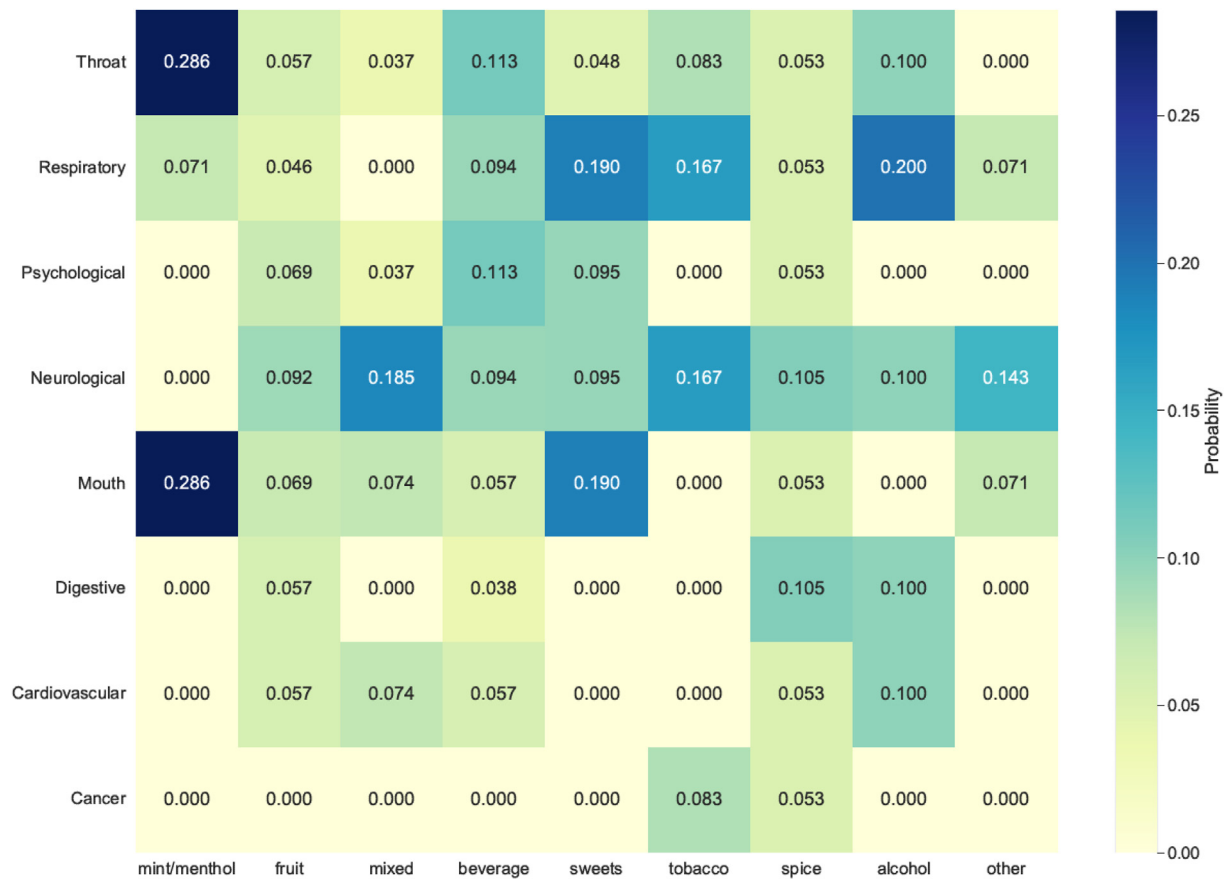


Figure 4. Conditional probability of co-mentioning waterpipe flavors with health categories.

flavors [34]. Another study conducted in 2018 showed that 82% of women waterpipe tobacco smokers preferred sweet flavors, such as fruit and sweets, over other flavors and unflavored tobacco [35]. The discrepancy between the previous study and our study might be due to the evolving trend of WTS and differences in the demographics of waterpipe tobacco smokers. Similar studies had been conducted on e-cigarette flavors using Reddit posts [29]. The results showed that the most popular flavors in e-cigarettes were fruit, sweets, beverage, and menthol or mint, which were the same as the four most popular flavors in waterpipe tobacco observed in this study.

Our study showed that the most mentioned health symptom category in waterpipe-related Reddit posts was neurological, followed by psychological, mouth, cardiovascular, and throat. A previous study suggested that the amount of carbon monoxide inhaled in waterpipe smoking activities was ten times as high as that for traditional tobacco smokers, which could result in carbon monoxide intoxication leading to nonspecific neurological manifestations [36]. Other studies also pointed out the risk of carbon monoxide when using hookah [37, 38, 39], providing a possible explanation for the prominent neurological problems observed in the Reddit posts.

In our study, we showed the potential associations between waterpipe flavor categories and health symptoms. Different flavors of waterpipe tobacco were likely to be associated with different health symptoms. One study showed that 79 types of volatile flavor compounds were identified in waterpipe tobacco, among which fragrance benzyl alcohol, limonene, linalool, and eugenol are known to be allergenic to human skin [40]. For e-cigarettes, throat problems have a high association with mint/menthol flavor [25]. This study showed that mint/menthol has the highest association with throat and mouth problems for waterpipe tobacco smoking, which is like that in e-cigarettes.

Infodemiology studies make use of data on the Internet to do health informatics research, and enable easy access to large volume of data [41].

In this study, we analyzed a large amount of Reddit posts that contains flavor and health information. The large amount of infodemiology data provide us a more rapidly and cheaper way to examine the health-related discussions of waterpipe tobacco use than survey data. We are aware that the infodemiology data contains a mixture of accurate and inaccurate health information, which is hard to be separated in social media data analyses and is a limitation of the infodemiology studies. Results from our study can be utilized to educate the health risk of waterpipe tobacco smoking through Reddit and other social media platforms, as social media could send wide and rapid messages to the target audience [42].

There are several limitations to our current study. First, the publicly available Reddit posts do not include Reddit users' demographic information (such as age, gender, and race/ethnicity), thus we were unable to examine the demographic differences in Reddit users who discussed waterpipe tobacco smoking. Second, waterpipe bands, products, and flavors we collected in this study are rather incomplete, and some yet-to-be-identified health symptoms associated with waterpipe tobacco smoking are not included in our study, which might introduce some biases. Third, the flavor categories and health symptoms mentioned by the Reddit users might not be the waterpipe tobacco flavor categories they were using and health symptoms they had. Fourth, the co-mentioning of waterpipe tobacco flavor categories and health symptoms does not reflect the causal effect, which only indicated potential associations. Lastly, our findings in this study might not be generalized to the general population.

5. Conclusions

Our study provided important information on longitudinal discussions about WTS on Reddit and shed light on popular waterpipe flavors mentioned and potential health symptoms related to waterpipe tobacco smoking, which provide useful guidance for future research on investigating potential health effects of flavored waterpipe tobacco smoking.

Declarations

Author contribution statement

Zihe Zheng: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Zidian Xie: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Dongmei Li: Conceived and designed the experiments; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

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