Potential impact of a COVID-19 and smoking paper on Twitter users' attitudes toward smoking: Observational Study

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Potential impact of a COVID-19 and smoking paper on Twitter users' attitudes toward smoking: Observational Study

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Abstract

Background: A cross-sectional study conducted by French researchers showed that the rate of current daily smoking was significantly lower in COVID-19 patients than in the French general population.

Objective: We aim to examine the dissemination of this French study among Twitter users and whether a shift in their attitudes towards smoking occurred after its publication on April 21st, 2020.

Methods: Twitter posts were crawled between April 14th and May 4th, 2020 by the Tweepy stream API, using a COVID-19 related keyword query. After filtering, the final 1,929 tweets were classified into three groups: 1) tweets not related to French study before it was published; 2) tweets not related to French study after it was published; 3) tweets related to French study after it was published. The tweets' attitudes towards smoking were compared among the above three groups using multinomial logistic regression models in statistical analysis software R.

Results: The temporal analysis showed a peak in the number of tweets discussing the results from the French study right after its publication. Multinomial logistic regression models on sentiment scores showed the proportion of negative attitudes toward smoking in tweets related to French study after it was published (17.07%) was significantly lower than tweets not related to the French study either before (34.92%, $P < 0.001$) or after the French study was published (34.34%, $P < 0.001$).

Conclusions: The public's attitude toward smoking shifted in a positive direction after the French study found a lower incidence of COVID-19 cases in daily smokers.

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Potential impact of a COVID-19 and smoking paper on Twitter users' attitudes toward smoking: Observational Study

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ABSTRACT

Background: A cross-sectional study conducted by French researchers showed that the rate of current daily smoking was significantly lower in COVID-19 patients than in the French general

population.

Objective: We aim to examine the dissemination of this Miyara et al. study among Twitter users and whether a shift in their attitudes towards smoking occurred after its publication on April 21st, 2020.

Methods: Twitter posts were crawled between April 14th and May 4th, 2020 by the Tweepy stream API, using a COVID-19 related keyword query. After filtering, the final 1,929 tweets were classified into three groups: 1) tweets not related to Miyara et al. study before it was published; 2) tweets not related to Miyara et al. study after it was published; 3) tweets related to Miyara et al. study after it was published. The tweets' attitudes towards smoking were compared among the above three groups using multinomial logistic regression models in statistical analysis software R.

Results: The temporal analysis showed a peak in the number of tweets discussing the results from the Miyara et al. study right after its publication. Multinomial logistic regression models on sentiment scores showed the proportion of negative attitudes toward smoking in tweets related to Miyara et al. study after it was published (17.07%) was significantly lower than tweets not related to the Miyara et al. study either before (34.92%, $P < 0.001$) or after the Miyara et al. study was published (34.34%, $P < 0.001$).

Conclusions: The public's attitude toward smoking shifted in a positive direction after the Miyara et al. study found a lower incidence of COVID-19 cases in daily smokers.

INTRODUCTION

Background

COVID-19 is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1], and given that it is mainly a disease of the respiratory tract, researchers have investigated whether cigarette smokers or vapers are at higher risk of SARS-CoV-2 infection, worse COVID-19 disease severity, clinical outcomes, or mortality. Although most literature shows that smoking worsens

COVID-19, there is seemingly paradoxical evidence regarding this association. Smoking history appears to increase the risk of severe disease in hospitalized patients, particularly among younger patients without diabetes [2]. An increased risk of mortality has also been shown among current smokers [3]. On the other hand, the SARS-CoV-2 binds the angiotensin-converting-enzyme 2 receptor (ACE2R). While it is unclear whether smoking increases the level of ACE2R expression in the respiratory tract, nicotine may also compete with SARS-CoV-2 for binding of the nicotinic acetylcholine receptor (nACfR) [4]. The interrelationship among smoking, nicotine, SARS-CoV-2, and COVID-19 is an active and evolving area of research, where new studies emerge regularly.

Researchers in France conducted a cross-sectional study on COVID-19 infected patients in a large French university hospital, placed on a preprint server on April 21st, 2020 [5]. The results showed that the rate of current daily smokers was significantly lower in COVID-19 outpatients and inpatients (6.1% and 4.1%, respectively) as compared to that in the French general population, after standardization by age and sex [5] which was estimated as between 22.4% and 26.9% [6]. The authors concluded that their results suggest that active smokers may be protected against symptomatic COVID-19 [5]. However, they did note that healthcare workers were over-represented in the outpatient group, patients in intensive care units were excluded, smoking status may have been under or over-reported, smoking status was assessed only in symptomatic COVID-19 patients (even though many infected individuals are asymptomatic), and the association found does not imply causality [5]. Furthermore, the authors of this paper emphasized that nicotine and the nicotinic receptor were of interest and acknowledged the negative consequences of smoking cigarettes [5]. A follow up report suggested studying nicotine patches as a preventative option against COVID-19 [7]. Despite the limitations being noted in the paper, the title and nature of the main results could mislead the general public, who typically attend to headline findings and not caveats. This study on COVID-19 incidence among smokers was published in Qieos, an open science publishing platform, in May 2020. The article metrics on Qieos demonstrate that the paper was mentioned by one news outlet and

mentioned directly by 126 tweets (8% of which were in the United States), which has a top 5% attention score measured by Altmetric.

Twitter, a 'microblogging' platform [8], can contribute to scientific knowledge dissemination and translation [9]. Throughout the COVID-19 pandemic, Twitter has served as a platform for users to express their opinions, share information, and receive information from others -- over 63 million English tweets worldwide used COVID-19 related keywords from January to July 2020 [10]. With the evidence arising from the Miyara et al. study regarding the relationship between smoking and the novel coronavirus, conversations on Twitter about the study may provide an interesting case study in the transmission of potentially controversial or contrarian findings.

Objective

A previous Twitter study on COVID-19 and smoking (the only other Twitter analysis on this topic, to our knowledge) showed that preprints suggesting the benefits of smoking might increase reactions to tweets on tobacco products and the virus [11]. During this pandemic, people may be looking for something they can do to lower their risk. Methods for reducing the spread of the virus (such as using masks and quarantine) and discussion of fear/stress due to the lack of preventative options were found to be popular topics among Twitter users [12]. There is a possibility that those looking for a preventative action against COVID-19 could use the Miyara et al. study as a rationale to take up smoking (or vaping), or delay quitting. This paper presents a novel view of the change in sentiment towards smoking *before and after a specific paper was published* suggesting that the incidence of COVID-19 was lower among smokers compared to the general population. In this report, we aim to examine the spread of the Miyara et al. study among Twitter users, attitudes towards the study, attitudes toward smoking, and whether there was a shift in sentiment towards smoking/nicotine after April 21st, 2020.

METHODS

Data Collection and Preprocessing

The related tweets (Twitter posts) were crawled during April 14th, 2020 to May 4th, 2020 by the Tweepy stream API using keyword query with the COVID-19 related keywords, including "CORONA", "corona", "COVID19", "covid19", "covid", "coronavirus", "Coronavirus", "CoronaVirus", and "NCOV". The analysis period was chosen due to the nature of our study objective. Because we were interested in the change in sentiment before and after publication of the paper, we analyzed tweets immediately before and after the day it was published. Next, retweets without comments were deleted, since simple retweets typically do not explicitly reflect personal opinions (the behavior of retweeting can mean supportive, oppositional or neutral attitude towards the original tweet). Repetitive tweets were also removed from the collected dataset as the majority were copied news headlines without personal sentiments. Afterwards, research and tobacco related tweets were filtered out in sequence using keyword matching (we first filtered research related tweets using "study" and "research" and then tobacco related tweets were filtered using "smok", "cigarette", "tobacco", "nicotine", and "ace2"). Tweets discussing studies without clear findings were removed as those having no impact in shifting people's opinions. Finally, 1,929 tobacco and research related tweets remained and discussed, in some way, the effects of smoking on COVID-19 infections and symptom developments. Figure 1 showed the data preprocessing procedures for obtaining our final data set of 1,929 tweets.

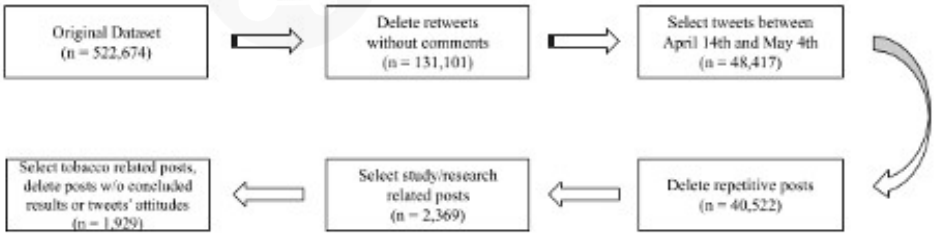

Figure 1: Dataset preparation procedures.

Sentiment Analysis

Three categories were used to categorize each tweet: about the Miyara et al. study (yes/no), articles attitude towards smoking (positive, negative, neutral), and users' attitudes towards smoking expressed in the tweet (positive, negative, neutral). For the first category, whether or not each tweet was related to the published Miyara et al. study was manually coded for all the selected tweets. For the second category, the article's attitude towards smoking discussed in the tweet was manually coded as positive, neutral, or negative. For example, if the tweet discussed an article that found smokers were at more risk for COVID-19, it was considered negative. For the third category, each tweet was manually coded as positive, neutral, or negative based on its attitude toward smoking. For example, if the user said 'smoking is bad for you', the tweet was categorized as negative. The term 'smoking' referred to in this category was not necessarily used in regards to cigarettes and could refer to the use of other tobacco products.

Two coders from the study team coded each tweet separately and disagreements were discussed among team members to achieve final agreements. High agreements were achieved between the two independent coders on coding the 1,931 selected tweets into different categories. The Cohen's Kappa statistics value was 0.92 (95% CI: 0.90 - 0.94) for categorizing whether the tweet discussed the French study. For the article's attitude toward smoking, the Cohen's Kappa statistics was 0.93 (95% CI: 0.92 - 0.95) for categorizing the attitude to positive, neutral, and negative groups, indicating very high agreement. The Cohen's Kappa statistics was also very high for the tweet's attitude toward smoking including positive, neutral, and negative attitudes groups, with almost perfect agreement (Kappa = 0.86, 95% CI: 0.85 - 0.88).

Statistical Analysis

According to whether the tweet was related to the Miyara et al. study and whether the tweet was posted before or after the publication date of the Miyara et al. study (April 21st, 2020), all selected tweets were classified into three groups: 1) tweets not related to the Miyara et al. study, before

publication; 2) tweets not related to the Miyara et al. study after it was published; 3) tweets related to the Miyara et al. study after publication. The tweets' attitudes towards smoking and the article attitudes towards smoking were compared among the above three groups using multinomial logistic regression models through the *multinom* function in the *nnet* package in the statistical analysis software, R. The significance level of all two-sided tests were set at 5%. The follower count of posters within groups related and not related to the Miyara et al. study was analyzed to reveal the impacts when tweets were posted by these accounts.

Topic Analysis

In order to capture certain themes that were prevalent within the tweets, the two members of the study team that hand-coded the tweets also created topics based on the content they read. The tweets were separated into two basic categories to allow for a more efficient comparison of themes: tweets not about the Miyara et al. study and tweets about the Miyara et al. study. Different focuses have been adopted during the theme capturing process considering the fact that people react differently within these two groups. Specifically, themes from tweets about the Miyara et al. study were mainly people's attitudes towards the research itself or speculations about unseen driving forces. Contrary to a comparably narrow but concentrated scope, tweets not related to the Miyara et al. study discussed diverse aspects of the field. For example, users showed sentiments beyond attitudes towards smoking such as generally distrusting research, stating reasons to support their stances, and requesting information for truth finding. Such diversity is also observed through various research directions that analyze smokers' risks of COVID-19 infections, which include but are not limited to the analysis of existing health conditions and harmful life habits. To obtain a comprehensive understanding of these themes which are not necessarily correlated with each other, multiple groups are thus needed for illustrations. As shown in Table 2, groups defined as "Stances on smoking", "Other sentiments", "Research focus on association between smoking and COVID-19" are used to reflect the uniqueness

of sentiments. Based on the themes that were notably expressed most in the tweets, topics were created for each of these two categories. The topics, for both tweets about and not about the Miyara et al. study, were chosen by the manual coders noting recurring themes throughout the hand-coding process. Each tweet was then categorized under one of the topics or put under ‘miscellaneous’ (unsorted). For each topic, tweets were chosen as a representative example of other tweets within that topic.

RESULTS

Temporal Analysis

The temporal analysis of the Miyara et al. study was done by compiling the hand coding results after the sentiment analysis. A clear comparison between numbers of tweets regarding the Miyara et al. study versus Non-Miyara et al. study tweets can be drawn from Figure 2. As shown, Non-Miyara et al. study tweets remained relatively steady through the study period. In contrast, tweets related to Miyara et al. study sharply increased beginning on April 22nd, 2020, the day after publication, with a spreading peak observed between April 23rd, 2020 and April 24th, 2020, when discussion appeared to be most intense. Throughout the whole period until May 4th, 2020, the number of Miyara et al. study related tweets surpassed all other tobacco/covid-related tweets, confirming its prevalence on Twitter.

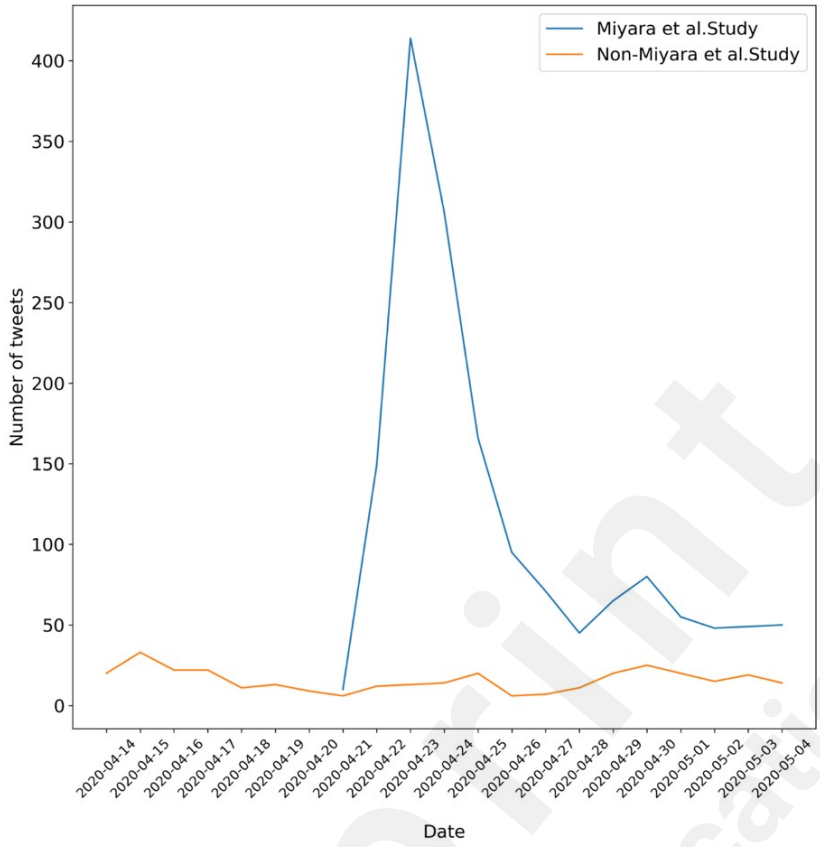

Figure 2: Temporal analysis of the Miyara et al. study's influence.

Sentiment Analysis

Figure 3 shows the classification of the final 1,929 tweets in different categories (Cohen's kappa 0.86 – 0.93; see Supplemental material). Among the 1,929 selected tweets that cited articles which have either positive or negative attitudes toward smoking, 324 tweets (16.80%) are not related to the Miyara et al. study (Non-Miyara et al. study), while 1,605 tweets (83.20%) are related to the Miyara et al. study (Miyara et al. study).

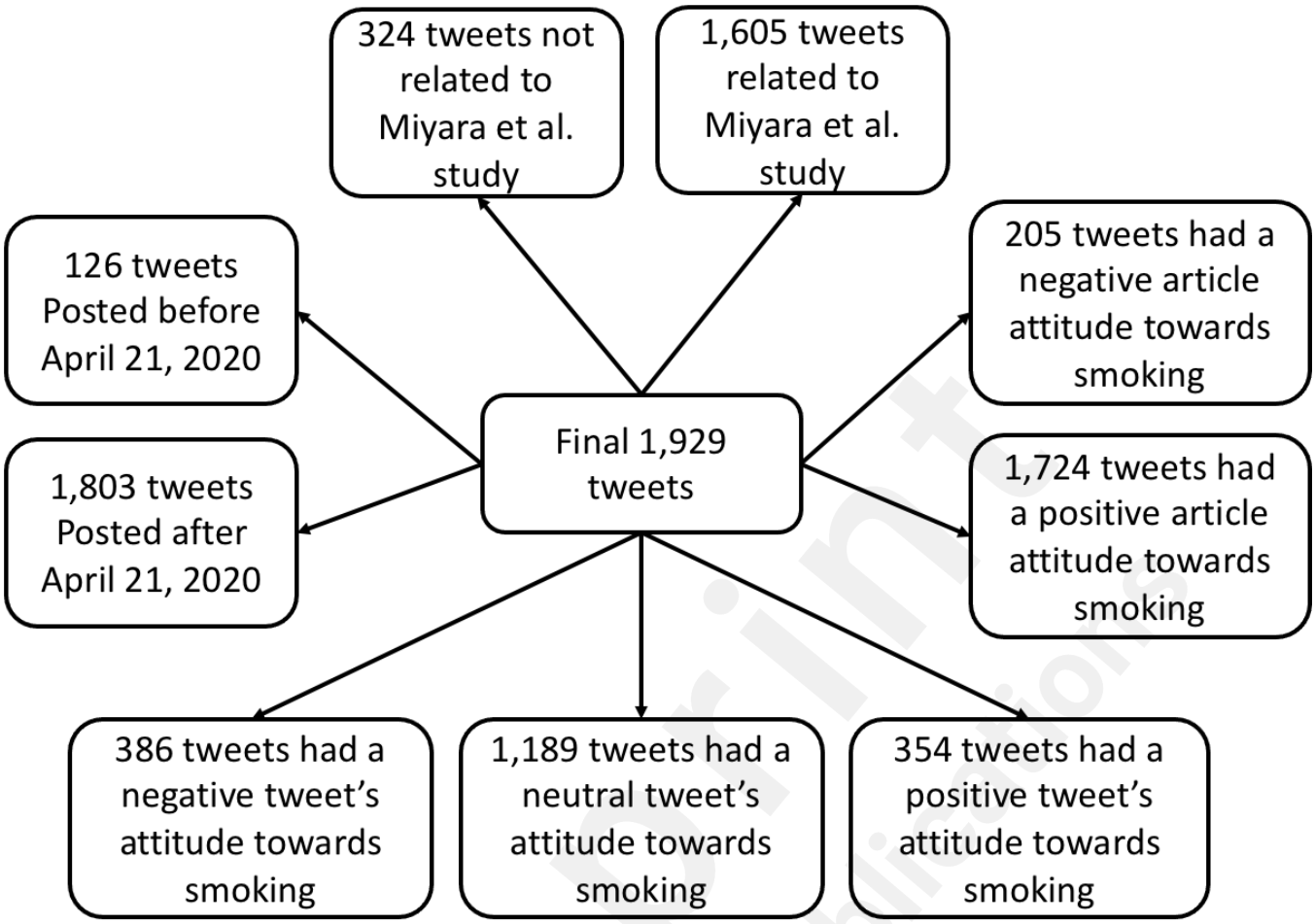

Figure 3: Final tweet classification in different categories.

Figure 4 shows the proportions of negative, neutral, and positive tweets regarding their attitude towards smoking in the three different tweet groups. In tweets not related to the Miyara et al. study before April 21, 2020, 17 out of 126 tweets (13.49%) showed positive attitudes, 65 out of 126 tweets (51.59%) showed neutral attitudes, and 44 out of 126 tweets (34.92%) showed negative attitudes toward smoking. In tweets not related to Miyara et al. study after April 21, 2020, 26 out of 198 tweets (13.13%) showed positive attitudes, 104 out of 198 tweets (52.53%) showed neutral attitudes, and 68 out of 198 tweets (34.34%) showed negative attitudes towards smoking. In tweets related to Miyara et al. study, 311 out of 1605 tweets (19.38%) showed positive attitudes, 1,020 out of 1605 tweets (63.55%) showed neutral attitudes, and 274 out of 1605 tweets (17.07%) showed negative attitudes toward smoking. Multinomial logistic regressions were conducted to compare the differences in proportions of positive and negative attitudes towards smoking across the three

different groups. The proportion of tweets showing a negative attitude towards smoking regarding the non- Miyara et al. study was significantly higher than the proportion of tweets showing a negative attitude towards smoking regarding the Miyara et al. study (both $P < 0.001$). Meanwhile, the proportion of tweets showing a positive attitude towards smoking regarding the non- Miyara et al. study was significantly lower than the proportion of tweets showing a negative attitude towards smoking regarding the Miyara et al. study (both $P < 0.001$).

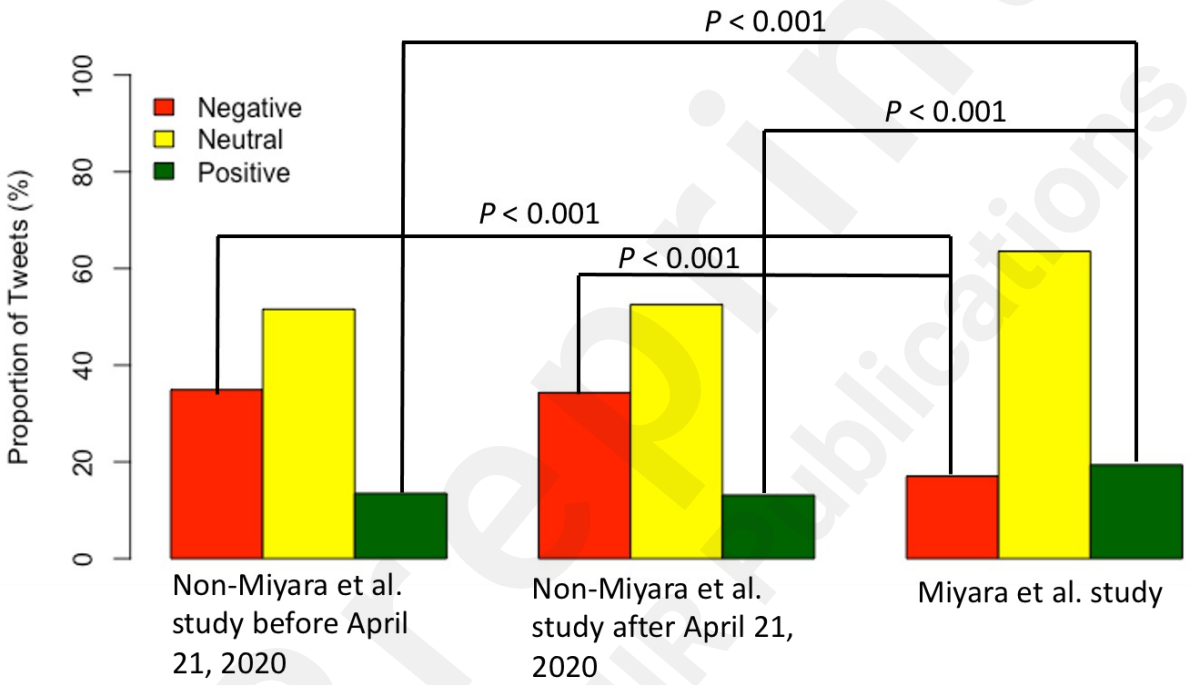

Figure 4: Proportion of negative, neutral, and positive tweets regarding their attitude towards smoking in three different tweets groups: 1) Tweets not related to the Miyara et al. study (Non-FS) before April 21, 2020; 2) Tweets not related to the Miyara et al. study (Non-FS) after April 21, 2020; 3) Tweets related to the Miyara et al. study. *P*-values were obtained from the pairwise comparisons within the multinomial logistic regression model framework.

Topic Analysis

Not about the Miyara et al. study. For the 324 tweets not related to the Miyara et al. study, 126 (38.89%) tweets were posted before April 21st, 2020 and 198 tweets (61.11%) were posted on April

21st or after April 21st, 2020. The 324 tweets were categorized from three perspectives to analyze users' opinions, various sentiments, and the research focus of the studies mentioned: "Stance on smoking", "Other sentiments", "Research focus on association between smoking and COVID-19", respectively (see Table 1). To better capture topic details, many posts were coded into more than one category. After comparison, similar weight distributions were seen between two periods (before and after April 21st, 2020) within the group "Stance on smoking", with the majority of tweets falling into the category "Stating the finding", followed by those within the categories "Discourage tobacco" and "Encourage tobacco". Significant changes were found between two periods in the weights within categories "More info requested" (P = 0.006), "Advocating quitting smoking" (P = 0.013) and "Health conditions (diabetics, asthma, etc.)" (P < 0.001) using the two proportion Z test. With a weight decrease of 6.99%, 6.80%, 12.79%, their two proportion Z test scores are 2.75, 2.47, and 4.56 respectively, which shows that there is statistical differences with a 5% confidence interval with respect to these three categories between the two periods. For other categories, no clear change was observed. Table 1 shows a breakdown of categories with two example tweets provided for each topic.

Table 1: Topics categories for Non-Miyara et al. study posts

Group	Topic	N (% tweets)		Example
		Before Apr. 21st	After Apr. 21st	
Stance on smoking	Stating the finding	58 (46.03)	97 (48.99)	shocking result smokers are far less likely to be hospitalized with coronavirus than non smokers
				smoking is associated with doubling of covid 19 progression risk center for tobacco control research and education
	Discourage tobacco	39 (30.95)	67 (33.84)	this study is simple and others published since have made it pretty clear smokers die more from covid than nonsmokers
				this suggests that there has never been a better time to quit smoking to protect yourself from covid 19 study shows an incredibly high correlation between serious covid symptoms and habitual smoking
	Encourage tobacco	13 (10.32)	23 (11.62)	bibber indepth if you split current and former smokers current smokers will end up with a lower risk for hospitalization than or 0 7 and former smokers with a

				higher or there is no misleading this is a well done study of 4 103 corona patients in a nyc health system
				nicotin from tobacco can cure covid19 clinical trials are on in australia tobacco nicotin used as last remedy cure in medical science tobacco is best medicine for neurological disorder do some research goi is right
Other sentiments	Advocate quitting smoking	13 (10.32)	7 (3.54	a new study shows that cigarettes can help the coronavirus enter lung cells meaning it's time to stop smoking
				correct in fact most research on vaping and respiratory health shows that smokers who quit by switching to vaping experience better lung function reduced pneumonia risk and less severe asthma and emphysema
	More info requested	12 (9.52)	5 (2.53)	are there any official recording of those who smoke are more likely to suffer from covid19
				love your show do you have any more info about the study that said smokers are less likely to die from coronavirus thank you
	Debate with others	4 (3.17)	5 (2.53)	kwaza really please reference one scientific study that proves that smoking decreases your chance of surviving a covid19 infection specifically a study by the cdc found that just over 1 of those who died from a covid19 infection were smokers and just over 2 were previous smokers
				ok this isn t being reported enough you are at risk of covid if you are obese have asthma and smoke on a regular basis it is your responsibility to do your own research and act accordingly you can literally get rid of these conditions in weeks if you act now
	General distrust in research	3 (2.38)	5 (2.53)	such a musical chair this research on covid19 has become smokers will be at higher risk then smokers have a better chance of surviving this is when you shut it all off fda says smokers may have higher risk of catching covid 19
				those researchers based their recommendation against smoking on general attributes of the virus eg covid attacks the respiratory system it doesn t appear they consulted the covid specific data at all before issuing their advisory
Research focus on association between smoking and COVID-19	Smoking itself	97 (76.98)	185 (90.91)	smoking does not increase covid 19 susceptibility
				smoking protects against covid 19 symptoms says new research hiptoro interesting given the need for oxygen uptake of covid 19 victims
	Health conditions	18 (14.29)	3 (1.50)	only half of urban and rural pakistanis are aware of the fact that diabetics smokers and asthmatics are at a higher risk of falling severely ill from covid 19 study by aga khan university aku coronavirus
				it looks like the best chance to survive coronavirus is to be an overweight smoker according to the latest research justsaying

	ACE2 related	11 (8.73)	12 (5.56)	icilondres one theory is that nicotin blocks ace2 receptors the backdoor to the lungs for covid19 however research needs to be done before we all reach out to our patches
				some researchers suspect that nicotine binds to ace2 as well and that this makes i via
	Total	126 (100)	198 (100)	

About the Miyara et al. study. While manually coding the 1605 tweets about the Miyara et al. study, certain common themes arose: encouraging tobacco use, expressing feelings of surprise about the findings of the Miyara et al. study, stating the main finding of the Miyara et al. study, discussing the follow-up nicotine patch study, highlighting the negative consequences of tobacco use, and questioning whether or not the Miyara et al. study was funded by the tobacco industry. Table 2 shows a breakdown of these categorized tweets along with two example tweets per each topic. There is a possibility of topic overlap of these tweets that has not been accounted for here. From the table, we can see that the most common theme were tweets that stated the main finding of the study (40.06%). Following the stating the finding topic, the next most prevalent topic was the nicotine patch follow-up study (30.97).

Table 2: Tweet topics for Miyara et al. study posts

Group	Topic	N (% tweets)	Example
Stance on smoking	Encouraging Tobacco Use	51 (3.18)	that's hilarious so nicotine is actually good for something lol smoke em if you got em lol study finds smoking reduces chance of getting coronavirus symptoms
			you may have quit smoking too soon a study shows that nicotine addiction may play a protective role against contracting covid 19
	Stating the finding	643 (40.06)	a cross sectional study strongly suggests that those who smoke every day are much less likely to develop a symptomatic or severe infection with covid 19 compared with the general population
			french researchers reveal that smokers are less likely to get covid 19
Other sentiments	Shocked/Surprised	28 (1.74)	shocking study supports smoking as preventive measure against covid19

			in surprising results and a warning from smoking a Miyara et al. study finds that nicotine may help to fight corona
	Tobacco Consequences Highlighted	24 (1.50)	french research suggests nicotine could protect against covid 19 but smoking remains biggest killer in france 75 000 people die every year from smoking related complications
			france finds smoking may help you resist covid 19 if you don t mind dying of something else in a reversal of prevailing covid 19 wisdom a Miyara et al. study appears to show smokers are less at risk from virus affirming results of an earlier chinese study
	Tobacco Industry Funded	34 (2.12)	this is insane to even suggest using substance such nicotine less likely to catch coronavirus is it tobacco companies is paying for this study
			this is based on data analysis not a controlled study and i m deeply suspicious of possible big tobacco influence but as a 63 yr old still hooked on nicotine mints i m hoping hard
Research focus in the future	Nicotine Patch Study	497 (30.97)	french researchers to test nicotine patches on coronavirus patients
			the study at a major paris hospital suggests a substance in tobacco possibly nicotine may be stopping patients who smoke from catching covid 19 clinical trials of nicotine patches are awaiting the approval of the country's health authorities
Unsorted	Miscellaneous	328 (20.44)	treat this research with caution it was my solid understanding that this virus affects smokers far worse than a non smoker as the lungs are already compromised from damage by smoking
			not gonna read this as i m not a smoker but all i can say is of course it s a Miyara et al. study
	Total	1605 (100.00)	

Miyara et al. study *topics vs Non-Miyara et al. study topics.* By topic comparison, both similarities and differences are seen. Regarding consistency, topics found within the Miyara et al. study and Non-Miyara et al. study tweets show that the majority simply stated the finding of the article; 643 (40.06%) of Miyara et al. study related tweets belonged to this category compared to 155 (47.55%) of Non-Miyara et al. study related tweets. However, while both groups contain tweets that hold negative attitudes towards smoking, tweets related to Miyara et al. study discourage tobacco use in a more comprehensive way. For example, within Miyara et al. study related tweets, 24 (1.50%) highlight the risks of tobacco use and 34 (2.12%) speculated whether the study was funded by the

tobacco industry. Within the non-Miyara et al. study tweets, 67 (33.84%) discouraged tobacco use while 23 (11.62%) encouraged tobacco use. Furthermore, there were tweets that demonstrated doubts regarding the potential benefits of smoking but many did not absolutely reject such possibilities. This suggests that users may have been open to exploring whether there is a positive effect of smoking on COVID-19, but that they proceeded with caution. Before the publication of the Miyara et al. study, such rejections were frequently observed, which indicates that most users shared a neutral or more negative opinion of smoking's influence on COVID-19 and suggests that users may have begun to think more critically about smoking's impact on the novel coronavirus after the Miyara et al. study was published. The distributions of the number of followers in Twitter users who posted either Miyara et al. study-related tweets or Non-Miyara et al. study-related tweets were both highly skewed to the left. The median number of followers to Twitter users who posted Miyara et al. study-related tweets was 585 with an interquartile range of 3,407. The median number of followers to Twitter users who posted Non-Miyara et al. study-related tweets was 630 with an interquartile range of 2,681. The number of followers of Twitter users indicated the bandwidth of outreaches of those posted tweets.

DISCUSSION

This report presents novel findings observing a shift in attitudes towards smoking among Twitter users after publication of a Miyara et al. study that reported lower rates of daily smoking among COVID-19 cases. The relatively large number of median followers to Twitter users who posted the Miyara et al. study-related tweets indicated the results of the Miyara et al. study were widespread. Overall, the findings suggest that this study was successfully disseminated and appears to have led to more positive attitude towards smoking amongst our population. Every post that stated the main finding of the Miyara et al. study (which was considered a neutral sentiment) can be looked at as a spread of information from one user to other users, leading to even more spread of the study. When comparing tweet sentiments before and after April 21st, 2020, there was a significantly more positive

attitude towards smoking among all tweets.

The largest percentage of tweets, from before and after April 21st, 2020 and about the Miyara et al. study, had a neutral sentiment towards smoking, including mentions of wanting more information and a sense of uncertainty regarding the study's findings. The most prevalent tweets stated the main finding of the study and/or mentioned the nicotine patch follow-up study. The main findings of the articles tweeted about in this sample (that were not about the Miyara et al. study) reflected both the benefits and risks of smoking on COVID-19 [13, 14]. People's opinions of smoking varied a lot throughout the periods, encouraging or discouraging nicotine use. Among different studies, the up or down regulation effects of ACE2 proteins where viruses bind to were frequently discussed to explain smoking's impact on COVID-19 [14, 15]. The similar distributions of the number of followers in Twitter users who posted either Miyara et al. study-related tweets or Non-Miyara et al. study-related tweets indicated similar bandwidths of outreaches of those posted tweets.

Nevertheless, differences in people's opinions and study focuses were observed in some ways. Even among posts not directly discussing the Miyara et al. study, there was still a shift to a more positive attitude towards smoking after its publication. Not necessarily shifting all others' attitudes towards smoking from negative to positive, the release of Miyara et al. study did at least waver stances of those who oppose smoking, confirming its positive impact. This speculation is supported by a 6.82% weight decrease of tweets not related to Miyara et al. study that advocate quitting smoking. To conclude, a different reaction pattern is seen between tweets within French and non-French groups. Beyond its influence of changing people's attitudes towards smoking, it also informs a critical thinking mindset behind how people observe smoking's effects. For example, while people's stances varied regarding smoking's effect on COVID-19, more tweets (10.32%) were observed that called on people to quit smoking before April 21st, 2020 compared to after (3.54%). This decrease is perhaps due to the impact of the Miyara et al. study, which highlighted a potential benefit of smoking.

Significant changes were also seen regarding how people analyzed smoking's impacts on COVID-

19. Before April 21st, many tweets (14.29%) discussed the increased risks of infection if smokers have existing health conditions, such as diabetes and asthma [16]. Some tweets cited articles that stated former smokers would be at higher risks of infection compared to current smokers [17]. These mixed perspectives did not analyze the direct impact of smoking and reiterated the combined effects of existing health issues and smoking on COVID-19 infection. The findings of these articles reflect the uncertainty of research directions about smoking itself, which is expressed in the Non-Miyara et al. study related tweets. However, the publication of the Miyara et al. study could have led to less uncertainty about the impact of smoking on COVID-19 after April 21st, 2020, with only 1.5% of tweets discussing the influence of smokers' health conditions on infection, compared to 14.29% before.

Strengths

Twitter is a valuable tool used in health research and can be used to analyze up to date data about a specific topic, while the topic is at its peak discussion point [18]. Another study examining Twitter sentiments on smoking and COVID-19 found that the sentiment of tweets was generally negative but became less negative in April (when the Miyara et al. study was released) [11]. We observed a shift towards positive sentiments revolving around smoking among posts discussing the Miyara et al. study after April 21st, 2020, compared to posts before the publication. Overall, this study presents a useful example of the impact of the dissemination of a particular contrarian study, and how it can shift the field of discussion on a topic. That is, one particular finding can color a conversation.

Limitations

Although the results met our original expectations of Miyara et al. study's impact on people's opinion change, several limitations of our analysis can be found. Firstly, some posts might be missing since keywords were used to filter out tweets before hand-coding. The potential problems of this are whether or not all posts about our topic contain the chosen keywords. For example, keywords "study" and "research" were used to filter out research related posts however users might use words

like “result”, “report”, etc. to reflect a research finding. In our case, “result” and “report” would bring in a lot of off-topic tweets, thus those were not included in the keywords list. Nevertheless, an alternative analysis could consider adding those tweets and starting the filtering process afterwards. Similar problems might be relevant if some users comment on a research result without referring to the subject, in which case users’ sentiments are still related to our analysis but are ignored. Secondly, we analyzed tweets written only in English and missed tweets in other languages, which might bias the study results. However, analyzing tweets written only in English could avoid misinterpreting translations. Thirdly, we did not collect and analyze the number of likes and retweets of the original posters, which could also help to analyze the impact of those tweets. Furthermore, although inter-coder variances are small enough to make the results valid, hand coding is a subjective method, implying potential cognitive differences in coding. Tweets were posted globally, which suggests that tones from distinct regions might imply different meanings (e.g. sarcasm). Though hard to eliminate, such limitations could be alleviated by incorporating more coders with diverse backgrounds. Lastly, it’s possible that smokers tend to tweet more about smoking related studies. They may even have a positive attitude towards smoking before seeing any studies demonstrating smoking’s beneficial effects. To address that, studies quantifying such likelihood may be needed and should be taken into consideration during analysis to more precisely observe the impact of the Miyara et al. study.

Implications and Future Directions

Note that this paper is not a criticism of the Miyara et al. study’s authors or their research – our focus here is on using that paper and its findings as a jumping-off point for exploring how a particular study is disseminated on Twitter, and how that information may influence the sentiment of Tweets moving forward. Information-based communication strategies can be used to modify people’s attitudes by providing evidence for or against an idea. Previous literature has described the impact of research and research dissemination as affecting knowledge, attitudes, and behavior with respect to health risks [19]. Our findings suggest that among Twitter users discussing tobacco research, a

substantial number of posts were related to the Miyara et al. study on COVID-19 and smoking for several days after its publication on April 21st, 2020. There was a significant increase in the number of tweets with a positive sentiment towards smoking both when comparing before and after the Miyara et al. study publication date and when comparing tweets about and not about the Miyara et al. study (after April 21st, 2020). Therefore, the results of the Miyara et al. study could have contributed to a positive shift in attitude towards smoking among some Twitter users. We understand the number of tweets used in the analysis might be only 1% of the total number of tweets related to the Miyara et al. study on COVID-19. However, given the assumption that the tweets obtained from free Twitter streaming could be treated as a random sample from all tweets related to the Miyara et al. study on COVID-19, the statistical significance in a positive shift in attitude towards smoking is valid. Given the negative consequences of tobacco use, it is imperative to disseminate accurate messaging and concise evidence/recommendations regarding the relationship between COVID-19 and nicotine to prevent initiation and encourage cessation. Given the dissemination of the Miyara et al. study's results and the confusion expressed by users, there is a need for further research on the true effects of nicotine and the novel coronavirus. The World Health Organization has since published a scientific brief stating that "smoking is associated with increased severity of disease and death in hospitalized COVID-19 patients" and that "there is no evidence to quantify the risk to smokers of hospitalization with COVID-19 or of infection by SARS-CoV-2" [20]. Twitter can serve as a useful resource to monitor the spread of and reactions to tobacco research to identify potentially problematic public interpretations or misrepresentations of findings.

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Authors' Contributions

ZX, DL, ROC: conceived and designed the study. ZX, CT, LC: extracted and preprocessed the data, CT, DD, DL: analyzed the data. CT, DD, ZX, LC, DL, ROC: wrote the manuscript, assisted with interpretation of analyses results, and edited the manuscript.

Disclaimer

The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH or the FDA.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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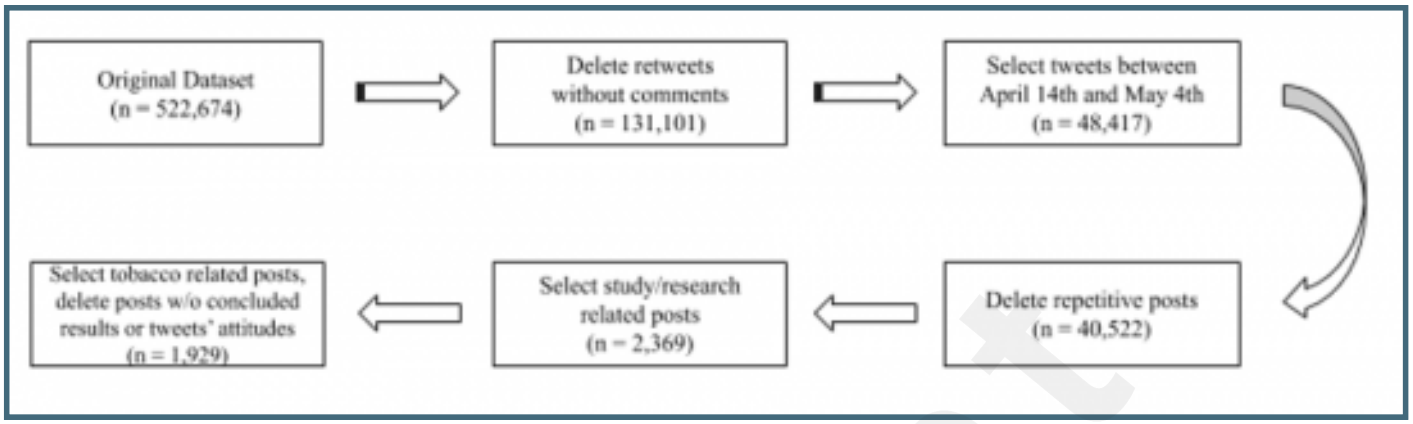
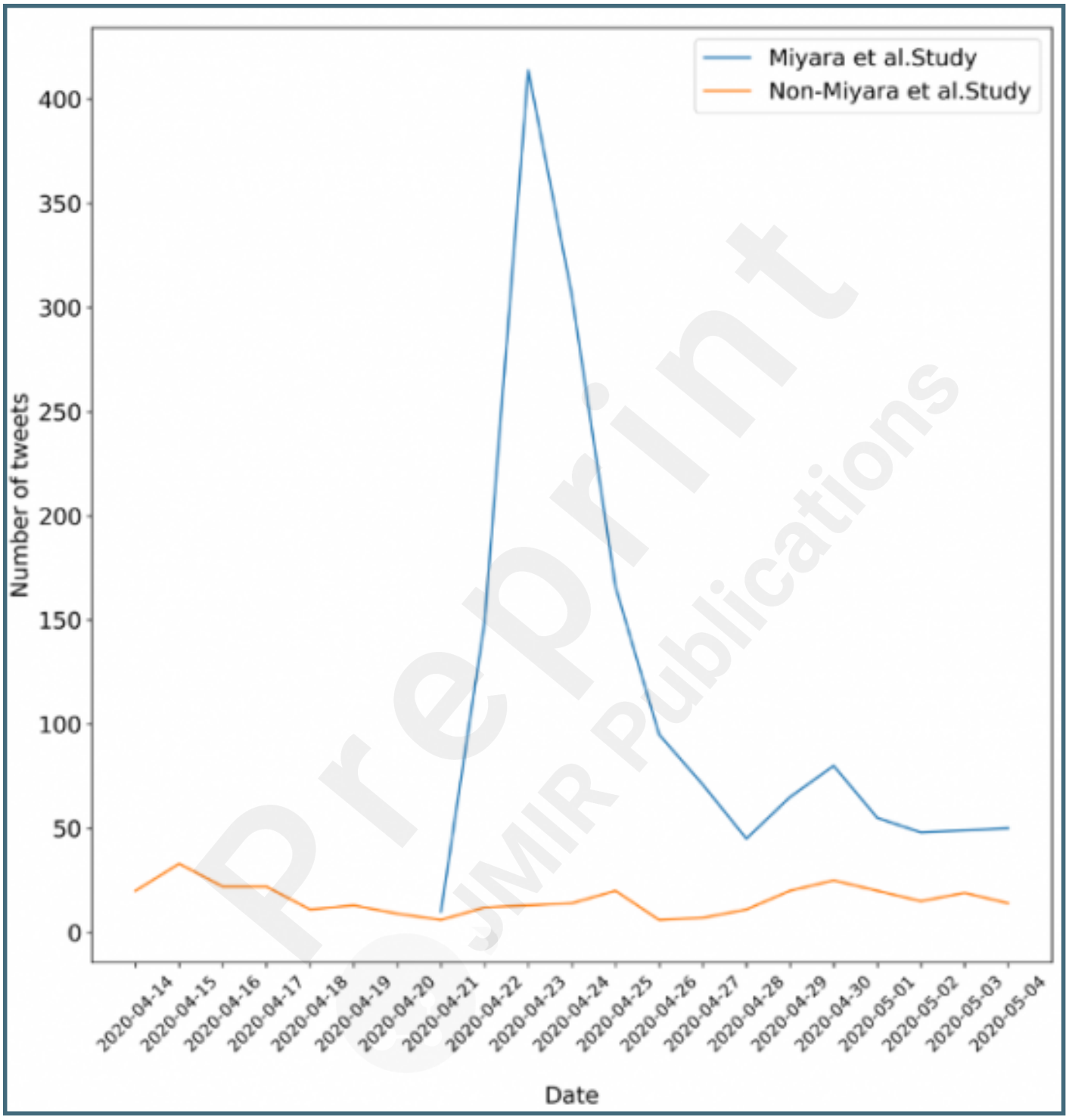
Supplementary Files

Figures

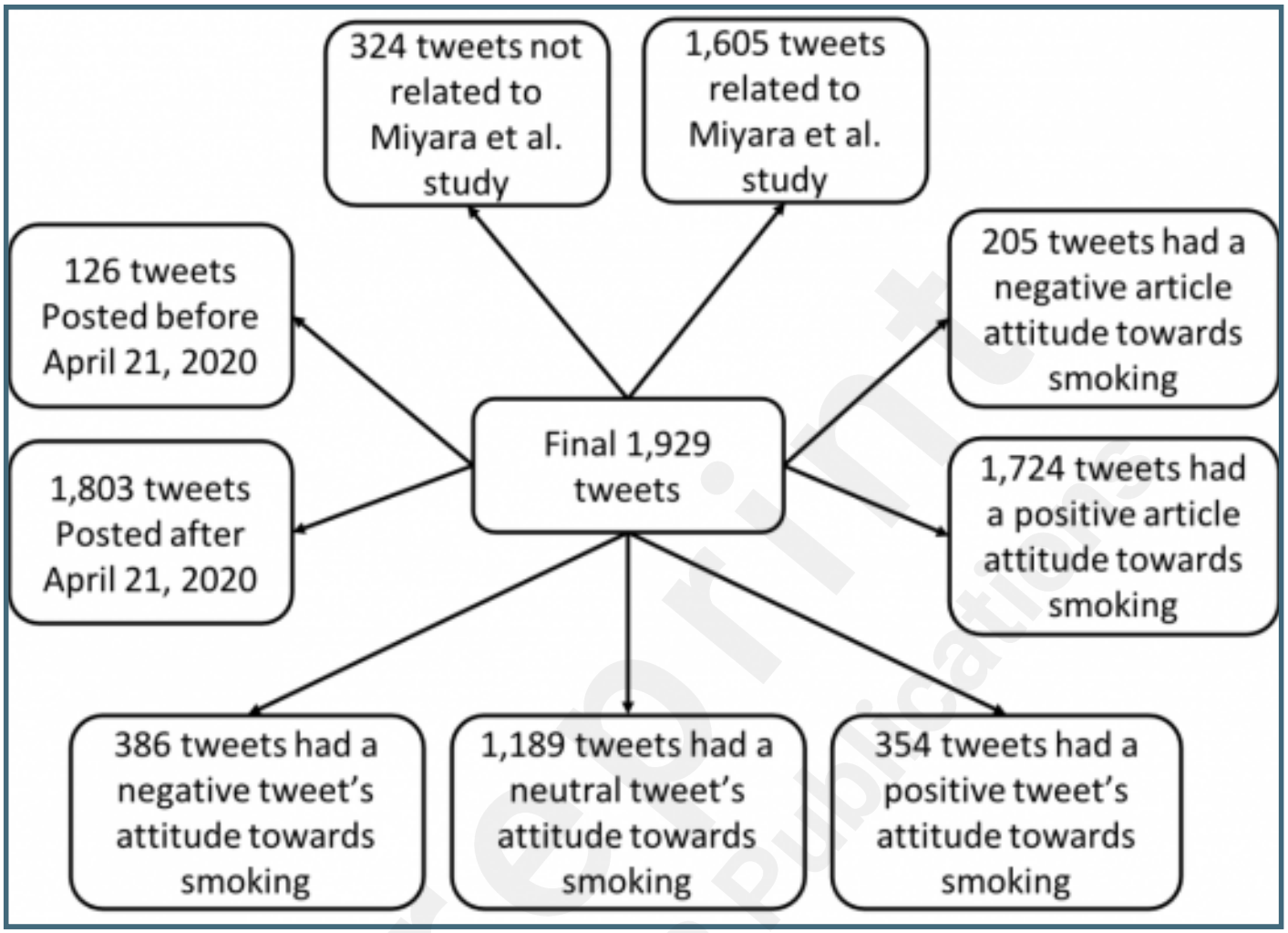
Dataset preparation procedures.



Temporal analysis of the Miyara et al. study’s influence.



Final tweet classification in different categories.



Proportion of negative, neutral, and positive tweets regarding their attitude towards smoking in three different tweets groups: 1) Tweets not related to the Miyara et al. study (Non-FS) before April 21, 2020; 2) Tweets not related to the Miyara et al. study (Non-FS) after April 21, 2020; 3) Tweets related to the Miyara et al. study. P-values were obtained from the pairwise comparisons within the multinomial logistic regression model framework.