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Changes of Diurnal Rhythms of Social Media Activities During the COVID-19 Pandemic

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Abstract

The COVID-19 pandemic has dramatically changed many aspects of our lives throughout the world. The Stay-at-Home orders imposed by the pandemic have exacerbated the stress and anxiety during the pandemic. To investigate how the social confinements affect people's circadian rhythms at the population level, social activities on Twitter were analyzed for three different stages during the COVID-19 pandemic development. Results confirmed the diurnal rhythms of daily tweets before the Stay-at-Home orders, and also found that the diurnal rhythmicity of tweets was severely abolished during the Stay-at-Home orders, and then was restored after reopening. This study has a public health implication that circadian rhythms of the general public were significantly impacted by the social confinements during the COVID-19 pandemic, and circadian health education targeting the general population should be given enough attention and priority.

Keywords: COVID-19; pandemic; social media, circadian rhythms.

1. Introduction

The Coronavirus 2019 (COVID-19) outbreak has led to a global pandemic, which has dramatically changed many aspects of our lives throughout the world. The COVID-19 pandemic has produced extensive stress, anxiety and depression about health, safety, employment, financial crisis and many other uncertainties about the future.

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Many governments announced social distancing requirements and Stay-at-Home orders to limit the spread of COVID-19 in the public. These imposed social confinements further exacerbated the existing stress and anxiety, because they altered people's daily routines, which may profoundly disturb the sleep and circadian rhythms. In the recent years, social media has significantly changed the ways in which people socialize and interact with each other in the modern society. Social media plays unique and important roles during the COVID-19 pandemic. It enables the general public to access to various information and resources, to connect to each other despite of the physical distancing, and to have channels to express options. As people continue to stay home and remain physically distant from each other during the pandemic, more and more people rely on social media to stay connected. The overall activities on social media reflect the daily activities of people at a population level. Therefore, activities on the social media could be used as a proxy to estimate the circadian rhythms of the society. Several studies have analyzed activities from different platforms of the social media, and demonstrated that the social activities exhibited circadian rhythms [1–8]. To explore how the Covid-19 pandemic imposed social confinements have changed the daily rhythms of people, I compared the daily patterns of tweeting activities on Twitter at three different stages of the pandemic. These included the pre-Stay-at-Home stage in February, the strictest phase during Stay-at-Home orders in April, and the post-Stay-at-Home stage in June. Results showed that the social confinements by Stay-at-Home orders had a significant impact on the daily rhythms on Twitter. The tweets posting rhythms were abolished during the Stay-at-Home orders, and were restored after the widespread reopening.

2. Materials and Methods

The dataset of social media was tweets acquired from the Twitter Stream related to COVID-19 chatter collected and maintained by Georgia State University's Panacea Lab [9] and collaborators. The data were collected by query of Covid-19 related words. A cleaned version with no retweets on the full dataset of version 20 was used in this study.

The global pandemic was declared on March 11, 2020 by World Health Organization. The Stay-at-Home orders were announced in the U.S. starting from March 16, 2020 in San Francisco to April 6, 2020 in Southern Carolina [10]. The widespread reopening started from May 18, 2020 in the U.S [10]. Therefore, taking these critical dates in consideration, the COVID-19 pandemic could be divided into three different stages, and three representative periods from each stage of the pandemic were selected for the analysis in the present study: 1) February 21 – February 25: period before the Stay-at-Home orders; 2) April 10 – April 14: period during the Stay-at-Home orders; 3) June 2 – June 6: period after the Stay-at-Home orders and widespread reopening in the U.S. Each period included five days of data from Twitter.

The distribution of the number of tweets across 24 hours (00:00:00-24:00:00) was analyzed. The rhythmicity of the distribution was tested by one-way ANOVA [11]. A low F statistic value and a high P value, > 0.05, indicate the lack of rhythmicity. Comparisons between the daily rhythms of tweets on different stages were analyzed by two-way ANOVA. The data mining and all statistical analyses were conducted using R (version 4.0.2) software [12].

3. Results

Because the dataset was collected based on a query of Covid-19 related words, the number of tweets was changing rapidly while the pandemic was developing (Figure 1). In February, in the early stage of the pandemic, i.e. before the Stay-at-Home orders were in effect, the number of daily tweets was 250165 ± 45828. In April, during the period of Stay-at-Home orders in effect, the number of daily tweets was 1022891 ± 36449. In June, after reopening, the number of daily tweets was 798153 ± 31528. The differences between the numbers of tweets at different stages reflected people's attention on the topic of COVID-19 pandemic.

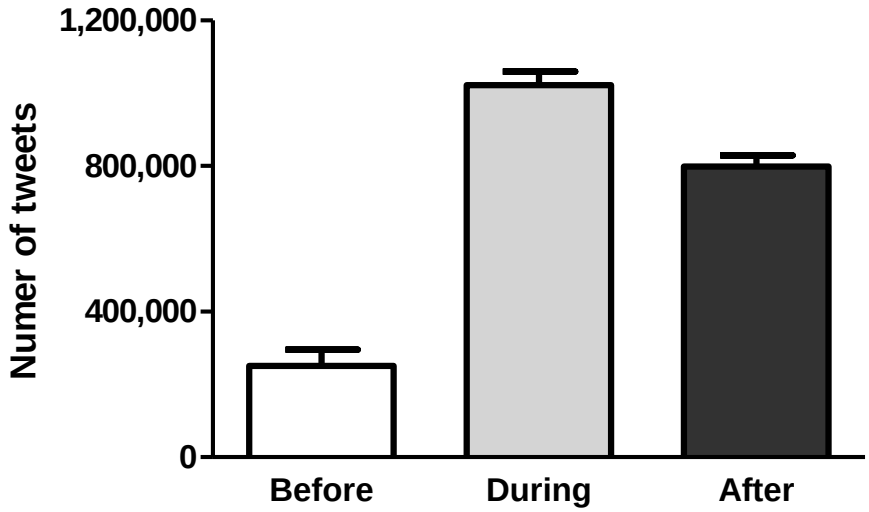

Figure 1: The daily tweets at different stages of the COVID-19 pandemic. "Before" represents the data from the period before the Stay-at-Home orders. "During" represents the data from the period during the Stay-at-Home orders. "After" represents the data from the period after the reopening.

The time of posting tweets represented a good time stamp for the social media activity. The distribution of the tweets posting over 24 hours exhibited a clear circadian pattern before the Stay-at-Home orders in effect (Figure 2A), with the peak in the late afternoon around 4-6pm and the trough in the early morning around 4-6am. This distinct diurnal pattern was strikingly changed after the Stay-at-Home orders in effect. As seen in Figure 2B, the tweets distribution curve was almost flattened across a day. Large increase of tweets happened during the late night and early morning, the period in which people usually took sleep and rest. Interestingly, after the widespread reopening, the diurnal pattern of tweets became clear again, restoring to a level closer but not identical to the normal condition (Figure 2C). The differences between the activity patterns before the Stay-at-Home orders and after reopening were significant ($F_{\text{Stage*Time}} = 15.82$, $P < 2e\text{-}16$, Figure 2D), although both of them exhibited clear daily rhythms, suggesting that it was not yet a complete recovery from the reopening. Overall, these results indicate that the Stay-at-Home orders had a strong impact on changing diurnal patterns of social activities on Twitter at the population level.

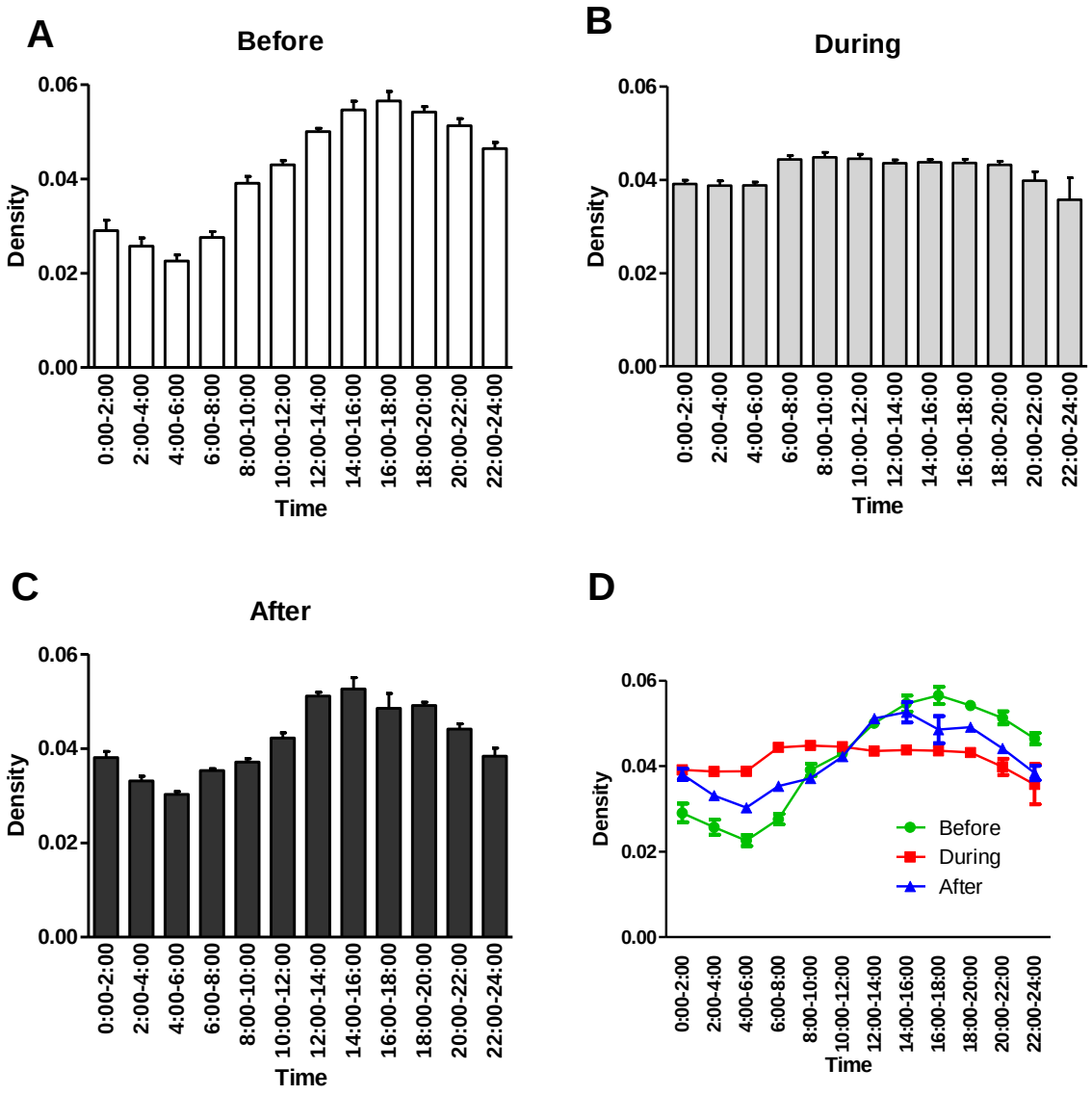

Figure 2: The distribution of tweets across 24 hours at different stages of the COVID-19 pandemic. (A) The distribution of tweets exhibited a clear diurnal pattern before the Stay-at-Home orders in effect. (B) The diurnal pattern of the social activities on Twitter was abolished during the period of the Stay-at-Home orders in effect. (C) The distribution of tweets exhibited a diurnal pattern again after widespread reopening. (D) The distribution patterns of tweets from three stages were overlaid, showing the time specific differences of activity distribution.

This on-off-on pattern in diurnal rhythms of social activities on Twitter across different pandemic stages was further confirmed by statistical analysis. ANOVA tests showed that the F statistic of tweets during the Stay-at-Home period was much lower than that of tweets before and after Stay-at-Home orders in effect (F_{before} = 122.2, F_{during} = 0.012, F_{after} = 26.3, Figure 3A). Accordingly, the P value of tweets during the Stay-at-Home period was much higher than that of tweets before and after Stay-at-Home orders in effect (P_{before} = 6.65e-16, P_{during} = 0.915, P_{after} = 3.52e-6, Figure 3B), indicating that the diurnal rhythmicity was abolished during the Stay-at-Home period.

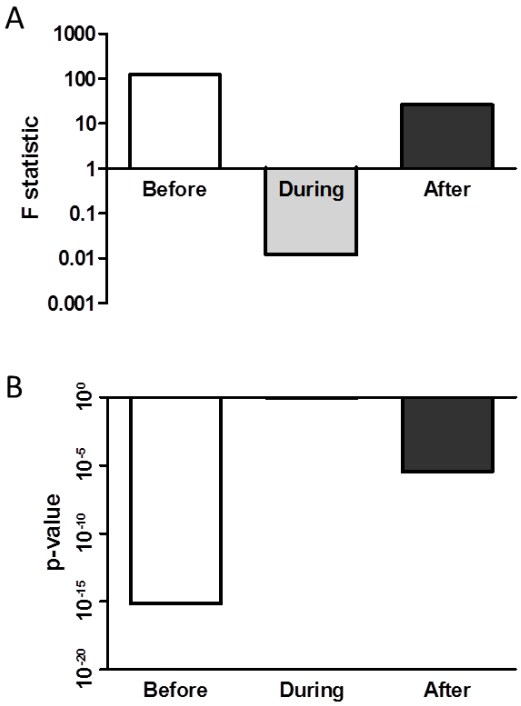

Figure 3: One-way ANOVA statistics for testing the rhythmicity of tweets distribution at different stages of the COVID-19 pandemic. (A) The *F* statistics. (B) The *P* value.

4. Discussion

The present study utilized the activities on Twitter as a proxy to explore the effects of Stay-at-Home orders on diurnal rhythms at the population level during the COVID-19 pandemic. Results confirmed that the distribution pattern of daily tweets exhibited clear diurnal rhythms before the Stay-at-Home orders. Strikingly, the diurnal rhythmicity of tweets was severely abolished during the Stay-at-Home orders, and then restored after reopening. It is noteworthy that there were still significant differences between the daily activity patterns before and after the Stay-at-Home orders, although the rhythmicity was restored after reopening. The levels of activities during the night after reopening were significantly higher than those before the social confinements, suggesting that the impact of the pandemic on daily rhythms to some extent still exist in general population despite the reopening.

The loss of daily rhythmicity on tweets during the social confinements may be caused by the altered daily routines in general population. Significant amount of people were required to work from home or just stay at home without any work. This could be difficult for people to still maintain their strict working schedules as usual and consequently lost the normal time structure of daily life. Although many essential workers and front-line health care professionals still kept working during the pandemic, including the period of Stay-at-Home orders, their schedules have been extensively changed. Extended working hours and/or shift work were very common, which disrupted circadian rhythms in those working people. Even after widespread reopening, the actual working schedules have not been returned to normal. People adopted various ways, such as shift work or

flexible work schedule, to limit the potential contacts between co-workers after widespread reopening. This could be part of the reason that the restored diurnal rhythms after reopening were still different from those before the social confinement. The public health implication of the present study is that circadian rhythms of the general public were significantly impacted by the social confinements during the COVID-19 pandemic, and circadian health education targeting the general population should be given enough attention and priority. The unpreceded COVID-19 pandemic presents tremendous challenges in many aspects for everyone. In addition to the large amount of SASRS-Cov-2 infected patients, there have also been health concerns related to social confinements and distancing, such as disturbed sleep and increased anxiety and depression, in the general public. There have been several studies from different countries on the impact of COVID-19 pandemic on sleep and related mental health. Some of them focused on the health-care professionals [13–15], and some of them turned to the general population [6,7]. All of them demonstrated that the mental health and sleep were significantly impacted and the health concerns were not trivial. Although two studies showed that the social lockdown imposed by COVID-19 pandemic increased sleep duration [8,9], one common finding was that the quality of sleep was negatively affected by home quarantine due to COVID-19 pandemic [18–20]. The methods to study sleep and rest-activity rhythms in the above mentioned studies, however, were primarily self-report surveys. The survey-based approach has apparent advantages during the pandemic. Nonetheless, the disadvantages of subject bias in survey-based approach require additional evidences. Millions of people stay on social media every day, and millions of posts are generated during their social activities. The time at which people create a post on the social media is a type of objective real-time record of human activity. Analysis of these activities on social media could be a new way to study the human behavioral rhythms. This approach is also as convenient and inexpensive as the survey-based approach, and the sample size could be much larger than a regular survey. Circadian patterns of social media activities have been observed in several studies [1–8,21–23]. The rhythmic daily patterns of social activities reported in these studies are very similar to what was found before and after Stay-at-Home orders in the present study. The important and unique finding of the present study was the significantly abolished diurnal rhythms during the social confinements and the recovery of the rhythmicity after reopening, which have not been investigated in other studies. However there were still limitations in the present study. It only focused on one of the social media, Twitter. It could be possible that different social media platforms may result in different observations, because the users and audience may be very different across social media. Additionally, the types of activities could also be very different between social media. For example, people may simply post some text messages on one platform, but may take much longer time to prepare satisfying videos or photographs on the other platform. Future work may explore data from different platforms, and focused on the in-depth analysis of the diurnal rhythms of social media activities from more perspectives.

5. Conclusion

The COVID-19 pandemic has a significant impact on diurnal rhythms in the general population. Particularly, the imposed Stay-at-Home orders severely disrupted the daily rhythms of social activities on Twitter. The reopening improved the daily rhythms on Twitter, but has not restored the activity patterns to the original level before the Stay-at-Home orders.

6. Recommendations

Governments and employers should take circadian health into consideration when making decisions. Public health education should give circadian health enough attention and priority in the general population. Individuals should maintain regular schedules to keep the body clocks synchronized.

7. Conflict of Interest

The author declares no conflict of interest.

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