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Impact of environmental variables on COVID–19 – a study from the Telangana State, India

Abstract

The objective of the present investigation is to compare the pollution levels during the lockdown and unlock period to the pre-lockdown phases of the COVID-19 pandemic and intends to investigate the relationship between COVID-19 incidences and atmospheric in Hyderabad, Telangana, India. Throughout the lockdown and unlock periods, pollutants in the atmosphere were significantly reduced; a significant reduction was observed in Hyderabad with higher traffic levels with a maximum reduction of $PM_{2.5}$ and PM_{10} levels (60.3% and 53.4%, respectively) compared to pre-lockdown levels. The number of COVID-19 cases relative to most of the air pollutants was negatively correlated, which may be a mere coincidence as a result of the lockdown. The correlation test reveals a positive association between the ambient temperature and COVID-19 confirmed cases (r = 0.99, 0.07) during the lockdown phase and throughout the study period, suggests that the warm, tropical weather in the area of the study region is successful in preventing the spread of COVID-19. The findings of this study can help us comprehend how environmental variables play a part in the spread of COVID-19 in tropical and subtropical nations. The results of this study also suggest that temporary lockdowns useful tool for managing environmental imbalances.

Keywords: correlation, COVID–19, environmental variables, Hyderabad, lockdown

Volume 13 Issue 2 - 2024

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Received: April 22, 2024 | **Published:** May 06, 2024

Abbreviations: PM, particulate matter; NO, nitrous oxide; CO, carbon monoxide; SO_2, sulphur dioxide; O_3, ozone; AQI, air quality index

Introduction

In December 2019, Wuhan, China, reported the first case of COVID-19, which is related to the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). In the end, this illness spread quickly over the world, covering the majority of nations by April 2020. The worst effects of COVID-19 have been documented in Italy and the United States. In 2020, WHO proclaimed this disease to be a pandemic? On January 30, 2020, news of the first COVID-19 case in India was released from the Thrissur area of Kerala State. The sick individual had previously traveled from Wuhan, China. As a result, COVID-19 instances began to rise, and within a month Kerala emerged as the Indian state with the highest number of cases. The Prime Minister of India requested all Indian residents to follow a "public curfew" on March 22, 2020, after 180 COVID-19-positive cases were confirmed. Later, the curfew evolved into a 21-day nationwide lockdown, which was declared on March 24, 2020, to halt the coronavirus's spread throughout the nation and break its chain of transmission. Lockdown has since been extended three times: on April 14, 2020; on May 3, 2020; and on May 17, 2020. During the first nationwide lockdown, people were limited from leaving their houses unnecessarily and all transportation services—including air, land, and rail—were suspended except for fire, police, and some emergency services, as well as the conveyance of necessities. Throughout the lockdown, educational institutions and industrial operations were also shut. In comparison to several other countries worldwide, India has done better at confining the coronavirus and has sped up the doubling time due to the early recognition of the disease's severity and prompt lockdown implementation. To handle this urgent problem, the State and Federal Governments are acting in several ways. This meant withdrawing into oneself, drastically cutting back on air and road travel, and ceasing all other outdoor activity, such as commercial, industrial, and construction work. Nonetheless, the majority of India's states and union territories have been gradually infected by the novel coronavirus, indicating that the country has not entirely recovered from it. Telangana reported 1,012 confirmed COVID-19 cases as of April 30 (the ninth-highest number nationwide).[1] There are certain benefits and drawbacks to the government of India's decision to implement a nationwide lockdown to stop the virus from spreading throughout society. Psychological and socioeconomic effects are among the drawbacks. There are some benefits as well, such as the abrupt removal of pollutants and effluent that had been introduced, either directly or indirectly, into river water, fewer obstacles for wildlife, and fewer fatalities from traffic accidents, but the main advantage is the enhancement of the quality of the air, which has been directly related to several negative effects on human health. The correlation between ambient air pollutants like $PM_{2.5}$, PM_{10}, NO_x, and CO and the incidence of COVID-19 has garnered significant attention due to the well-established link between air pollution and a host of respiratory diseases, with longer exposure leading to higher risk. Poor air quality has been related in certain studies to the severity of COVID-19 results. Other reports are linking this pandemic to additional demographic parameters, such as household age profiles, population density, and sex ratios. Several studies on the decrease of air pollution in China, the USA, Brazil, Italy, and other nations have been published.[2] Likewise, reports of this have already surfaced from several of India's megacities, including Delhi, Mumbai, Kolkata, and others.[3] To ascertain how one variable affects the other, a time-varying co-relational analysis was conducted.[4] This research, however, primarily covered the early trend; there is a dearth of evidence regarding the post-lockdown period. In addition, Telangana and other southern states are still feeling the effects of this lockdown and its aftermath. Numerous investigations have been conducted recently to try and figure out what is causing SARS-CoV-2 to spread. According to certain research, this virus can spread through the air. Additional research showed that temperature and humidity are related to the SARS-CoV-2 virus's ability to survive and spread. Another variable that is thought to be contributing to the spread of this illness and increasing the death toll is air pollution. The results of these investigations are still debatable, though, and there is currently little information available. Consequently, additional research is needed to validate these findings and provide a deeper comprehension of the virus's dissemination. With the aforementioned discoveries and the need for additional research in mind, the present study concentrated on Telangana's capital city. Telangana is an Indian state renowned for its industrial growth, information technology, and agricultural productivity. The combustion of biomass and the state's numerous industrial sites are often credited for the significant deterioration in air quality, which frequently results in a high Air Quality Index (AQI) and its effects on human health as determined by the Central Pollution Control Board's 2014 guidelines (Table 1).[5] The COVID-19 epidemic has significantly impeded global industrial, transportation, and human activity. In light of this, the goal of this study was to assess how these limitations have made it easier to improve the quality of the air, particularly about the major criterion pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2, Ozone, and SO_2), as well as the relationship between COVID-19 and the weather and air pollution in Hyderabad, Telangana, India. Furthermore, the distribution of COVID-19 can differ from one area to another based on regional environmental factors, local conditions, government regulations, etc. Therefore, to accurately estimate this epidemic, more thorough and rigorous research is needed in every place where these aspects are taken into account. In light of this, the current study is to assess the influence of the lockdown and unlock on air quality and investigate the relationship between environmental factors, such as the meteorological temperature parameter, and the incidence and mortality of COVID-19 in the Indian state of Telangana.[6–8]

Table 1 AQI Color Index & Health Effects (CPCB, 2014)

Good (0-50)	Minimal impact
Satisfactory(51-100)	Minor breathing discomfort to sensitive people
Moderate (101-200)	Breathing discomfort to people with lung, asthma, and heart disease
Poor (201-300)	Breathing discomfort to most people on prolonged exposure
Very poor (301-400)	Respiratory illness in people on prolonged exposure
Severe (>400)	Affects healthy people and seriously impacts those with existing diseases

Note: Adapted from http://app.cpcbccr.com/

Materials and methods

Study area

Located in the southern region of the nation, Telangana is the most developed and urbanized state in the Indian Union. It is also the youngest state. With 33 districts, the state is the most agriculturally and industrially developed, as well as the center of India's information technology industry. This state's capital, Hyderabad, is inhabited by an estimated 8.7 million people and has a population density of 18,480 per square kilometer, with a significant increase predicted (WPR, 2023).[9] The climate in the area is tropical, moist, and dry (Figure 1).

Figure 1 (a) Map showing the location of the study area of Telangana, India. (b) Map showing the area (GHMC) of the study was focused. (c) Map showing the outline locations of air quality and weather monitoring stations in the GHMC area, Hyderabad, Telangana, India.

Data collection

As shown in Figure 1, the study was done in the Greater Hyderabad Municipal Corporation (GHMC) area of Telangana. The online resources of the Telangana State Pollution Control Board[10] (TSPCB: https://tspcb.cgg.gov.in/Pages/Envdata.aspx) and the Central Pollution Control Board (CPCB) provided the concentrations of the various pollutants, including $PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, O_3, AQI, and temperature. Initially, the data was preprocessed and the station average was taken into consideration for appropriate representation while assessing these metrics. For the same period, time series data on COVID-19 cumulative infections and deaths were collected. The necessity to include the various stages of the COVID-19 lockdown and the availability of data led to the consideration of a research period beginning in January 2020. Additionally, based on stringent national regulations, the data from all environmental and climatic indicators as well as COVID-19 occurrences were categorized into three distinct COVID-19 phases: the before the lockdown stage (March 14–24, 2020), the lockdown stage (March 25–31, 2020), and the unlocking stage (June 2020–June 2022).[11,12]

Correlation test

Correlation was used to analyze the association between air pollution, climate conditions, and the influence of COVID-19 in the GHMC area from March 14, 2020, to May 3, 2021, because the dataset was not normal. To explain the relationship between all the parameters and other elements, a correlation matrix was computed. One of the simplest ways to determine the relationship between any two variables is to use the correlation coefficient. The most significant strength or weakness of the monotonic relationship is found between -1.00 and +1.00. The threshold values for the various forms of segregation are as follows: weak positive correlation (0, 0.3), moderate positive correlation (0.3, 0.7), and strong positive correlation (0.7, 1.0). In the same way, there are three kinds of negative correlations: weak (-0.3, 0), moderate (-0.7, -0.3), and strong (-1.0, -0.7). The following is the equation for the correlation coefficient:

$$r_s = 1 - 6.\frac{\sum_{i=1}^{n} d_i^2}{n(n^2-1)}$$

Where n is the number of observations and d_i is the difference in the rank between two variables.

Time-varying correlation coefficient

This research technique is used to identify minute changes in data when it exhibits volatile behavior. An important application of the Exponential Weighted Moving Average correlation technique is to identify time-varying shifts between the variables being studied. EWMA calculates the volatile covariance for every observation

Citation: Kandukuri K. Impact of environmental variables on COVID–19 – a study from the Telangana State, India. *Biom Biostat Int J.* 2024;13(2):36–40. DOI: 10.15406/bbij.2024.13.00412

across every time interval. This approach assigns higher weights to recent data, which reduces geometrically with time, to estimate the parameter using a weighted mean sequence using the Maximum Likelihood methodology. $EWMAV_n$ is described as

$$EWMAV_n = \lambda * CovV_{n-1} + (1-\lambda) * r_n$$

where, λ is a weighted constant such that $\lambda \in [0,1]$.

Results

Non-parametric Spearman rank correlation tests were employed to investigate the relationship between COVID-19 occurrences and ecological indicator factors. Excel and the R programming language were used for all statistical analyses. Table 5 shows the mean pollutant concentrations throughout the various lockdown and unlock periods as well as the percentage shifts from the pre-lockdown. The pre-lockdown period spanned from March 1 to March 24, followed by lockdown phases 1.0, 2.0, and 4.0, which were respectively from March 25 to April 14, April 15 to May 3, May 4 to May 17, and May 18 to May 31. Phases 1.0 and 2.0 of the unlock were from June 1 to June 30 and beyond, respectively. In summary, the findings indicate that the lockdown had a significant effect on air quality compared to the pre-lockdown period. Specifically, the average $PM_{2.5}$ level decreased by up to 37% during lockdown and up to 60% following un-lockdown 2.0. In a similar vein, during lockdown and um-lockdown 2.0, PM_{10} levels dropped by up to 26% and 53%, respectively (Table 5). This has resulted in less industrial activity, a halt to construction projects, and a decrease in on-road traffic. However, during the full un-lockdown phase, $PM_{2.5}$ and PM_{10} levels began to rise once more. This might be the result of the lockdown regulations being loosened more, which would allow emissions from vehicles and other human activity to return. Additionally, using machinery for work and mobilizing industrial activities contribute to the problem during this time by increasing the amount of dust particles in the air.

Figure 2 shows monthly COVID-19 infections and incidents of death. This shows that COVID-19 spread quickly in Telangana at the start of the lockdown and then picked up speed at the end. In a similar vein, the death toll initially rose quickly. In the initial few months, the number of dying cases reached the level seen in Figure 2. The correlation is used to analyze the relationship between COVID-19 incidence mortality and air pollution. Tables 2 through 4 show the matrices for the three phases: the lockdown phase, the unlock phase, and the overall duration. During the lockdown, very few pairs of parameters' correlation coefficients proved to be significant (Table 2). During the lockdown period, there is a strong negative connection (p-value < 0.05) between the cumulative cases and $PM_{2.5}$ (r = -0.89), PM_{10} (r = -0.76), NH_3 (r = -0.84), and CO (r = -0.94). Additionally, these metrics have a negative correlation, which could just be a coincidence brought on by the shutdown (Table 2). Based on the results, there was a strong association in the unlock phase between COVID-19 instances and $PM_{2.5}$ (r = -1.0), PM_{10} (r = 0.68), NO_2 (r = -0.91), NH_3 (r = -0.98), CO (r = -0.83), SO_2 (r = 0.98), and O_3 (r = -0.98) parameters. The majority of COVID-19 cases and fatalities are positively associated with temperature.

Table 2 Spearman's correlation coefficient during the lockdown stage

Lockdown	SO_2	NO_x	$PM_{2.5}$	PM_{10}	NH_3	O_3	CO	Benzene	AQI	Noise	Confirmed cases	Confirmed deaths	Temp
SO2	1.00												
NOx	0.73*	1.00											
PM2.5	0.90*	0.36	1.00										
PM10	0.98*	0.56	0.97*	1.00									
NH3	0.94*	0.45	0.99*	0.99*	1.00								
O3	-0.16	0.56	-0.58	-0.37	-0.49	1.00							
CO	0.84*	0.24	0.99*	0.94	0.97*	-0.67*	1.00						
Benzene	1.00*	0.74*	0.89*	0.97	0.94*	-0.15	0.83*	1.00					
AQI	0.96*	0.50	0.99*	1.00*	1.00*	-0.44	0.96*	0.95*	1.00				
Noise	0.72*	1.00*	0.34	0.55	0.44*	0.57	0.22	0.73*	0.48	1.00			
Confirmed Cases	-0.60*	0.10	-0.89*	-0.76*	-0.84*	0.88*	-0.94*	-0.60*	-0.81*	0.12	1.00		
Confirmed Deaths	-0.48	0.25	-0.82*	-0.66*	-0.75*	0.94*	-0.88*	-0.47	-0.72*	0.26	0.99*	1.00	
Temperature	-0.50	0.23	-0.83*	-0.68*	-0.77*	0.93	-0.89*	-0.49	-0.73*	0.24	0.99*	1.00*	1.00

Table 3 Spearman's correlation coefficient for unlock stage

Unlock	SO_2	NO_x	$PM_{2.5}$	PM_{10}	NH_3	O_3	CO	Benzene	AQI	Noise	Confirmed cases	Confirmed deaths	Temp
SO2	1.00												
NOx	-0.97*	1.00											
PM2.5	-0.97*	0.89*	1.00										
PM10	0.81*	-0.93*	-0.65*	1.00									
NH3	-1.00*	0.98*	0.97*	-0.82*	1.00								
O3	-1.00*	0.97*	0.97*	-0.81*	1.00*	1.00							
CO	-0.93*	0.99*	0.81*	-0.97*	0.93*	0.92*	1.00						
Benzene	0.94*	-0.99*	-0.84*	0.96*	-0.95*	-0.94*	-1.00*	1.00					
AQI	0.86*	-0.95*	-0.71*	1.00*	-0.86*	-0.85*	-0.99*	0.98*	1.00				
Noise	-0.83*	0.68*	0.94*	-0.36	0.83*	0.84*	0.57	-0.61*	-0.43	1.00			

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Table 3 Continued...

Unlock	SO_2	NO_x	$PM_{2.5}$	PM_{10}	NH_3	O_3	CO	Benzene	AQI	Noise	Confirmed cases	Confirmed deaths	Temp
Confirmed Cases	0.98*	-0.91*	-1.00*	0.68*	-0.98*	-0.98*	-0.83*	0.86*	0.73*	-0.93*	1.00		
Confirmed Deaths	1.00*	-0.95*	-0.99*	0.77*	-1.00*	-1.00*	-0.90*	0.92*	0.81*	-0.87*	0.99*	1.00	
Temperature	-1.00*	0.94*	0.99*	-0.75*	0.99*	1.00*	0.88*	-0.91*	-0.80*	0.89*	-0.99*	-1.00*	1.00

Table 4 Spearman's correlation coefficients for the whole study period (Lockdown, Unlock, and continued till June 2022

	SO_2	NO_x	$PM_{2.5}$	PM_{10}	NH_3	O_3	CO	Benzene	AQI	Noise	Temp	Confirmed cases	Confirmed deaths
SO_2	1.00												
NO_x	0.31	1.00											
$PM_{2.5}$	0.53	0.70*	1.00										
PM_{10}	0.55	0.72*	0.97*	1.00									
NH_3	0.20	0.01	0.48	0.53	1.00								
O_3	0.52	0.46	0.60*	0.62*	0.22	1.00							
CO	0.47	0.52	0.91*	0.87*	0.59	0.44	1.00						
Benzene	0.30	0.09	0.59	0.56	0.71*	0.32	0.60*	1.00					
AQI	0.51	0.73*	0.98*	0.99*	0.52	0.54	0.87*	0.57	1.00				
Noise	0.23	0.28	0.02	0.08	-0.17	0.41	-0.16	-0.17	0.03	1.00			
Temp	-0.26	-0.55	-0.54	-0.51	-0.05	-0.05	-0.34	-0.29	-0.56	0.08	1.00		
Confirmed Cases	-0.17	0.08	-0.17	-0.13	-0.38	-0.17	-0.29	-0.31	-0.14	0.10	0.07	1.00	0.89
Confirmed Deaths	-0.33	0.04	-0.33	-0.32	-0.50	-0.21	-0.41	-0.46	-0.31	0.17	0.26	0.89*	1.00

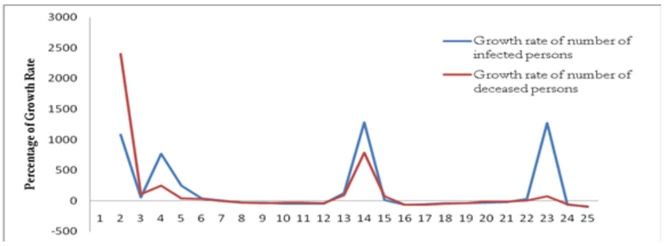

Figure 2 Growth rate of infected and deceased people.

There has been a notable 21 percent increase in the AQI over the prior year period. The limitations placed on industrial operations, the suspension of human activity and transportation, and other measures taken to contain the coronavirus transmission in the State can undoubtedly be attributed to the improvement in the AQI. On the majority of the days during the lockdown, these cities' AQI levels fell into the satisfactory class (51–100) (Table 5). This discussion leads to the conclusion that ambient air quality in Hyderabad and GHMC areas significantly improved during the lockdown enforced because of the COVID-19 pandemic. Additionally, the Correlogram (Figure 3) is a graphical representation of a correlation matrix that highlights the most correlated variables; the color intensity indicates the correlation coefficient between environmental variables and COVID-19 incidences, with positive correlations shown in blue and negative correlations in red.

Table 5 Average concentration of criteria pollutants in pre-lockdown (PL), lockdown (LD1, LD2, LD3, LD4), and unlock stages (UL1, UL2) and their reduction concerning PL (average values)

Concentrations (in μg/m³)									
Phases	SO_2	NO_x	$PM_{2.5}$	PM_{10}	NH_3	O_3	CO	Benzene	AQI
Pre Lockdown	4.5	34.2	50.8	101.5	39.4	27.6	0.6	0.9	100.3
Lockdown	3.5	25.5	32.0	74.7	22.8	28.6	0.5	1.6	74.2
Unlock down	3.8	28.8	20.2	47.3	14.0	18.0	0.3	0.8	52.7
% change concerning pre-lockdown stage (PL)									
Pre Lockdown	-	-	-	-	-	-	-	-	-
Lockdown	**-21.5**	**-25.3**	**-37.1**	**-26.4**	**-42.1**	3.5	**-25.3**	79.6	**-26.0**
Unlock down	**-15.4**	**-15.8**	**-60.3**	**-53.4**	**-64.5**	**-34.8**	**-49.7**	**-10.1**	**-47.4**

The EWMA approach was used to assess the time-varying correlations between the environmental variables and COVID-19 occurrences (Figure 4) and deaths (Figure 5), and the results show that the variables are positively associated.

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DOI: 10.15406/bbij.2024.13.00412

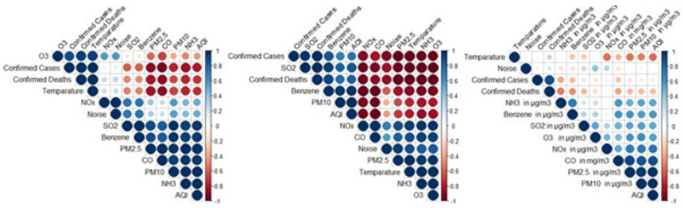

Figure 3 Correlogram for Lockdown, Unlock, and Whole Study Period (Mar -20 to June – 22).

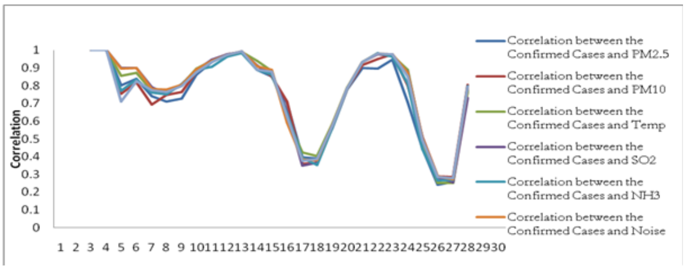

Figure 4 Time-varying correlations between environmental indicators and confirmed cases.

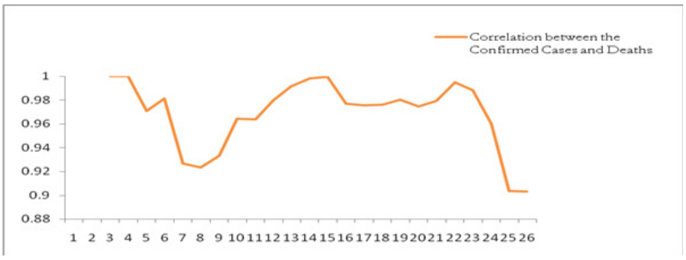

Figure 5 Time-varying correlation between the confirmed cases and deaths.

Discussion

An exclusive benefit and an abundance of forced lockdown, which shut down most human-caused activities like sectors, traffic congestion, and road and development of infrastructure, is the sharp decline in most major air pollutants like $PM_{2.5}$, PM_{10}, NO_2, and CO along with the AQI during lockdown (Table 5). These activities are key contributors to the two fractions of particulate matter and other air pollutants. Therefore, the primary cause of the dramatic drop in these pollutants during the lockdown periods is the closure of the transportation (road, rail, and aircraft) and industrial sectors. Therefore, the lesson learned from this COVID-19 lockout could provoke policymakers to utilize it as a benchmark or starting point for developing measures for improved air quality or managing air pollutants in metropolitan areas that are frequently disregarded, either directly or indirectly. Temperature is one of the meteorological characteristics that is said to have a significant impact on the spread of respiratory infections like influenza and SARS. These viruses often become more active in colder weather and become less active in warmer weather. Additionally, findings will contribute to the current debate about the influence of environmental factors on the spread of COVID-19 and aid in the implementation of control measures.

Conclusion

The COVID-19 lockdown has reduced the number of air pollutants, something the federal and state governments have been attempting to do for a while. One key lesson from this shutdown is to (1) reduce pointless activities as much as possible. (2) Promoting online learning and teaching activities and work-from-home projects. (3) Promoting online shopping (4) Promote carpooling, cycling, and the use of electric vehicles that consume less energy, and steer clear of needless vehicle trips. Therefore, to reduce carbon footprints and protect future generations from terrible diseases associated with air pollution, we must adopt more environmentally friendly practices and reorder our priorities. Now conclude that "immediate" improvements in air quality inside heavily industrialized and populated areas can enhance livelihood through pollution mitigation thanks to COVID-19. Policymakers might utilize these findings to establish new standards for air pollution that would enhance living conditions for large swaths of the global population. We can adjust when needed, as COVID-19 has demonstrated. The results could also guide future investigations that will help shape policy on the difficult decisions we will have to make between survival and quality of life.

Conflicts of interest

The author declares that there are no conflicts of interest.

Acknowledgments

None.

Funding

None.

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