Science of the Total Environment 737 (2020) 139659

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Temperature and precipitation associate with Covid-19 new daily cases: A correlation study between weather and Covid-19 pandemic in Oslo, Norway

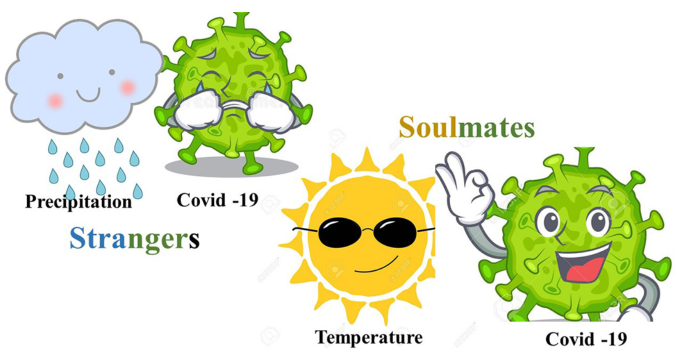
Mesay Moges Menebo

University of South-Eastern Norway, Norway

HIGHLIGHTS

- Temperature and precipitation associate with the incidence of daily covid-19 cases.
- Maximum and normal temperature are positively associated with covid-19. Whereas Precipitation is negatively related.
- One hypothesis for the association could be that rainfall (vs sunny weather) boosts the 'stay-home' rules
- A second hypothesis could be that sunny weather make people prone to break 'stay-home' rules and puts up to virus exposure
- As countries change between weather seasons, the findings might be an input to a strategy making against covid-19 fight

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 3 May 2020
Received in revised form 21 May 2020
Accepted 22 May 2020
Available online 29 May 2020

Keywords:
Covid-19 new daily cases
Temperature
Precipitation

ABSTRACT

This study aims to analyze the correlation between weather and covid-19 pandemic in the capital city of Norway, Oslo. This study employed a secondary data analysis of covid-19 surveillance data from the Norwegian public health institute and weather data from the Norwegian Meteorological institute. The components of weather include minimum temperature (°C), maximum temperature (°C), temperature average (°C), normal temperature (°C), precipitation level (mm) and wind speed (m/s). Since normality was not fulfilled, a non-parametric correlation test was used for data analysis. Maximum temperature ($r = 0.347$; $p = .005$), normal temperature($r = 0.293$; $p = .019$), and precipitation level ($r = -0.285$; $p = .022$) were significantly correlated with covid-19 pandemic. The finding might serve as an input to a strategy making in the prevention of covid-19 as the country prepare to enter into a new weather season.

E-mail address: Mesay.Moges.Menebo@usn.no.

https://doi.org/10.1016/j.scitotenv.2020.139659

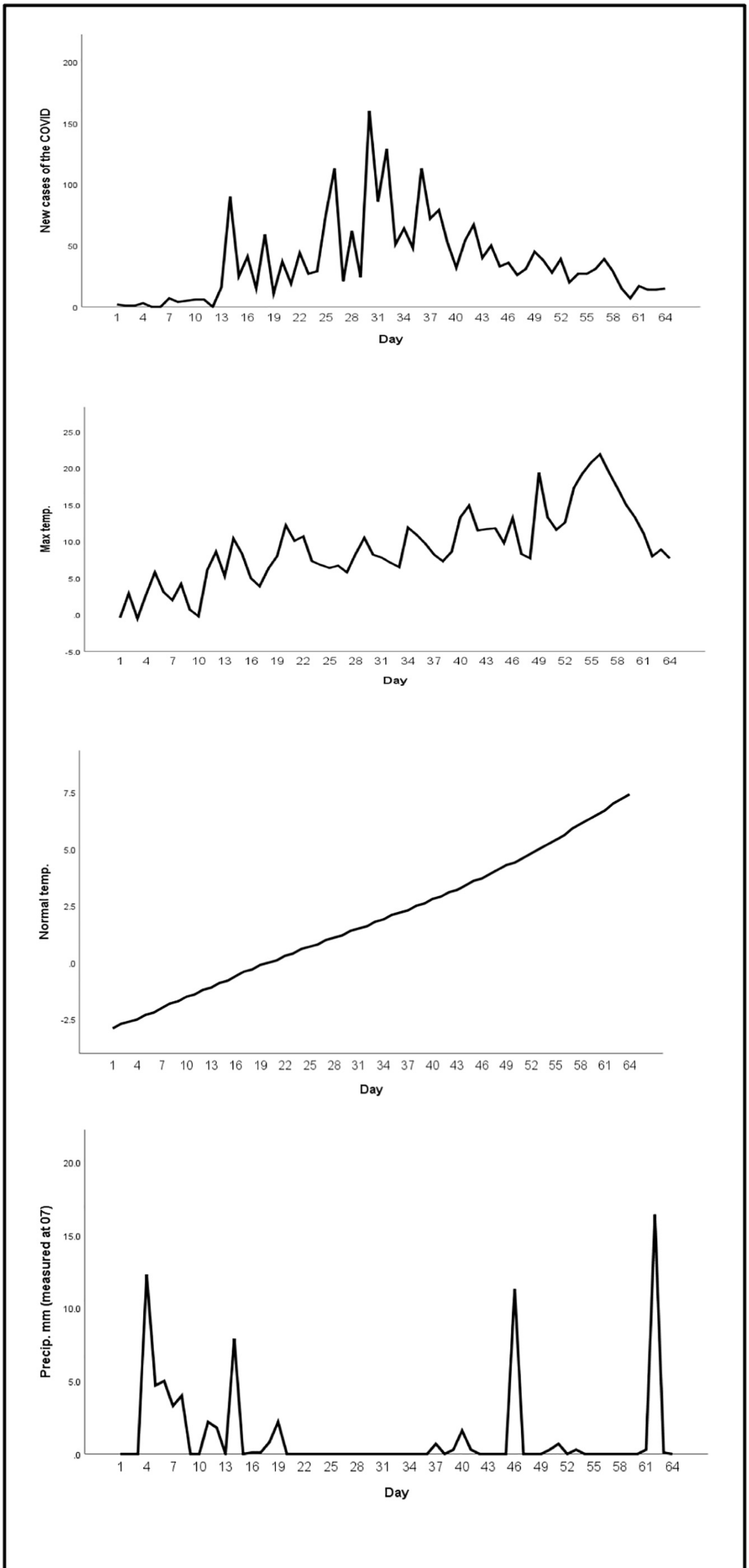


Fig. 1. (a) New daily cases of the Covid-19, (b) the amount of temperature maximum(°C), (c) normal temperature (°C), (d) precipitation (mm), in Oslo, Norway February 27–May 2, 2020.

1. Introduction

The Chinese government announced a new type of pneumonia, coronavirus (covid-19), with an obscured etiology on January 7, 2020 (WHO, 2020a). The rapid spread severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has led to the declaration of a global pandemic barely three months after its emergence. The infection included symptomatic or asymptomatic manifestations where 80% of infections are mild (no pneumonia manifestations) or asymptomatic(WHO, 2020b). Most people infected experience mild to moderate respiratory illness such as fever, coughing and shortness of breath. Most estimates of the incubation period for Covid-19 range from 1 to 14 days, most commonly around five days (Linton et al., 2020). In more severe cases, infection can cause pneumonia, severe acute respiratory syndrome, kidney failure and even death (Cheng et al., 2020). Fever (<39.1 °C) was the most frequent symptom, and Cough is the second most common symptom observed (Gu et al., 2020). Other symptoms reported include headache, rhinorrhea, gastrointestinal symptoms, sore throat, and fatigue (Michelen et al., 2020).

Norway have reported the first confirmed case of covid-19 on February 26, 2020 (FHI, 2020). As of May 3, 2020, it has increased to 7809 total confirmed cases, which means a 1.47 infection per 1000. The capital city Oslo has registered the highest number of cases (2399, 3.46/1000) followed by other provinces nearby like Viken (2088, 1.68/1000) (FHI, 2020).

According to studies (Wang et al., 2010), there are possibilities that extreme weather conditions might play a role in the rapid spread of the virus. Latitude and seasonality may also predict potential spread of COVID-19 (Sajadi et al., 2020). Previous studies on respiratory diseases have also considered certain climatic conditions as predisposing factors (D'Amato et al., 2014). Accordingly, climate components like temperature, rainfall and wind speed might in this specific case of covid-19 be biological catalysts for the interaction between covid-19 and humans. Virus transmission is affected by a number of factors, including host behavior, host defense mechanisms, and virus infectivity (Cory, 2015), population density (Brown et al., 2008) and environmental determinants. Uncertainties remain with respect to the relative importance of environmental factors and the roles that they play on covid-19. Especially little is known in Nordic countries that have four different weather seasons where the variability of weather change between days is large. Hence, this research will contribute to efforts against covid-19 as countries enter into new weather seasons and align their lock-down strategy measures accordingly.

2. Methods

2.1. Study area

Oslo, the capital of Norway, sits on the country's southern coast at the head of the Oslofjord. As of 4 November 2019, the municipality of Oslo has a population of 1,019,513 (SSB, 2019). 130 km^2 of Oslo's total area is built-up and the open areas within the built-up zone amount to 22 km^2. Oslo has a humid continental climate with warm summers and cold winters and a significant amount of rainfall during the year (ClimateData, 2018).

Table 1
Variables descriptive statistics.

Variables	Minimum	Maximum	Mean
Daily new cases	0	160	37
Min temp (°C)	−7.5	7.8	0.82
Max temp(°C)	−0.5	21.9	9.26
Average temp(°C)	−4.2	14.2	4.76
Normal temp (°C)	−2.9	7.4	1.89
Precipitation (mm)	0	16.4	1.19
Wind speed (m/s)	1.3	6.6	3.32
Highest wind speed (m/s)	2.2	10.3	5.90

Table 2
Relationship between the number of daily new cases of covid-19 and weather components.

Weather components	Spearman's correlation coefficient
Minimum temperature (°C)	0.062
Maximum temperature (°C)	0.347**
Average temperature (°C)	0.224
Normal temperature (°C)	0.293*
Precipitation(mm) measured at 07 am	−0.285*
Wind speed (m/s)	0.174
Highest wind speed (m/s)	0.233

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.

2.2. Data collection

A secondary data on daily cases of covid-19 with 64 (N) observations was obtained from the Norwegian public health institute database and weather data from the Norwegian Meteorological institute for the period February 27–May 2, 2020. The components of weather include minimum temperature (°C), maximum temperature (°C), temperature average (°C), normal temperature (°C), precipitation level (mm) and wind speed (m/s).

2.3. Data analysis

The basic assumption of Pearson's correlation for the variable '*number of daily new cases of covid-19*' was not fulfilled (*Shapiro-wilk test of normality*, $p < .0001$). Hence, the non-parametric correlation estimation (Spearman correlation coefficient) was used to examine and determine the relationships between covid-19 pandemic and weather components. A bivariate, two-tailed analysis at 95% confidence interval was applied.

3. Results and discussion

Covid-19 new cases escalated very rapidly in Norway, especially during day 25 to day 40 (see Fig. 1(a)). In the first 12 days after first confirmation of the case, the change in increase of new daily cases was near to zero. Since day 13, the daily reported new cases started to triple until it gradually came to a low daily increase on day 61. Descriptive overview of the weather data indicates (see Table 1) a minimum temperature of −7.5 °C and the highest maximum temperature of 21.9 °C during the study period. In addition to that, 0 mm was the lowest recorded rainfall while 16.4 mm was the highest. The lowest wind speed recorded on day 8 with value of 1.3 m/s and highest wind speed of 6.6 m/s on day 47.

Among the seven weather variables, maximum temperature ($r = 0.347$; $p = 005$), and normal temperature ($r = 0.293$; $p = .019$) were positively and significantly correlated with covid-19. In the contrary, precipitation that was measured at 7 am was negatively and significantly correlated with covid-19. However, the other weather variables (Minimum temperature, Average temperature, wind speed, highest wind speed) were not significantly correlated with covid-19.

In this study, the pattern of climate change provides a picture of the occurrence of covid-19 in Oslo. A preliminary evidence is found to state that high temperature (normal and maximum) and low precipitation (rainfall) level positively associate with incidence of Covid-19 (Table 2). This association is in line with previous research that shows the impact of temperature, dry weather and precipitation on human west Nile virus infections (Ruiz et al., 2010; Wang et al., 2010). A variety of arguments can be given for the positive relationship between temperature and new cases. One could be a hypothesis that people are more prone to break lock-down 'stay-home' rules when the sun is shining outside, so eventually become exposed to the virus. In the contrary,

Table 3
Assumptions of *Test date-Daily new cases-Infection date-Weather information* matching process and correlational comparison of results in four assumptions.

	Daily new cases				
	Test date = Infection date	Test date = Infection date +5 days	Test date = Infection date +6 days	Test date = Infection date +14 days	A portion of the data samples could have been tested at 5, other portion at 6, or other portion at 14 and some at unknown incubation dates.
Minimum temperature (°C)	0.062	0.096	0.009	−0.018	Limitation (Future studies could employ Vector AutoRegressive Models)
Maximum temperature (°C)	0.347**	0.220 ($p = .081$)	0.118	−0.015	
Average temperature (°C)	0.224	0.119	0.067	−0.091	
Normal temperature (°C)	0.293*	0.293*	0.293*	0.293*	
Precipitation(mm) measured at 07 am	−0.285*	−0.141	−0.287*	−0.216	
Wind speed (m/s)	0.174	0.147	0.127	−0.140	
Highest wind speed (m/s)	0.233	0.177	0.076	−0.156	

Note; Assumptions of matching *Test date-Daily new cases-Infection date-Weather information* were drawn before the correlational analysis. Findings on the first column are based on an assumption that testing was conducted without requirement of any symptoms as a pre-requisite for testing (e.g. a public mass testing campaigns). In this case, it could be that infection date and testing date are the same. Therefore weather information of the test date were considered in the analysis. Second is, an incubation period of days were considered since the Norwegian institute of public health at some point had some recommendations that testing should be conducted for people only with acute respiratory tract infection symptoms (e.g. fever, cough or breathing difficulties, or who a doctor suspects has COVID-19). In this case, infection date was considered 5, 6 or 14 days (corona incubation periods, 5–6 are common) before test date. Accordingly, weather information 5 days, 6 days or 14 days earlier to the testing date were considered in the correlation analysis column 2, column 3 or column 5 respectively.
** Correlation is significant at the 0.01 level;
* Correlation is significant at the 0.05 level.

the negative relationship between precipitation and new cases is the reverse: whereby people avoid coming out if it is rainy.

The implications in this study oppose with a recent finding from China by J. Wang et al. (2020) where their study claimed that high temperature and high humidity reduce the transmission of Covid-19. To answer the question of 'when or where is it/is not weather important on impacting covid-19 incidence?' requires an investigation of a moderating variable of the effect.

In spite of the weather, it is believed that factors like high mobility, population density, household condition contribute much to new covid-19 in big cities like Oslo. As the capital city of Norway, Oslo is the main economic destination for job seekers who come from various regions, making it the fastest growing major city in Europe at the time. Oslo's population density is also very high and this allows covid-19 transmission to be very fast. Oslo's municipality has an average of 1400 people per square kilometer, outpaced by the population density of Oslo's total urbanized area which is about 1500 people per square kilometer once its surrounding boroughs are factored in (Metrics, 2020). With population density like this allows covid-19 to spread rapidly (Kuchler et al., 2020).

This study brings new insight on the relationship of precipitation, temperature and new covid-19 cases, and could assist local policymaking. However, it still has its own limitations: Primarily, the impact of other key factors-, which might have greatly influenced the core relationship like lock-down implementation, testing capacities, development of herd immunities, sanitization attitudes were not accounted. Secondly, correlational analysis assumes linear relationship between two variables that correlates. In this study, testing dates (daily corona cases) might not exactly imply to infection dates (or virus transmission dates). It could be possible that the daily corona case reported on the testing dates has same infection date or a lag of incubation periods. Therefore, which date's weather information data to grab to match with the daily new cases is ill-defined and another limitation of this study. As an intervention to this problem, three additional correlational relationships (see Table 3) assuming weather information data from 5, 6 or 14 days (Covid-19 incubation periods) earlier to the dates the corona daily cases were reported is also conducted and compared with the main correlational analysis. The relationship significance between normal temperature (°C) and daily new corona cases is consistent in all the four scenarios, while the relationship significance between precipitation (mm) and daily new corona cases is consistent in the two scenarios.

4. Conclusion

Temperature and precipitation correlate with the incidence rate of daily covid-19 cases in Oslo. Maximum temperature and normal temperature are positively associated with covid-19. Whereas precipitation is associated negatively. One hypothesis could be that rainfall (vs sunny weather) boosts the 'stay-home' rules.

CRediT authorship contribution statement

Mesay Moges Menebo: Conceptualization, Methodology, Software, Validation, Resources, Formal analysis, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2020.139659.

References

Brown, H.E., Childs, J.E., Diuk-Wasser, M.A., Fish, D., 2008. Ecologic factors associated with West Nile virus transmission, northeastern United States. Emerg. Infect. Dis. 14 (10), 1539.
Cheng, Y., Luo, R., Wang, K., Zhang, M., Wang, Z., Dong, L., ... Xu, G., 2020. Kidney disease is associated with in-hospital death of patients with COVID-19. Kidney international 97 (5), 829–838.
ClimateData, 2018. . Retrieved from. https://en.climate-data.org/europe/norway/oslo/oslo-81/.
Cory, J.S., 2015. Insect virus transmission: different routes to persistence. Current Opinion in Insect Science 8, 130–135.
D'Amato, G., Cecchi, L., D'Amato, M., Annesi-Maesano, I., 2014. Climate Change and Respiratory Diseases. Eur Respiratory Soc.
FHI, 2020. Coronavirus disease - advice and information. Retrieved from. https://www.fhi.no/en/id/infectious-diseases/coronavirus/.
Gu, J., Han, B., Wang, J., 2020. COVID-19: gastrointestinal manifestations and potential fecal–oral transmission. Gastroenterology 158 (6), 1518–1519.
Kuchler, T., Russel, D., Stroebel, J., 2020. The Geographic Spread of COVID-19 Correlates with Structure of Social Networks as Measured by Facebook. pp. 0898–2937 (Retrieved from).
Linton, N.M., Kobayashi, T., Yang, Y., Hayashi, K., Akhmetzhanov, A.R., Jung, S.-M., ... Nishiura, H., 2020. Incubation period and other epidemiological characteristics of

2019 novel coronavirus infections with right truncation: a statistical analysis of publicly available case data. Journal of clinical medicine 9 (2), 538.

Metrics, M., 2020. Capital facts for Oslo, Norway. Retrieved May 2020. https://www.worldscapitalcities.com/capital-facts-for-oslo-norway/.

Michelen, M., Jones, N., Stavropoulou, C., 2020. In Patients of COVID-19, What Are the Symptoms and Clinical Features of Mild and Moderate Cases? Centre for Evidence-Based Medicine https://www.cebm.net/covid-19/in-patients-of-covid-19-what-are-the-symptoms-and-clinical-features-of-mild-and-moderatecase/accessed 16

Ruiz, M.O., Chaves, L.F., Hamer, G.L., Sun, T., Brown, W.M., Walker, E.D., ... Kitron, U.D., 2010. Local impact of temperature and precipitation on West Nile virus infection in Culex species mosquitoes in northeast Illinois, USA. Parasites & vectors 3 (1), 19.

Sajadi, M.M., Habibzadeh, P., Vintzileos, A., Shokouhi, S., Miralles-Wilhelm, F., Amoroso, A., 2020. Temperature and Latitude Analysis to Predict Potential Spread and Seasonality for COVID-19 (Available at SSRN 3550308).

SSB, 2019. Statistics Norway. Population, Q4 2019. Retrieved from. https://www.ssb.no/en/befolkning/statistikker/folkemengde/kvartal/2020-02-27.

Wang, G., Minnis, R.B., Belant, J.L., Wax, C.L., 2010. Dry weather induces outbreaks of human West Nile virus infections. BMC Infect. Dis. 10 (1), 38.

Wang, J., Tang, K., Feng, K., Lv, W., 2020. High Temperature and High Humidity Reduce the Transmission of COVID-19 (Available at SSRN 3551767).

WHO, 2020a. . Retrieved from. https://www.who.int/csr/don/05-january-2020-pneumonia-of-unkown-cause-china/en/.

WHO, 2020b. Coronavirus disease 2019 (COVID-19) situation report – 41. Retrieved from. https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200301-sitrep-41-covid-19.pdf?sfvrsn=6768306d_2.