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## Letter to the Editor

## Has SARS-CoV-2 evolved and adapted to circulate at high temperatures?

We read with interest the article of Tripathi et al.<sup>1</sup> who concluded that low temperatures and low sunlight may be important risk factors for boosting severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infectivity, especially in the northern hemisphere. This finding is in keeping with other previous studies, summarised in the meta-analysis of Majumder et al.,<sup>2</sup> and reporting a significant inverse correlation between air temperature and incidence of COVID-19. Nonetheless, SARS-CoV-2 has undergone a considerable genetic evolution over time, accumulating a kaleidoscope of mutations that may have dramatically altered its biological properties,<sup>3</sup> such as vulnerability and/or resistance to high air temperatures. To explore this phenomenon further, we investigated SARS-CoV-2 infectivity in the province of Verona (Italy) during the month of July of the first three pandemic years (i.e. 2020, 2021 and 2022).

The daily number of new COVID-19 diagnoses in the province of Verona between July 127 of the years 2020, 2021 and 2022 was retrieved from the database of the Regional Healthcare Service,<sup>4</sup> whilst the mean daily air temperature during the same period in the same area was downloaded from an official Italian meteorological website.<sup>5</sup> The study was conducted in accordance with the Declaration of Helsinki under the terms of relevant local legislation. This analysis was based on electronic searches in open and publicly available repositories such that no informed consent or Ethical Committee approval was necessary.

The results of our analysis are summarised in Fig. 1. The mean July air temperature in Verona was  $24 \pm 2^\circ\text{C}$  in 2020,  $25 \pm 2^\circ\text{C}$  in 2021 and  $28 \pm 2^\circ\text{C}$  in 2022. Nonetheless, the daily number of new COVID-19 diagnoses in the province of Verona increased from  $2.5 \pm 5.7$  in July 2020, to  $106.0 \pm 71.8$  in July 2021, up to

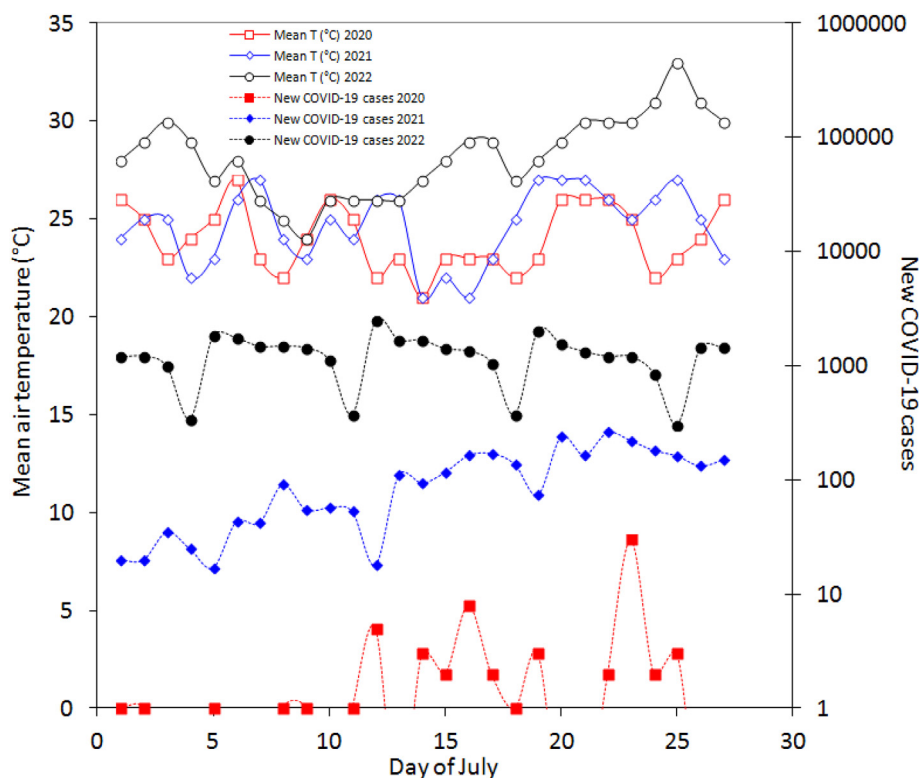


Fig. 1. The mean daily air temperature and new COVID-19 cases recorded in the province of Verona in July of the years 2020, 2021 and 2022.

1287.4 ± 509.9 in July 2022. The number of new COVID-19 diagnoses made in the province of Verona in July 2022 has hence increased by 519- and 12-fold in 2022 compared with the same month of the previous 2 years, despite the fact that the mean air temperature has also notably increased by 18% and 15% compared with the years 2020 and 2021, respectively.

The results of this analysis suggest that the strong evolutive pressure placed on SARS-CoV-2 over time may have fostered the accumulation of mutations that have contributed to evolving and adapting the virus to circulate even at high temperatures, as in July 2022 in Verona. Alternatively, the impact of temperature on viral transmissibility may be relatively constant but offset by the significant increase in infectivity with continued viral mutation over time. Higher daily average temperatures leading to more indoor activities and/or increased community transmission in light of decreased preventative health measures may also be contributing factors to our observations. Regardless of the cause, these findings have paramount public health consequences, in that some effective preventive measures for preventing SARS-CoV-2 infection (social distancing, use of face masks, hand hygiene) should not be abandoned even during the warmest periods of the year, whilst healthcare administrators and policymakers shall also consider that the number of SARS-CoV-2 infections needing hospitalisation may no longer decline during the hot season.

#### Author statements

##### Ethical approval

None declared.

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#### Competing interests

The authors declare no competing interests.

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G. Lippi\*

Section of Clinical Biochemistry and School of Medicine, University of Verona, Verona, Italy

C. Mattiuzzi

Service of Clinical Governance, Provincial Agency for Social and Sanitary Services (APSS), Trento, Italy

B.M. Henry

Clinical Laboratory, Division of Nephrology and Hypertension, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA

\* Corresponding author. Section of Clinical Biochemistry University Hospital of Verona Piazzale L.A. Scuro, 10 37134 Verona - Italy.  
Tel.: +39 045 8122970; fax: +39 045 8124308  
E-mail address: [giuseppe.lippi@univr.it](mailto:giuseppe.lippi@univr.it) (G. Lippi).

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