Analysis of viral dynamics of SARS-CoV-2 challenge study patients

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Introduction

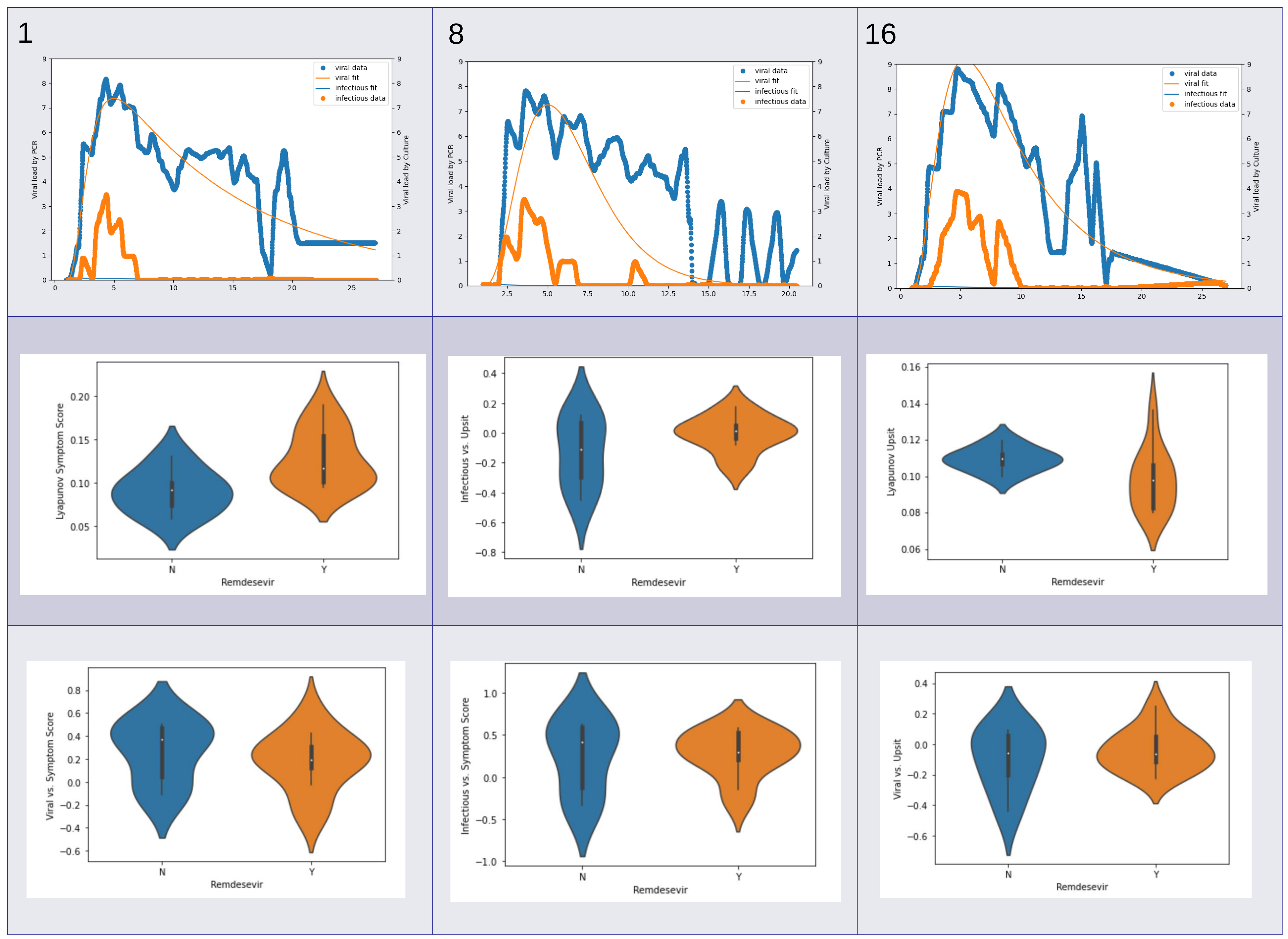
- Sars-CoV-2, also known as Covid-19, is a Coronavirus first discovered in Wuhan, China, in December 2019. Several months later, on March 11, 2020, the World Health Organization declared Covid-19 a pandemic.
- Since then, Covid-19 has led to over 6 million deaths worldwide and has become one of the deadliest pandemics in history.
- In addition, the Covid-19 pandemic has cost the United States alone 16 trillion USD, approximately 90% of the United States's GDP.
- Previous studies have aimed to quantify crucial viral coefficients for Covid-19 and understand the virus's infectious kinetics. Such an understanding is crucial for the development of treatment strategies and the prevention of infection.
- To get a better understanding of the Covid-19 virus's kinetics, Dr. Killingley and his team at UCL conducted a challenge study in which healthy young adults, ages 18 to 29, were purposely infected with the Covid-19 virus.
- Challenge studies are used to garner a better understanding of viruses that are difficult to research due to long latent infectious periods and inconsistent symptoms.

Methodology

- Dr. Killingley's published research included viral load measurements taken twice daily. This bi-daily viral load data was measured through qPCR and FFA.
- To calculate viral coefficients for Covid-19, this study fit a widely used differential equation model to the publicly available data from the Killingley et al. paper.
- Using Python mathematical packages data, each participant in the study had the model fit to their data, which determined important viral variables such as infection rate, eclipse phase lengths, and viral decay, among others.
- The Killingley study also collected upsit and symptom score data along with the bi-daily viral load measurements.
- Covariance between symptom and viral load was calculated for each participant using mathematical Python packages.
- Lyapunov exponents for the qPCR, FFA, Upsit, and Symptom Score for each participant were also calculated using Python packages.

Infectious vs. Upsit (Mean)	Viral vs. Upsit (Mean)	Infectious vs. Symptom Score (Mean)	Viral vs. Symptoms Score (Mean)
-0.049	-0.188	0.103	0.220

Lyapunov Exponent Viral (Mean)	Lyapunov Exponent Throat (Mean)	Lyapunov Exponent Viral Upsit Score (Mean)	Lyapunov Exponent Symptoms Score (Mean)
0.173	0.164	0.183	0.102



This study attempted to measure each stage of Covid-19's spread through the human body to better understand how it is transmitted from person to person and if symptoms reflect the severity of the illness. However, the equations usually used to model other Covid-like viruses did not prove effective with the data and could not generate a proper measurement. Also, the study concluded that there is little correlation between the amount of Covid-19 virus in the human body and the severity of symptoms. Future research will include testing other equation models to see if they fit the data better.

Let's Talk Science

Differential Equation System

$$\begin{aligned}
\frac{dT}{dt} &= -\beta T V_{\text{inf}} \\
\frac{dE}{dt} &= \beta T V_{\text{inf}} - kE \\
\frac{dI}{dt} &= kE - \delta I \\
\frac{dV_{\text{inf}}}{dt} &= pI - c_{\text{inf}} V_{\text{inf}} \\
\frac{dV_{\text{DVG}}}{dt} &= \rho I - c_{\text{DVG}} V_{\text{DVG}}.
\end{aligned}$$

Results and Conclusions

- The average RSS of the differential equation model on the data was 4e3, indicating that the model did not catch the nuances of the data.
- Due to the model's underfitting, the viral coefficients generated by this differential system are likely inaccurate and do not truly reflect the nature of the Covid-19 virus.
- There is weak correlation between severity of symptoms and viral load, which was expected considering many of the participants did not show symptoms until long after infection.
- The Lyapunov exponents of the viral load, symptom scores, and upset scores were positive and small, thus indicating that there is little chaos in the data.
- Future research will consist of applying new differential equation systems with diversified parameters to generate a better fit.

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