

Modeling Update: The Current State of COVID-19 in Colorado

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Prepared by the Colorado COVID-19 Modeling Group

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Summary

- The reproductive level is < 1 and transmission control remains at 82%.
- Infection prevalence has continued to drop but remains high at 1 in 105.
- Any effect of holidays is not yet manifest, but insufficient time has elapsed. Rising case counts and percent positivity over the last week are concerning.
- Time away from home is increasing across the state. Out of state ski visitation is increasing.

Snapshot of Current SARS-CoV-2 Transmission in Colorado Based on COVID-19 Hospitalization Data Through 01/04

Effective reproduction number: 0.7 (95% CI: 0.67, 0.73).

Infections are decreasing.

Estimated prevalence of infections: Approximately 960 (95% CI: 904, 1,000) of every 100,000 Coloradans or 1 in every **105** Coloradans are currently infectious.

The estimated infection prevalence is lower than last week.

Estimated number of infections to date: Approximately 22.5% (95% CI: 22.4%, 22.6%) of the Colorado population has been infected to date.

Estimated current level of transmission control: 82% (95% CI: 81.6%, 83.1%) for the period of 12/06 to 12/22.

There is an approximate 82% reduction in total transmission-relevant contacts, including reductions due to mask-wearing, physical distancing, contact tracing, self-isolation, and all other policy and behavioral changes compared to uncontrolled transmission, as in the very early days of the pandemic.

Snapshot of the Potential Future Trajectory of SARS-CoV-2 in Colorado

In the next two weeks: At the end of the next two weeks, there is a 50% chance that the count of patients hospitalized with COVID-19 will be at least 610, including 200 patients in the ICU, if we remain on the current trajectory at 82% transmission control.

Introduction

We used our age-structured SEIR (susceptible-exposed-infected-recovered) model and COVID-19 hospital census data to characterize the current status of the COVID-19 epidemic in Colorado and the collective impact of efforts to date to reduce the spread of the SARS-CoV-2 virus. We use these estimates of the current state of the epidemic to generate projections of the potential future course of SARS-CoV-2 in Colorado under different scenarios of transmission control measures. These include estimates of hospital needs over the next two weeks based on the current estimated trajectory, and long-term projections that consider the impact of changes in transmission control level due to policies and/or behaviors.

The model has been parameterized to Colorado-specific data whenever possible. For example, the length of time a COVID-19 patient is assumed to spend in the hospital varies by age and over time, and is based on data provided by Colorado hospitals. Further details and model documentation are available at <https://agb85.github.io/covid-19/SEIR%20Documentation.pdf> This report provides updates from the most recent model fit and short-term projections. The estimates presented in this report are based on hospitalization data through **01/04**. Longer-term projections will be released during the week of January 11-15.

COVID-19 Hospitalizations

Figure 1 shows the daily number of people hospitalized with COVID-19 since March 2020, when the first case of SARS-CoV-2 was reported in Colorado. COVID-19 hospitalizations are a sensitive measure of SARS-CoV-2 transmission. While many SARS-CoV-2 infections are not captured by surveillance systems, we expect that almost all COVID-19 hospitalizations are identified.

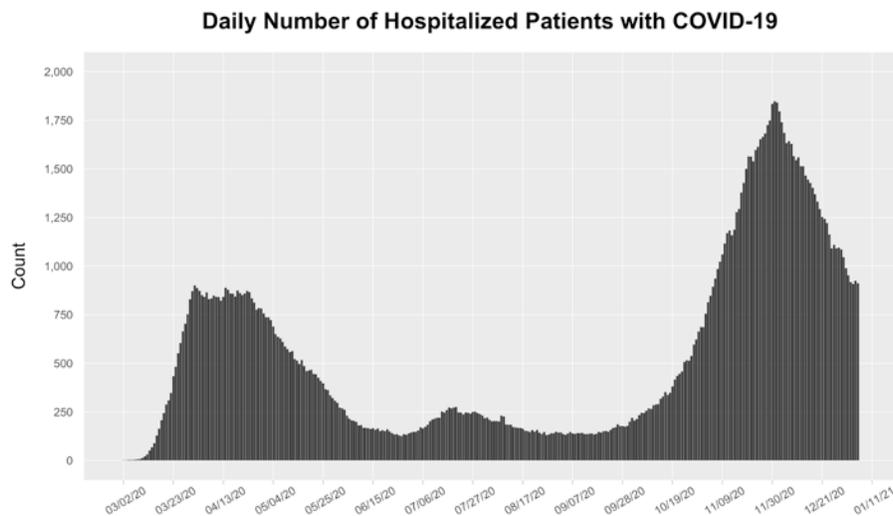


Figure 1 (above). Daily count of hospitalized COVID-19 cases through 01/04. The time series of COVID-19 hospitalizations in Colorado is based on hospitalization data provided by CDPHE through 4/07/2020 and the EMResource hospital census of COVID-19 hospitalizations starting 4/08/2020 (EMResource hospital census appeared to undercount COVID-19 hospitalizations before that date).

Transmission Control

Transmission control is an estimate of the collective impact of behaviors and policies such as mask wearing, physical distancing, case isolation, contact tracing, and moving activities outside. When transmission control is 0%,

spread of infections is uncontrolled, as in the very early days of the pandemic. When transmission control is close to 100%, the spread of the virus from an infected person to others is rare. We estimate transmission control for each two-week period since March (Figure 2). Transmission control is estimated by fitting model output to hospitalization data using model fitting approaches.

Our current estimate of transmission control is 82% (95% CI: 81.6%, 83.1%). This estimate is for the period 12/06 to 12/22, given the timespan between infection and hospitalization.

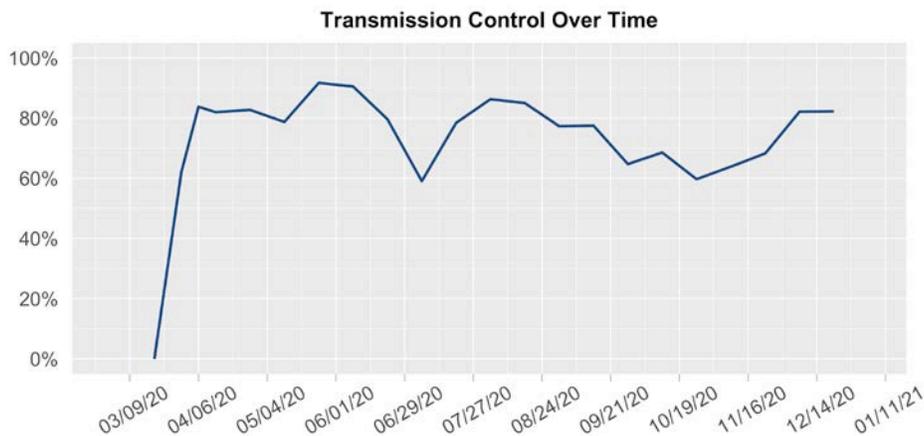
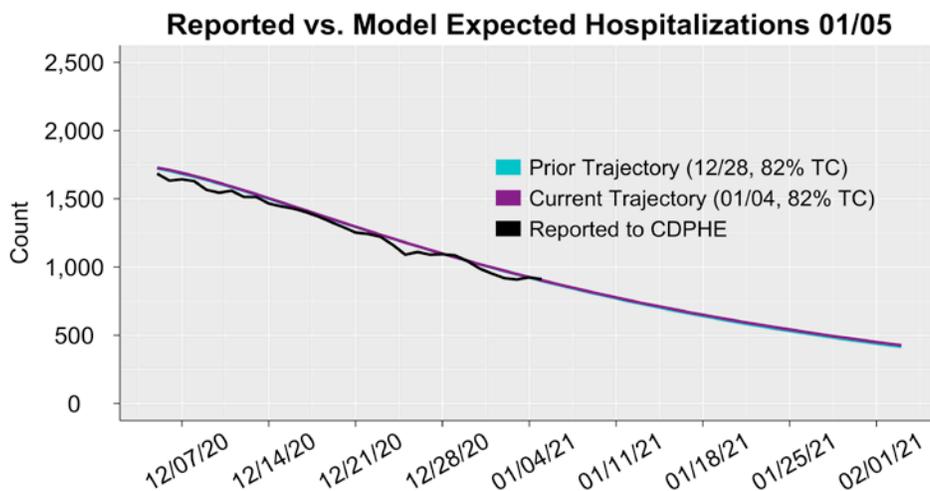


Figure 2 (above). The estimated transmission control value for each two-week period since the beginning of the epidemic. On the graph, the value is shown for the mid-point of each two-week period. Transmission control is estimated using model fitting approaches to align model output with COVID-19 hospitalizations.

Model Fit

We assess model fit by comparing the model-estimated number of hospitalizations to actual hospitalizations. Figure 3 shows the current estimated trajectory of hospitalizations, based on the most recent model-fit, compared to the daily reported number of people hospitalized with COVID-19. For reference, a line showing the estimated trajectory one-week prior is also shown.



911 Active COVID-19 Hospitalizations as of Tuesday, 01/05

Figure 3 (above). The projected course of COVID-19 hospitalizations if Colorado were to remain on the current estimated trajectory (purple line) or on the trajectory estimated one week prior (turquoise line). Each trajectory is generated assuming transmission control remains at the current or one-week prior estimate.

The Effective Reproduction Number

The effective reproduction number (R_e) is a measure of how rapidly infections are spreading or declining. When the effective reproduction number is below 1, infections are decreasing. When the effective reproduction number is above 1, infections are increasing. The effective reproduction number is estimated using our age-structured SEIR model fit to hospitalization data.

Our current estimate of R_e is 0.7. Due to the lag between infections and hospitalizations, this estimate of R_e reflects the spread of infections occurring on approximately 12/22. The estimated values of the reproduction number since March are shown in Figure 4 and the most recent three estimates are presented in Table 1.

Table 1 (below). Estimates of the effective reproduction number (R_e) in Colorado over the last three weeks based on the SEIR model. We also include estimates from RT-Live, an external source that calculates the reproductive number using reported SARS-CoV-2 cases and testing data. Note that the confidence interval for RT-Live is an 80% CI around the mean point estimate.

	Current Estimate (01/04)	Estimate One Week Prior (12/28)	Estimate Two Weeks Prior (12/21)
Estimate of R_e , approach 1, TC model*	0.70 (0.67, 0.72)	0.72	0.72 (0.70, 0.75)
Estimate of R_e , approach 2, TC model*	0.71	0.72	0.73
Estimate from RT-Live	1.09 (0.86, 1.29)	0.94 (0.71, 1.09)	0.95 (0.74, 1.1)

*Our estimates are based on hospitalization data through the date listed. Estimates from the external sites are extracted on the date listed. Due to the lag between infection and hospitalization, our estimates reflect transmission approximately 13 days prior to the date listed. Approach 1 uses model output to estimate the average number of new cases generated by existing cases, accounting for the latent period and duration of infectiousness. The second method uses the model structure to estimate the dominant eigenvalue for a matrix describing population flows across the model compartments.

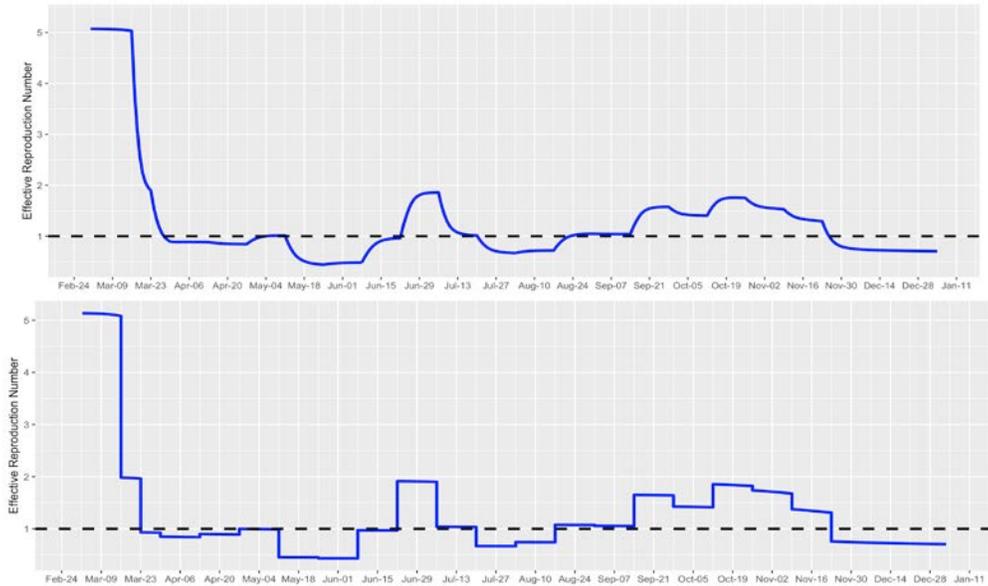


Figure 4 (above). Estimates of the effective reproduction number over time, using approach 1 (top) and approach 2 (bottom) based on the TC model.

Infection Prevalence

Infection prevalence provides an estimate of the proportion of the population that is currently (as of 01/04) infected with SARS-CoV-2 and capable of spreading infections. At higher levels of infection prevalence, susceptible individuals are more likely to encounter infectious individuals among their contacts. Because many people experience no symptoms or mild symptoms of COVID-19, many infections are not identified by surveillance systems. The estimates we present here are intended to provide an approximation of all infections, including those detected and not detected by the Colorado Electronic Disease Reporting System (CEDRS).

Infection prevalence is estimated using our age-structured SEIR model fit to hospitalization data. These estimates are generated by assuming the most recent transmission control parameter (estimated for the period 12/06 to 12/22) remains at the estimated value through 01/04. These estimates are sensitive to the model assumptions, including assumptions about the probability an infected individual will be symptomatic and require hospital care, and assumptions about length of hospital stay, which vary over time; we assume that all variables vary by age category.

We estimate that there are approximately 55,900 (95% CI: 52,797, 58,408) infectious individuals in Colorado at present (01/04): approximately 960 (95% CI: 904, 1,000) of every 100,000 Coloradoans or 1 in every 105 people (95% CI: 100, 111).

Figure 5 illustrates the estimated infection prevalence over time in comparison to the number of hospitalized COVID-19 patients. Because, on average, COVID-19 patients are spending less time in the hospital now than at the start of the pandemic, more infections are estimated per hospitalized COVID-19 patient now compared to March when stays were substantially longer.

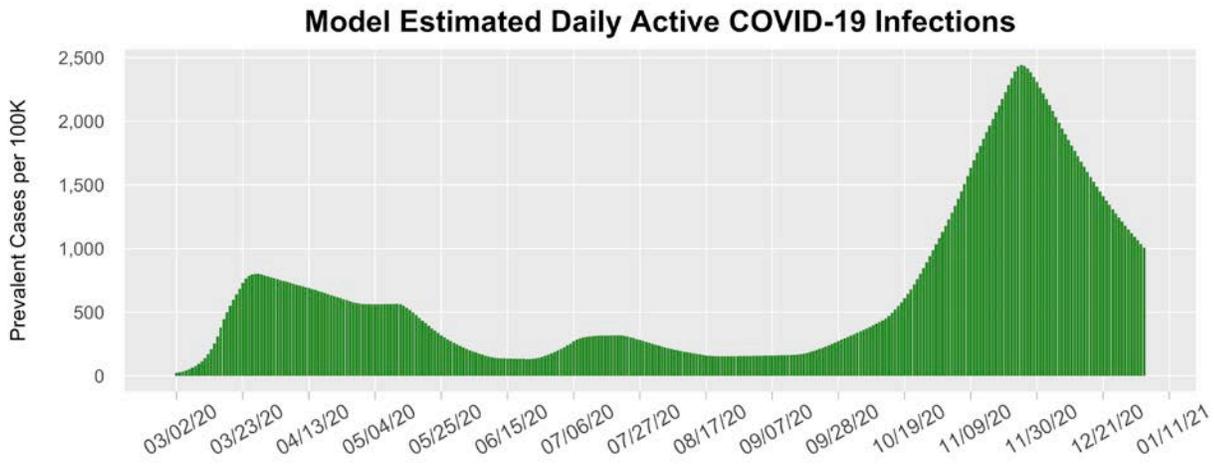
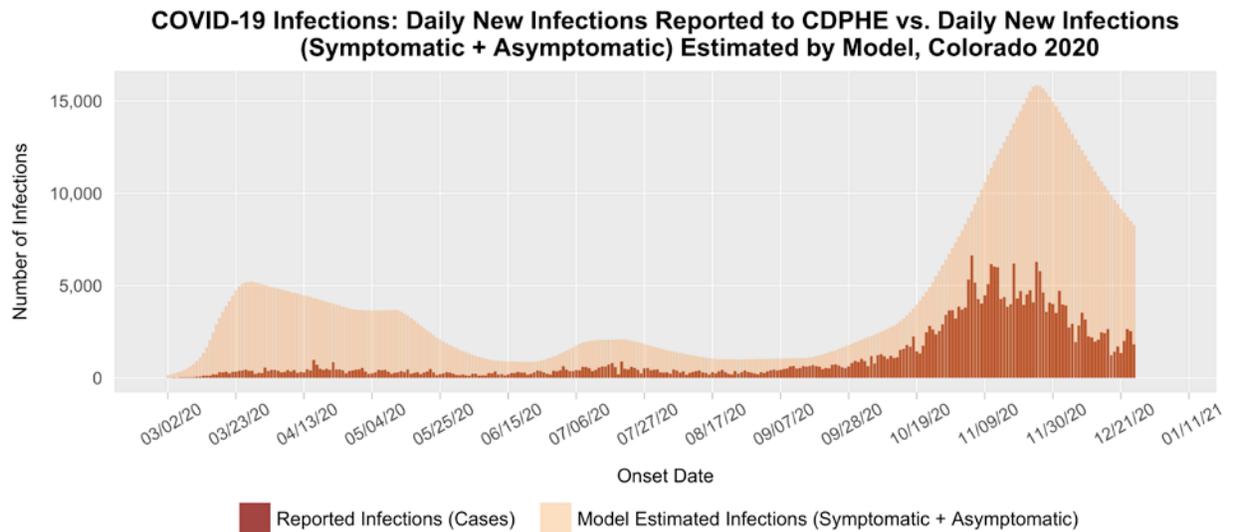


Figure 5 (above). Estimated daily number of people who are infectious and infected with SARS-CoV-2 (point prevalence). Estimate is shown per 100,000 population. The number of infectious individuals is inferred using the model and based on hospitalizations.

Case Detection

Comparing observed to model-estimated infections, **we estimate that approximately 21% of infections were detected by state surveillance systems, including both asymptomatic and symptomatic infections in the two week period from 12/12 to 12/25 (Figure 6).**



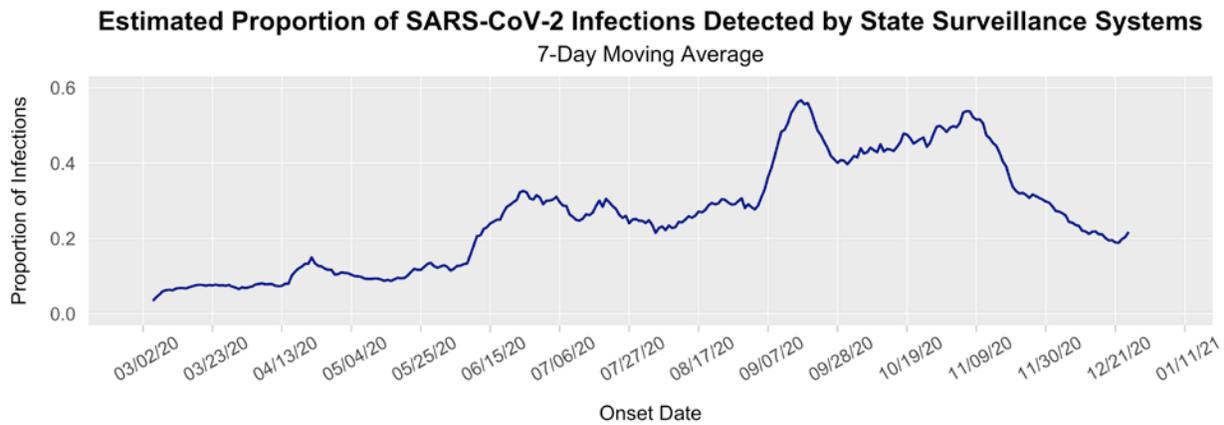


Figure 6 (above). Estimated daily number of new (incident) SARS-CoV-2 infections based on the SEIR model (light orange graph) and reported cases (dark orange graph) over time shown in the top panel. Lower panel shows the 7-day moving average of the estimated proportion of SARS-COV2 infections that are being captured by Colorado state surveillance systems, over time. The proportion detected is estimated by dividing the total number of new cases captured by state surveillance systems by the model-estimated number of new infections each day. The number of cases captured by the state surveillance systems is the number of cases reported by CDPHE, using the onset date of symptoms (if onset date is not available, onset date is imputed by CDPHE using a proxy distribution of recent onset dates). Data are shown through 12/25 to account for typical lags between symptom onset and case report.

Cumulative Infections

As more people develop immunity, due to vaccination or prior infection, the spread of infections slows because infectious individuals are less likely to encounter individuals that are still susceptible to infection. The estimated cumulative number of infections provides an estimate of the percent of the population that may be immune, although we still do not know how long immunity lasts after an infection. As a vaccine becomes available and our understanding of SARS-CoV-2 immunity changes, these estimates will be updated.

The cumulative number of infections is estimated using our age-structured SEIR model fit to hospitalization data. As with our prevalence estimates, these estimates are generated by assuming the most recent transmission control parameter estimate remains at the estimated value through 01/04. These estimates are sensitive to model assumptions, including assumptions about the probability an infected individual will be symptomatic and require hospital care, as well as assumptions about length of hospital stay, which varies over time; all of the above are variables that we assume vary by age.

We estimate that approximately 1,310,000 (95% CI: 1,309,416, 1,320,592) people in Colorado, or 23% (95% CI: 22.4%, 22.6%) of the population, have been infected to date (01/04).

Reported Infections and Hospitalizations by Age and Race/Ethnicity

Like many infectious diseases, COVID-19 is not equally distributed across the population. Some groups may face higher exposures and/or more severe health effects. We use reported case and hospitalization data provided by CDPHE to examine the distribution of infections and hospitalizations by age group, as well as by race and ethnicity. Age groups are defined to align with the four age groups used in the model.

Reported SARS-CoV-2 Cases by Age Group. Figure 7 shows the 7-day moving average of reported new SARS-CoV-2 infections by age group.

People under age 40 account for 52% of reported SARS-CoV-2 cases in the two weeks between 12/14 and 12/28.

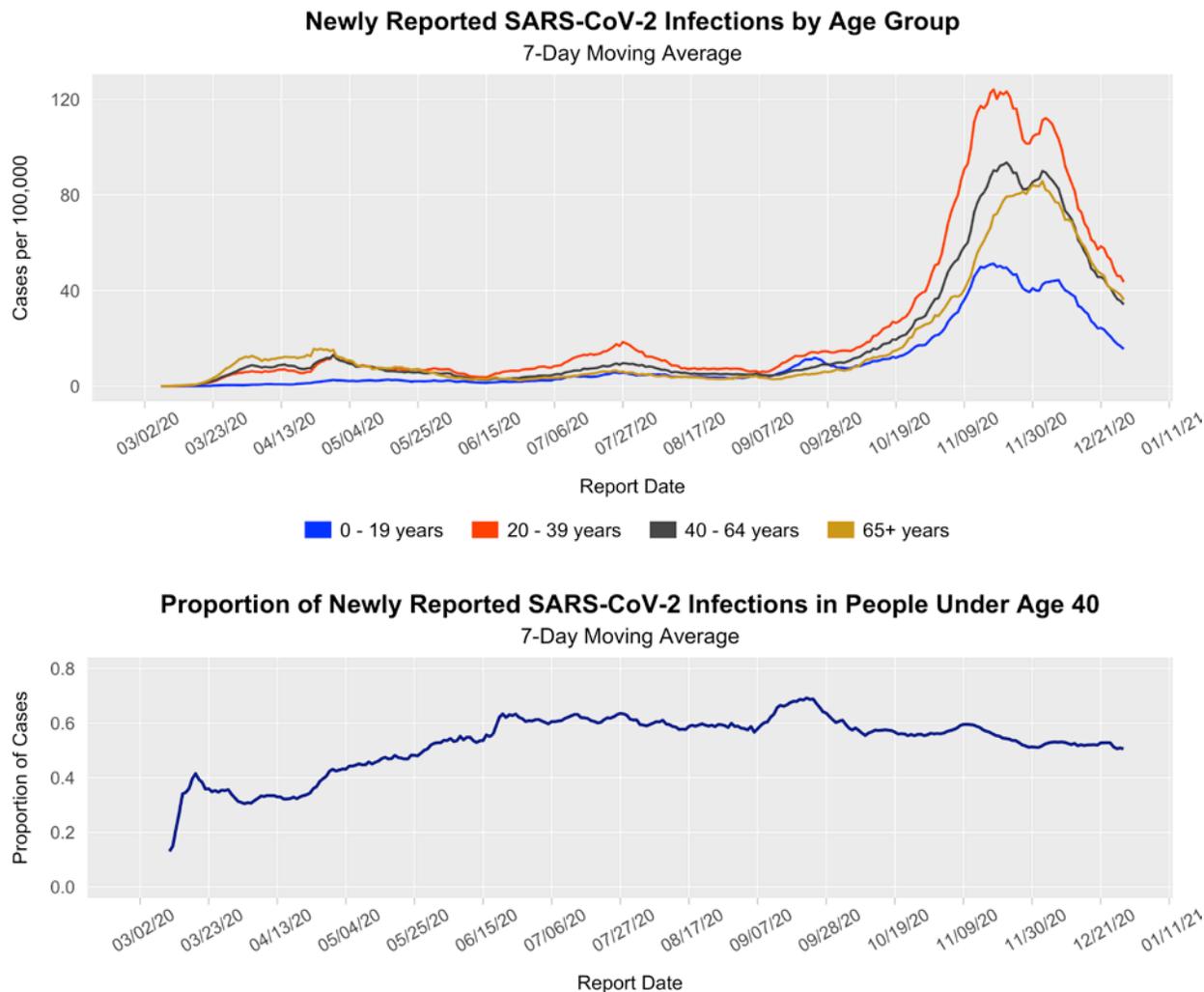


Figure 7 (above). Distribution of 7-day moving average of newly reported SARS-CoV-2 infections by age group (top) and the proportion of all cases among individuals under 40 (bottom). Reported cases are based on CDPHE data and shown by report date. Incident cases per 100,000 were obtained by standardizing weekly reported age-specific case and hospitalization counts to the Colorado population distribution by age, gathered from the Colorado Census 2020 estimates. Data are shown through 12/28, to account for typical lags in collection of age data for reported cases.

COVID-19 Hospitalizations by Age Group. Figure 8 shows the daily count of individuals hospitalized with COVID-19 by age group from March through the present, based on COvid Patient Hospitalization Surveillance (COPHS) provided by CDPHE. Due to lags in reporting, COPHS data include hospitalizations through 01/01.

People under age 40 account for **11%**, people age 40 to 64 account for **36%**, and people age 65+ account for **53%** of COVID-19 hospital use over the two weeks between 12/19 and 01/01.

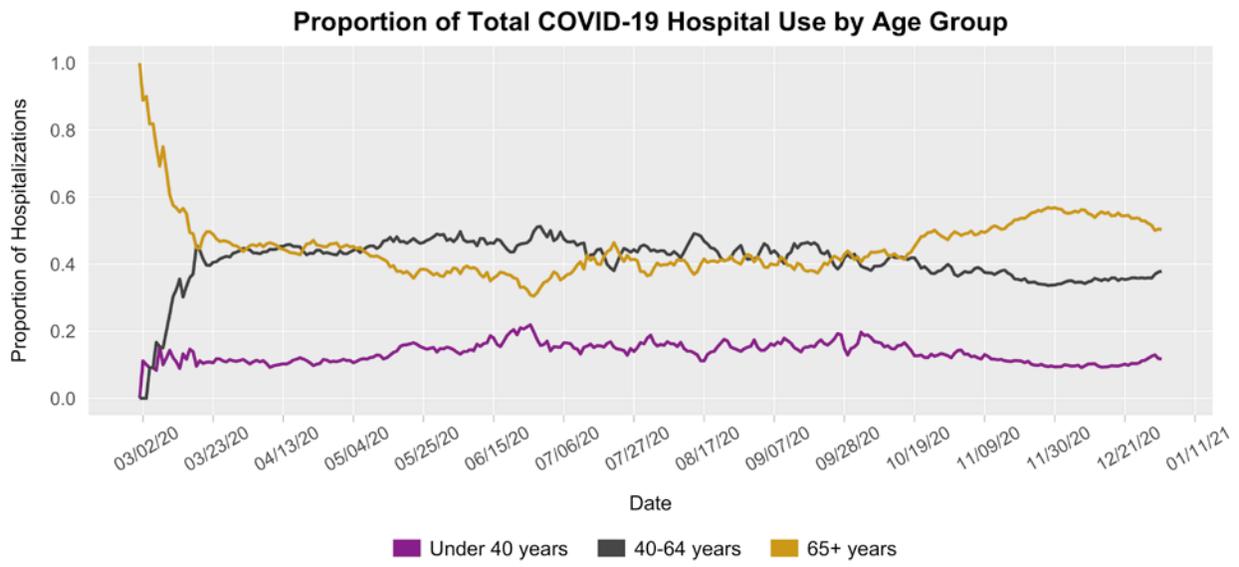
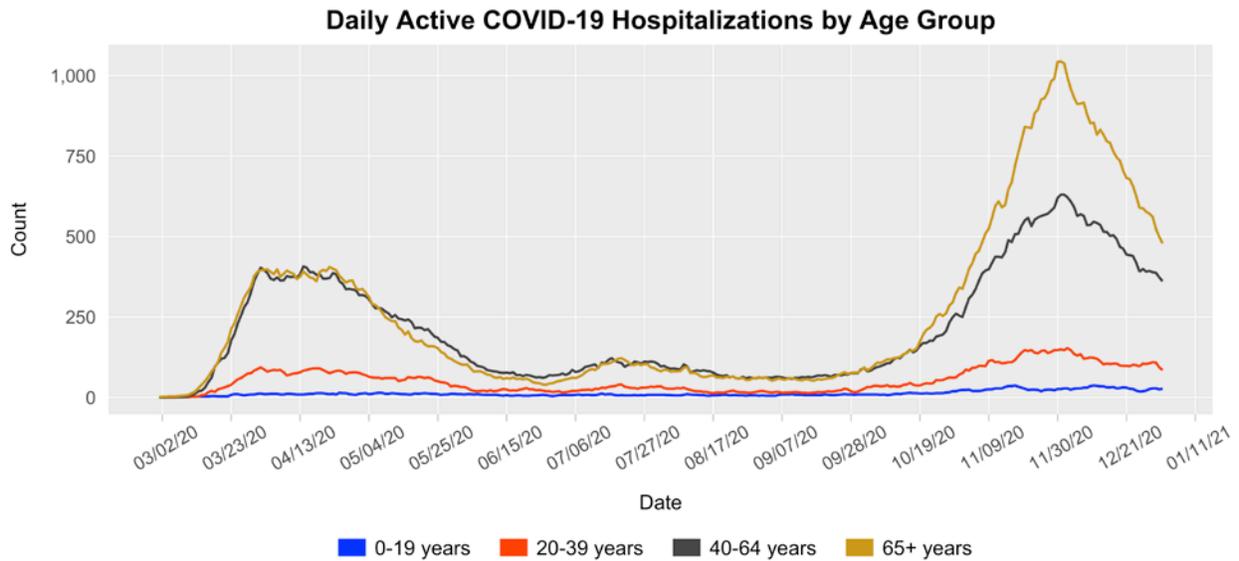


Figure 8 (above). The number of individuals hospitalized with COVID-19 by age group from March through the present (top) and the proportion of COVID-19 hospital beds occupied by individuals under 40 years, 40-64 years, and 65+ years (bottom). Data based on COVID Patient Hospitalization Surveillance (COPHS) through 01/01.

COVID-19 Reported Cases by Race/Ethnicity. Figure 9 shows the number of reported cases by race/ethnicity from March through the present.

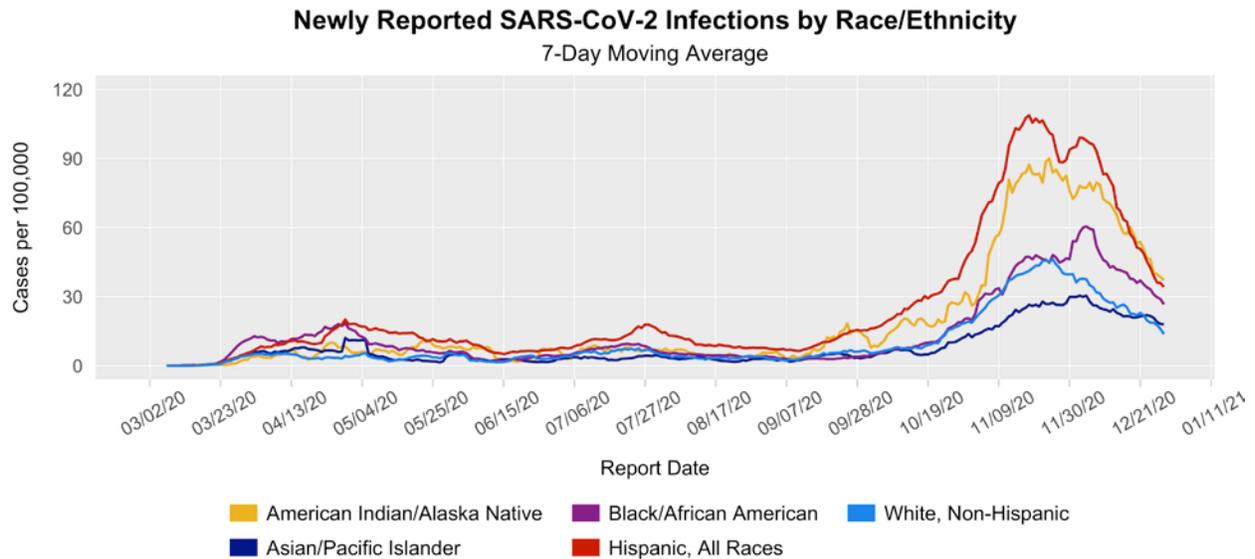


Figure 9 (above). Distribution of 7-day moving average of newly reported SARS-CoV-2 infections by race and ethnicity in Colorado. Reported cases are based on CDPHE data and shown by report date. Cases per 100,000 were obtained by standardizing weekly reported race-specific case counts to the race/ethnicity distribution of the state of Colorado gathered from the CDPHE COVID-19 Case Summary Dashboard. These standardized estimates combine Asian and Native Hawaiian/Pacific Islander races and exclude Other/Unknown races (which account for 27% of observations over the last two weeks). Data is shown through 12/28 to account for lags in collection of race/ethnicity data for reported cases.

Near-Term Forecast

We generated estimated hospital and ICU demand over the next two weeks assuming Colorado remains on the current trajectory and accounting for uncertainty in our current estimated trajectory (Figure 10). **In two weeks on 01/19, there is a 50% chance that at least 610 patients will be hospitalized with COVID-19, including 200 patients in the ICU, if we remain on the current trajectory.**

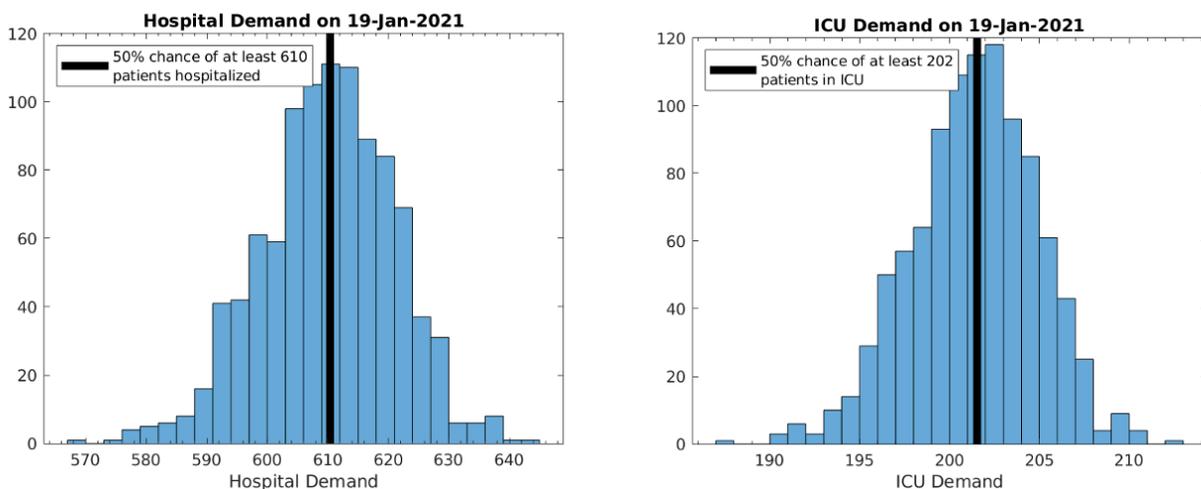


Figure 10 (above). Estimated number of hospitalized COVID-19 patients (left) and COVID-19 patients requiring ICU care (right) in two weeks if we remain on the current trajectory. These estimates are based on 10,000 simulated runs of the model, with 1,000 of those runs randomly selected for visualization.