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

- COVID-19 hospitalizations increased to a small peak in mid-July and have been declining for the last month.
- We estimate the current effective reproductive number is well below 1.
- Our current estimate of social distancing is 79% (for the period 7/26 - 8/04). This estimate of social distancing is modestly higher than our estimate from last week of 73% for the period 7/19- 7/28, and at a level that would avoid growth in cases or hospital demand if sustained.
- School openings and an increase in contacts due to the Labor Day weekend have the potential to change our current trajectory leading to a growth in cases and hospitalizations.
- Preventing an increase in transmission over Labor Day weekend can put schools in a better place to open in September. Relaxation of social distancing around the Labor Day holiday could lead to an increase in infections and hospital demand shortly after school openings in early September, or ahead of school openings scheduled for October.

Current state of COVID-19 in Colorado

We used our age-structured SEIR 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. Modeling methods are detailed here, (see documentation tab). These estimates are based on hospitalization data through 08/17/2020.

To characterize the current state of COVID-19 in Colorado, we focus on three components

1. **The effective reproductive number.** This is an estimate of the recent growth rate of infections. If the reproductive number is above 1, the number of infections is growing, with higher values indicating faster growth. If the reproductive number is below 1, cases are declining.
2. **The cumulative and current number of infections in the population.** The current number of people who are infectious at a given time provides a measure of the risk of infection to the population at large. When the number of infectious individuals is high, there is a greater chance that an interaction between people may lead to a new infection. The cumulative number of infections to date provides an estimate of the size of the remaining susceptible population, the population that remains at risk of infection, assuming there is durable immunity.
3. **The distribution of reported infections and hospitalizations by age, race and ethnicity.** The impacts of COVID-19 have not been distributed evenly across the population. By examining

cases and hospitalization by age, race and ethnicity over time, we can identify high risk populations.

These estimates are based on currently available data and our current understanding of SARS-CoV-2 transmission. We note that the science is evolving rapidly and we regularly update our model assumptions as new information becomes available.

Current COVID-19 hospitalizations and model fit

Figure 1 shows COVID-19 hospitalizations (black bars) and the green line shows the current model fit to the data. Table A1 provides values for model parameters including social distancing estimated by the model from mid-March through the present. The social distancing parameters describe reductions in the contact rate, a measure of how rapidly infections spread from person to person. Our most recent estimate of social distancing, for the period 7/26 to 8/04, is 79%. We note that due to the approximately 13-day lag between infection and hospitalization, we are currently only able to estimate social distancing through 8/04.

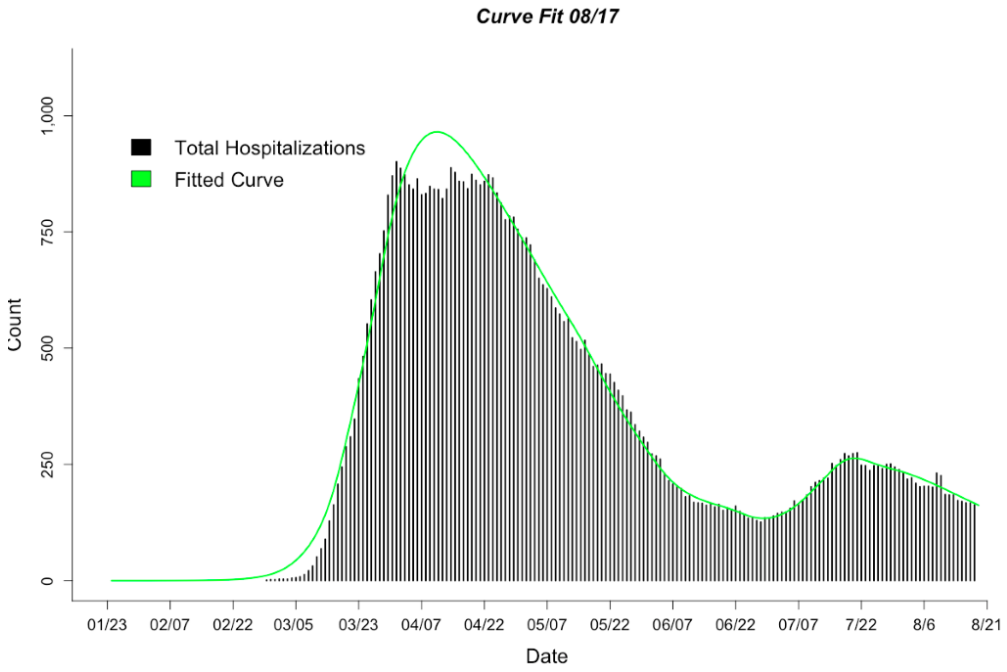


Figure 1. Current model fit (green line) to count of hospitalized COVID-19 cases (black lines) using the age-structured SEIR model. Hospitalized COVID-19 cases are from CDPHE reported COVID-19 hospitalizations and EMResource (EMR) hospital census data provided by CDPHE.

The effective reproductive number

The estimated effective reproductive number is shown in Table 1 and Figure 2. Table 1 provides estimates we generated using two different methods. We also provide values from two external groups that use different data and methods (RT-Live uses SARS-Cov-2 case data and covid-19-projections.com uses mortality data).

Table 1. Current and prior estimates of the effective reproductive number (Re) in Colorado.

	Current Estimate (8/17)	Estimates one week ago (8/10)	Estimates two weeks ago (8/03)
Estimate of Re, approach 1*	0.72	0.82	0.67
Estimate of Re, approach 2*	0.65	0.86	0.62
Estimate from RT-Live	0.95	0.99	1.00
covid-19-projections.com	0.96	0.96	0.98

*Our estimates are based on hospitalization data through the date listed. Estimates from the external sites are extracted on the day listed. Because of the 13-day lag between infection and hospitalization, on average, our current estimate reflects transmission up to approximately August 4. 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.

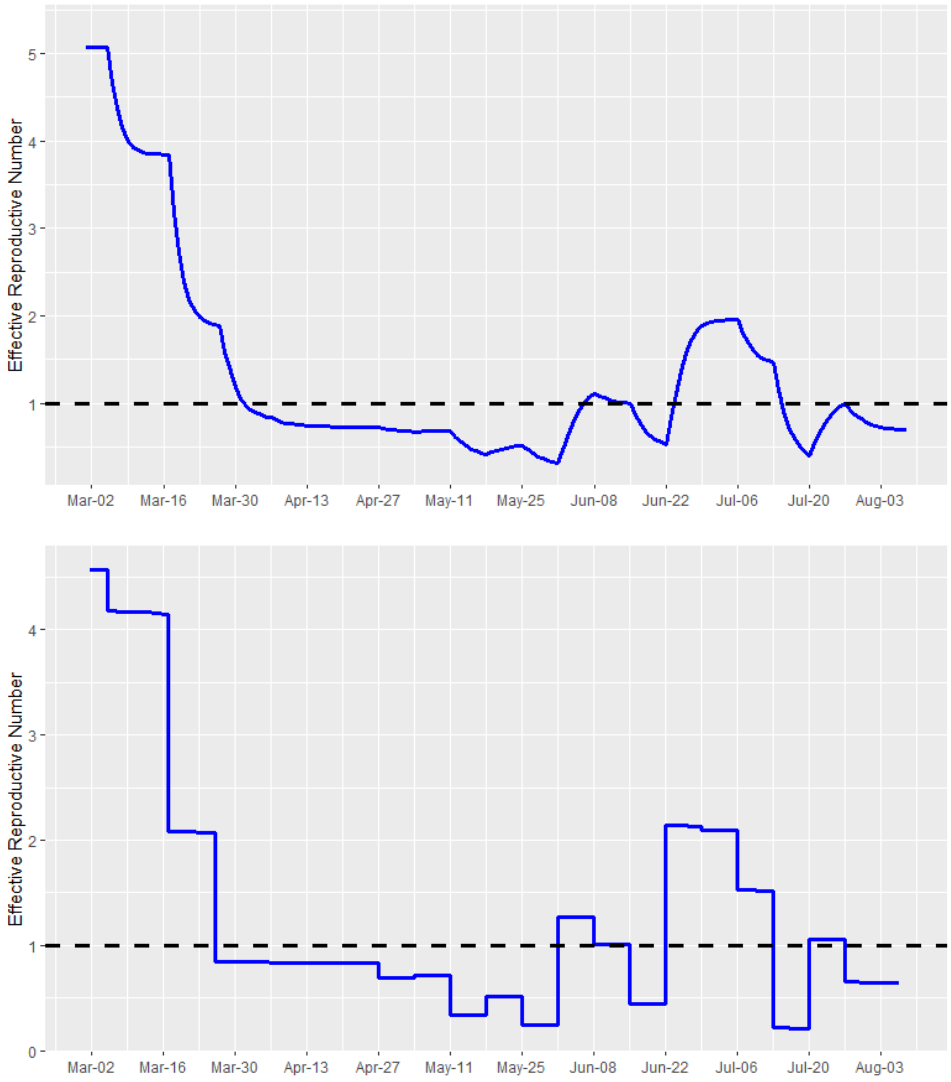


Figure 2. The effective reproductive number using approach 1 (top panel) and approach 2 (bottom panel) based on our SEIR model.

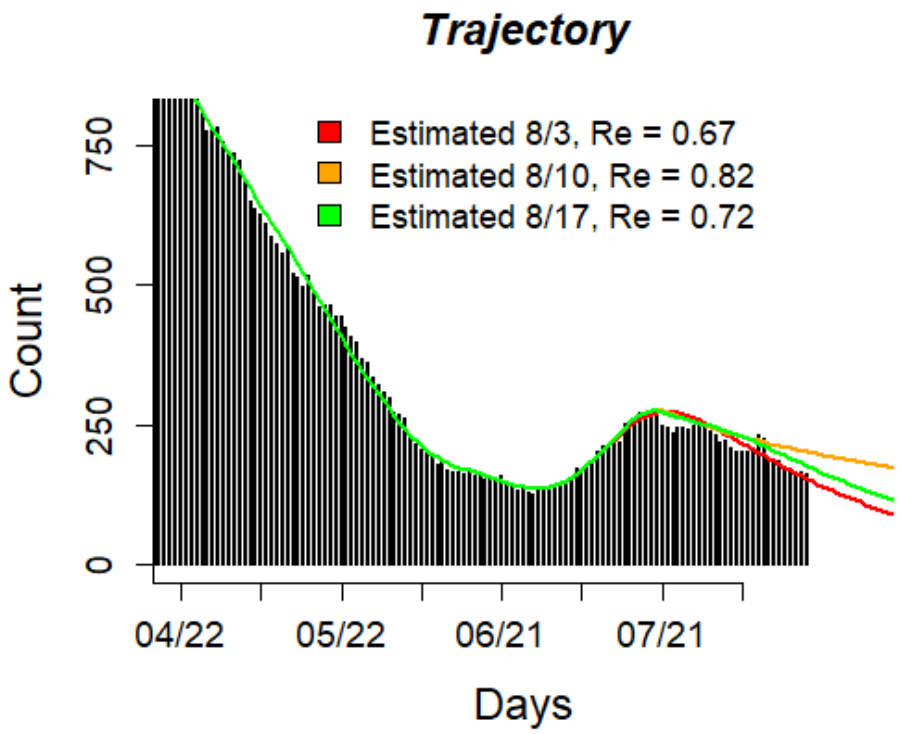


Figure 3. The projected trajectory of the COVID-19 hospitalizations if Colorado remains on the current estimated trajectory (red line), the trajectory estimated one week prior (blue line), and the trajectory estimated two weeks prior (green line). Each trajectory is generated assuming social distancing levels remained at the estimated levels: current estimate 79% based on the period 7/26 - 8/04 (green line), one week prior estimate 73% based on the period 7/19-7/28 (orange line), two weeks prior estimate 82% based on the period 7/12 - 7/21 (red line). Note that the estimation periods overlap as we re-estimate parameters each week and use the past approximately 10 days to estimate the most recent social distancing parameter.

The cumulative and current number of infections in the population

We use our model output to estimate the cumulative number of infections to date and the approximate number of infectious individuals in the population. It is clear that many infections are not detected by surveillance systems – the estimates provided here are intended to provide an approximation of the total number of infections, as well as the proportion detected by the Colorado surveillance system. These estimates are sensitive to our model assumptions, including assumptions about the probability an infected individual will be symptomatic and require hospital care, which we assume varies by age.

We estimate that approximately 280,000 people in Colorado, or 4.8% of the population have been infected to date.

We estimate that there are approximately 5,200 infectious individuals in Colorado at present: approximately 1 in every 1,120 Coloradoans.

We estimate that approximately 34% of infections were detected in past two weeks, including both asymptomatic and symptomatic infections. This estimate is generated by comparing daily reported SARS-CoV-2 cases in Colorado to model-estimates of the number of incident infections.

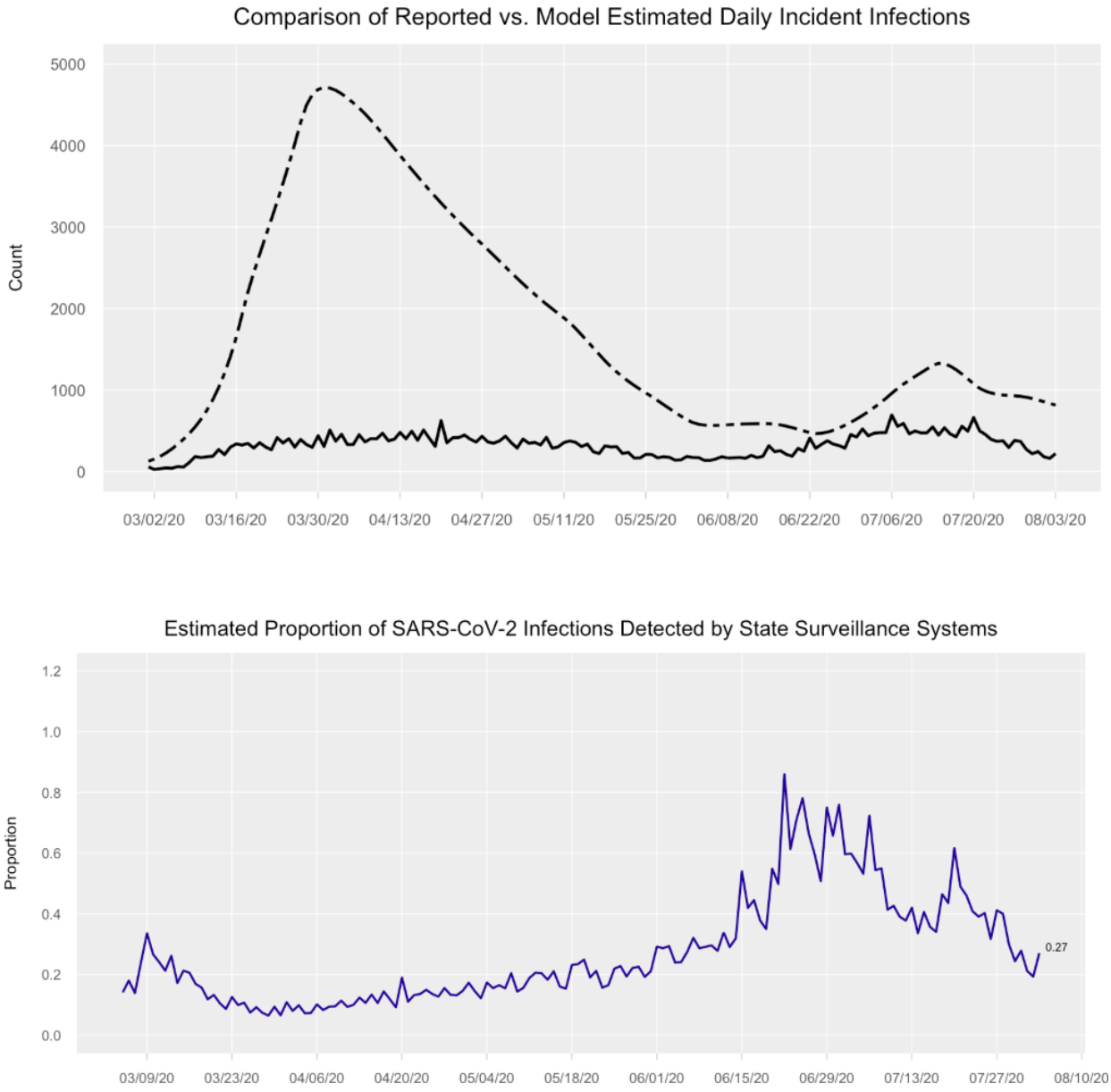


Figure 4. Estimated daily number of new (incident) SARS-CoV-2 infections based on the SEIR model (dotted line) and reported cases (solid line) over time shown in the top panel. Lower panel shows the estimated proportion of SARS-COV2 infections that are being captured by Colorado state surveillance systems, 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 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 8/03, to account for typical lags between symptom onset and case report.

The distribution of reported infections and hospitalizations by age, race and ethnicity

Figure 5 shows the daily number of reported new SARS-CoV-2 infections by age group. Recent new cases are highest for those aged 20 - 39. The average proportion of COVID-19 cases in people under age 40 over the last two weeks is approximately 60%.

Figure 6 shows the daily number of new COVID-19 hospitalizations by age group. Recent new hospitalizations are highest for those age 65 and over. The average proportion of COVID-19 hospitalizations in people under age 40 over the last two weeks is approximately 25%.

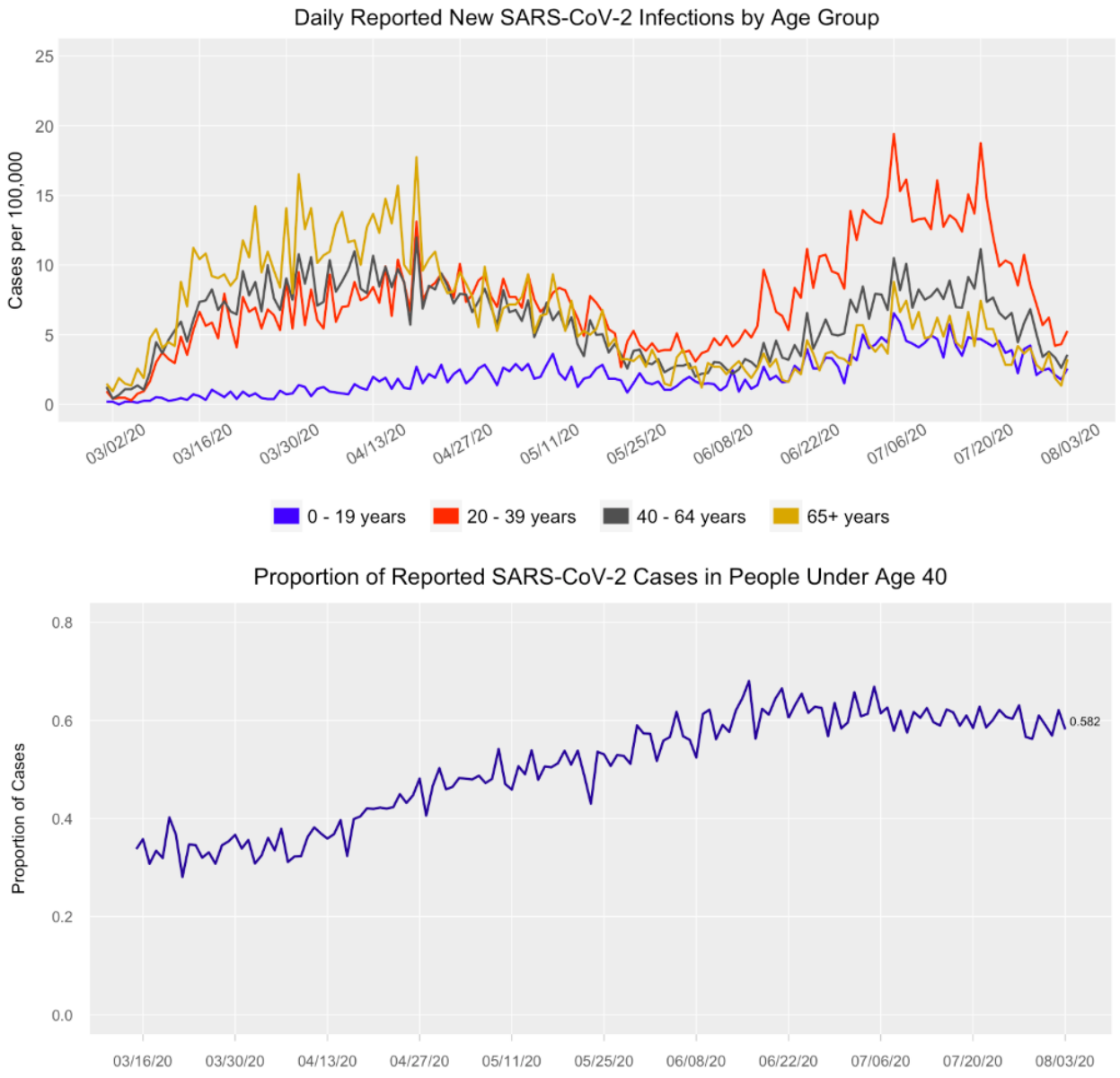


Figure 5. Distribution of daily new (incident) reported SARS-CoV-2 cases by age group (top) and the proportion of all cases among individuals under 40 (bottom). Reported cases are based on CDPHE data and shown by onset date (if onset date is not available, onset date is imputed by CDPHE using a proxy

distribution of recent onset dates). Incident cases per 100,000 were obtained by standardizing daily 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 8/03/2020, to account for typical lags between symptom onset and case report.

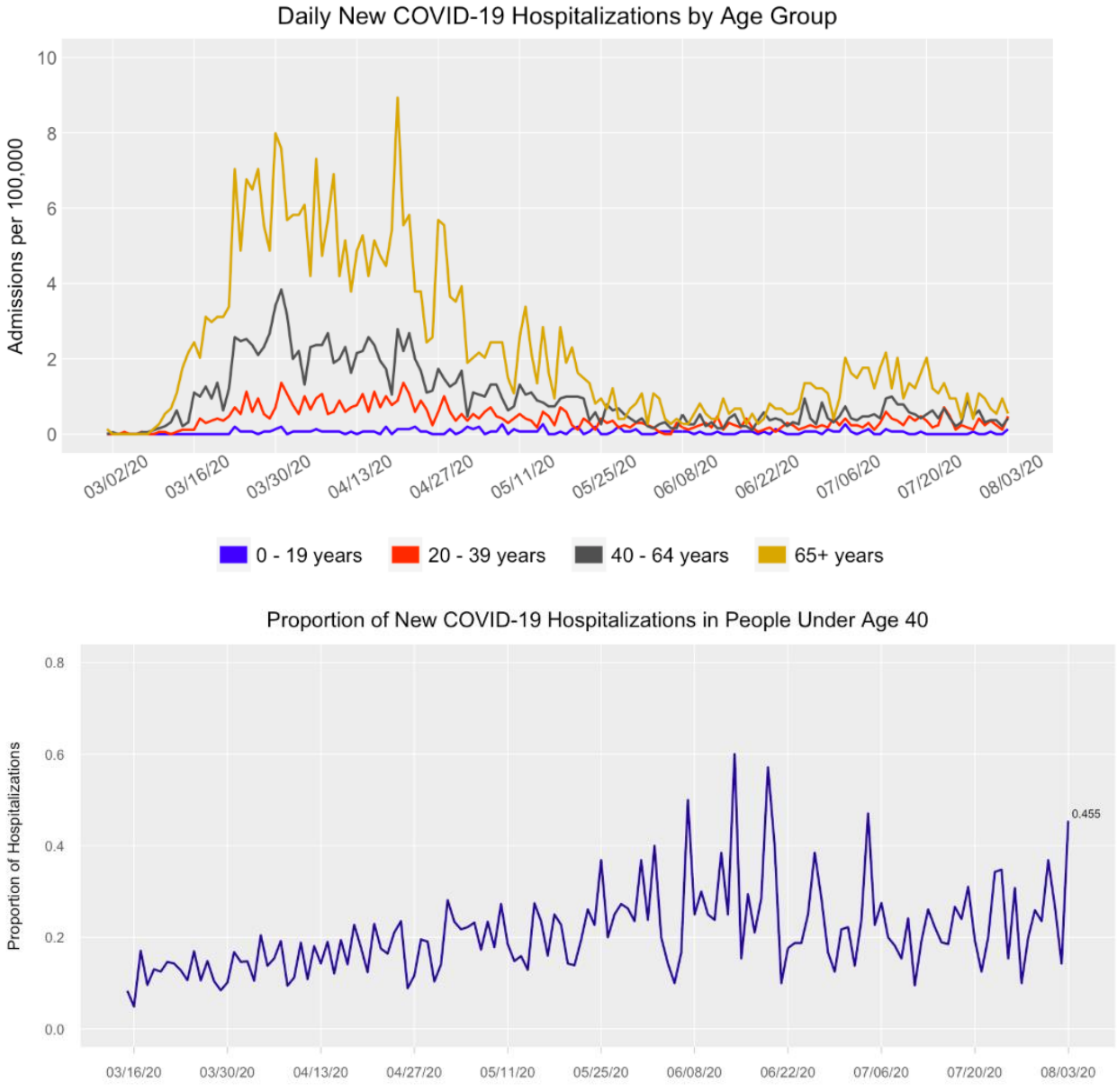


Figure 6. Distribution of daily new (incident) COVID-19 hospitalizations by age (top) and the proportion of hospitalizations occurring among individuals under 40 (bottom). Hospitalizations per 100,000 were estimated by standardizing daily reported age-specific hospitalizations based on CDPHE case reports to the Colorado population distribution by age, gathered from the Colorado Census 2020 estimates. Data are shown through 8/03/2020.

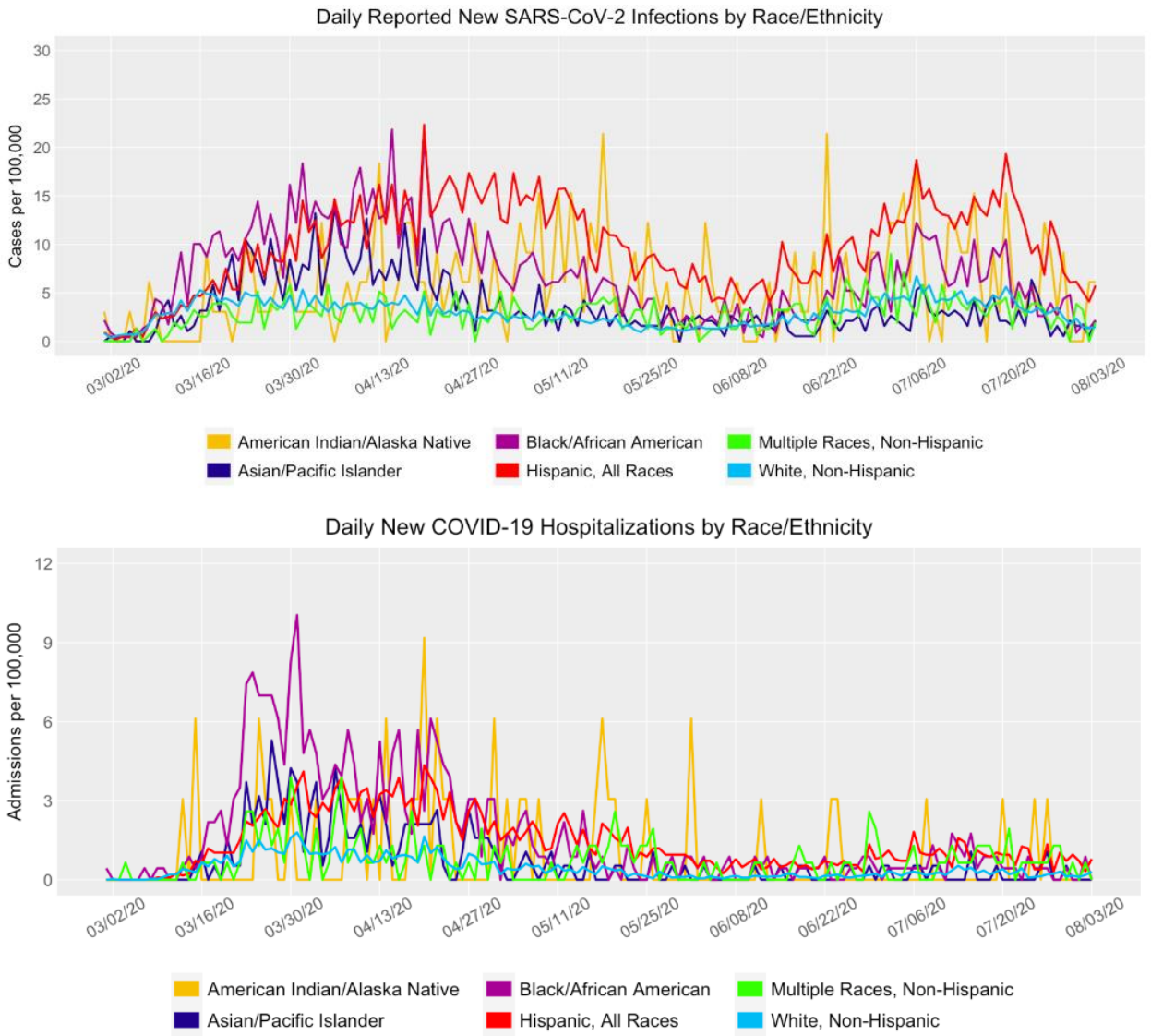
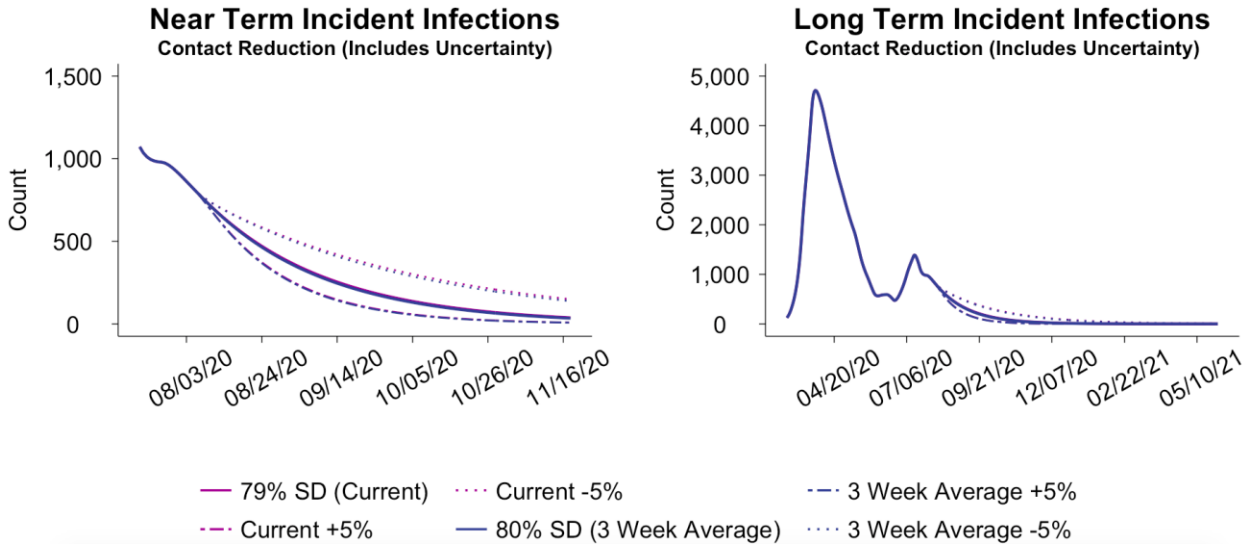


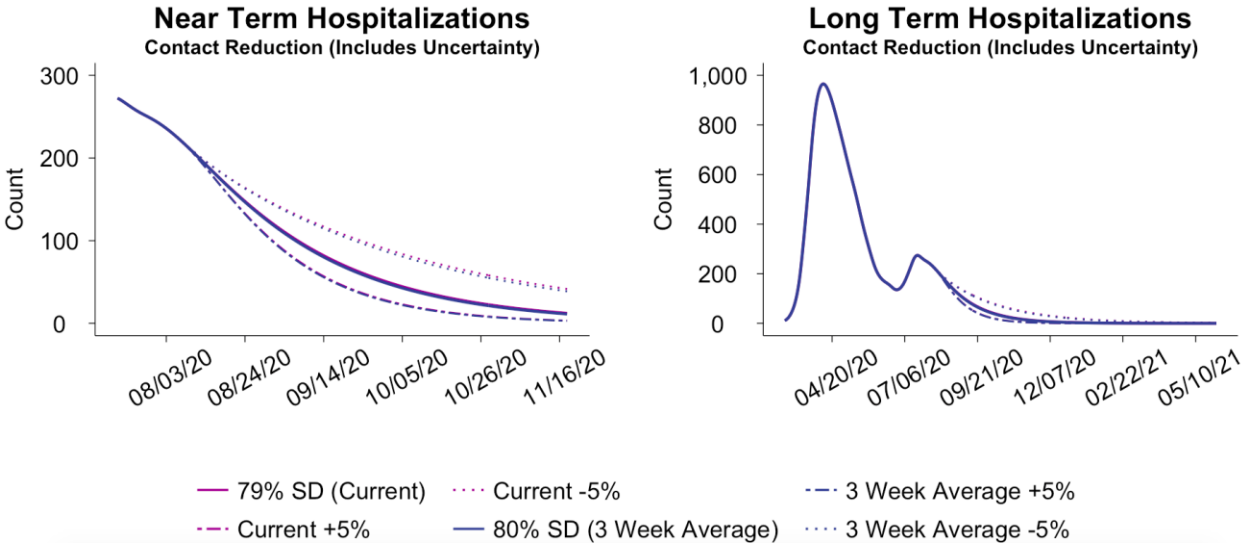
Figure 7. Distribution of daily new (incident) reported SARS-CoV-2 infections (top) and new hospitalizations (bottom) by race and ethnicity in Colorado. Reported cases are based on CDPHE data and shown by onset date (if onset date is not available, onset date is imputed by CDPHE using a proxy distribution of recent onset dates). Cases and hospitalizations per 100,000 were obtained by standardizing daily reported race-specific case and hospitalization 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.

What do we project for the coming months?

We used the age-structured SEIR model fit to the parameters described in Table A1 to project the expected number of total hospitalizations and need for critical care beds in the coming months for three sets of scenarios 1) current and recent trajectories, 2) relaxation of social distancing and increased mask wearing, 3) school opening and a Labor Day surge.

Current and recent trajectories. A set of projections are generated assuming we remain on the current trajectory and accounting for uncertainty in our current estimated trajectory (Figure 8). As hospitalization numbers have fluctuated in recent weeks, leading to variation in estimates of social distancing, we estimate current trajectory two ways: first examining the trajectory based on the most recent social distancing parameter estimated for the most recent period, 07/26 – 8/04, and second by using the average social distancing parameter estimated for the last three estimating periods (the period 07/13 to 08/04). These fluctuations underscore the challenges of generating predictions about the future course of SARS-CoV-2. Projections assuming we remain on our current trajectory or the average July trajectory, indicate that we are unlikely to see a surge in infections or exceed hospital capacity in the next 8 weeks.





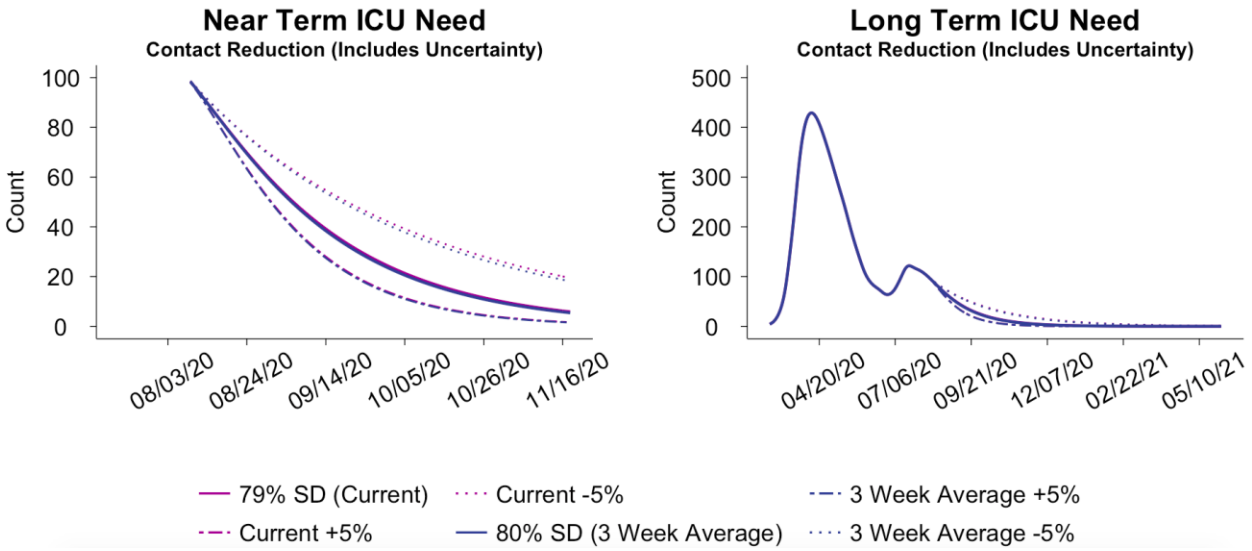


Figure 8. Projected daily count of new infections (top left), hospital (top right), and intensive care (ICU) demand (bottom left) in the near-term if we remain on the current trajectory estimated based on the most recent social distancing estimate (purple line, 79% for the period 7/26 – 8/04), and based on the three-week average (blue line, 80% for the period 7/13 – 8/04). Dashed and dotted lines represent a 5% overestimate / underestimate respectively in the social distancing parameter. These scenarios assume mask wearing increases to 90% on 7/16, the date of the state-wide mask order, and case isolation remains at current levels. These projections use model-fit parameters through 8/04 and then switch to the projected parameter values.

Relaxation of social distancing and increasing mask wearing. Projections were also generated to evaluate the potential impact of changes to the current trajectory – looking at the potential impact of reductions in social distancing and increased mask wearing (Figure 9 and Table 2). For the purpose of these projections, we assume social distancing is relaxed on 8/21. Projections are generated assuming mask wearing increased to 90% on 7/16, the date of the state-wide mask order.

Projections show that if social distancing is relaxed to 60, 55, or 50%, we could see substantial growth in cases in the months ahead, with the sharpest growth at the lowest levels of social distancing. ICU capacity is expected to be exceeded this fall at the 55 and 50% scenarios.

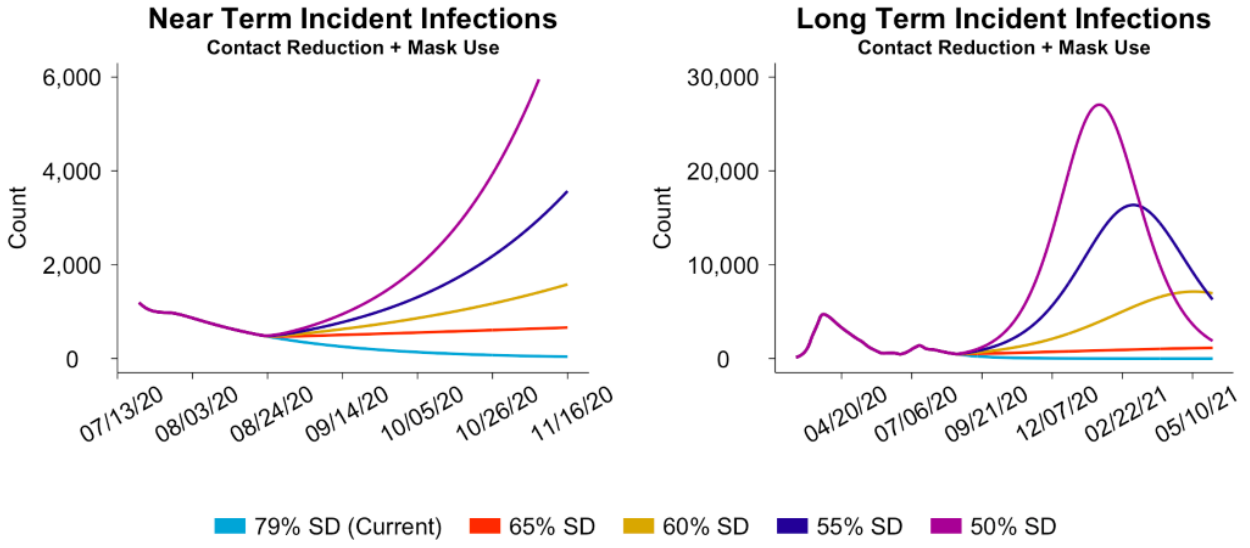
Table 2. Comparison of the projected date that ICU capacity is reached, the date ICU demand peaks, the estimated number of ICU beds needed at the peak, and the cumulative COVID-19 deaths at different levels of social distancing. Based on CDC recommendations, in the 50 – 65% scenarios, half of older adults (age 65+) are assumed to practice high levels of social distancing (80%). Projections are showing assuming mask wearing and case isolation remain at current levels.

	Date ICU Capacity Reached*	Date of ICU Peak	ICU Need at Peak**	Cumulative cases through 12/31/2020**	Cumulative deaths through 12/31/2020**
Current trajectory					
Current trajectory (7/26 - 8/04, 79%)	N/A	past	past	304,000	2,030
Three-week average (07/13 - 8/04, 80%)	N/A	past	past	303,000	2,030
Intervention scenarios					
Social distancing at 50%¶	11/25/20	2/08/21	2,620	1,470,000	6,200
Social distancing at 55%¶	N/A	3/17/21	1,600	818,000	3,900
Social distancing at 60%¶	N/A	5/23/21	710	504,000	2,800
Social distancing at 65%¶	N/A	past	past	378,000	2,360

*ICU capacity for COVID-19 patients is estimated to be 1800 in Colorado, a figure provided by the Colorado Department of Public Health and the Environment.

**Estimates are rounded to three significant figures.

¶ Intervention are modeled assuming social distancing remains at the current estimated level until 8/14, at which point it changes to the indicated value. These intervention scenarios differ from current trajectory scenarios in that they assume half of individuals 65 and older maintain high levels of social distancing.



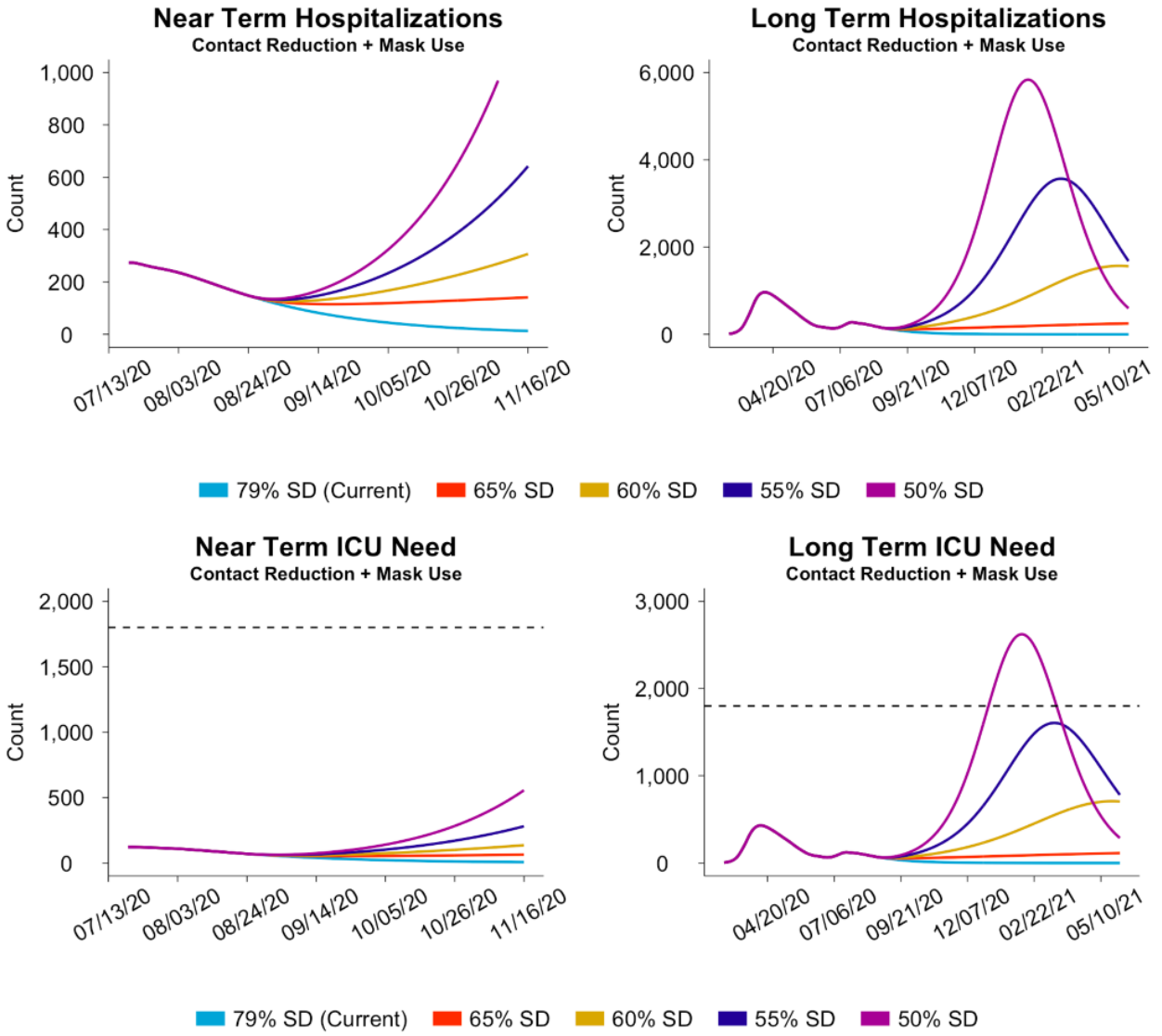


Figure 9. Projected daily count of new infections (top), hospital demand (middle), and intensive care (ICU) demand (bottom) in the near-term (left) and long-term (right), assuming social distancing remains at current levels (79%), or switches to 65, 60, 55 or 50% on 8/14. Projections are shown assuming mask wearing remains at 90% starting from 7/16, the date of the state-wide mask order. Based on CDC recommendations, in the scenarios half of older adults are assumed to practice high levels of social distancing (80%). Case isolation is assumed to remain at current levels.

School opening and Labor Day. Projections were generated to examine the potential impact of an increase in cases over Labor Day weekend, school-reopening and the combined impact of both. Colorado experienced an increase in cases in late June and early July. While we do not know what caused this, one hypothesis is that people increased their contact rate over the holiday, raising concerns that a similar phenomenon could occur over Labor Day. The Labor Day scenario mirrors the increase seen around 4th of July, with an average of 42% social distancing for three weeks beginning the Wednesday before the holiday weekend (Sep 1st – Sep 21st). Opening schools will increase the contact rate, but it is unclear by how much and to what degree hybrid schedules, mask wearing and

transmission control measures will prevent contacts that spread virus. Given the uncertainty, we model school openings using three scenarios – modeling opening schools as a 10, 20 and 30% reduction in social distancing compared to current levels (73%) by individuals age 0 to 19 starting on September 1. We note that in reality, schools will open on different dates across the state – the scenarios presented here are hypothetical and do not account for changes in social distancing by parents whose children are in school or by teachers. Lastly, we model the combined impact of school opening and a Labor Day increase in transmission. The combined scenarios include assumed decreases in SD among individuals under 20 as a result of schools opening, combined with population wide decreases for the three weeks around Labor Day. Over the period Sep 1st - Sep 21st individuals under 20 are assigned reductions in social distancing due to school re-openings, multiplied by the percent decrease expected due to Labor Day (42%). These scenarios assume case detection remains at current levels and mask wearing is 90% starting on 7/16, the date of the state-wide mask order.

A Labor Day decrease in social distancing could lead to an increase in hospital demand in the next six weeks that is steeper and occurs sooner than increase that might occur with school opening.

Table 3. Estimated hospital and critical care demand for a simulated Labor Day "spike" that mirrors what was seen around the Fourth of July holiday, as well simulated school opening. There are considerable uncertainties as to how schools will impact the contact rate. Here, school opening is modeled as a 10, 20 and 30% reduction in social distancing from current levels for individuals age 0 to 19 years.

	Est Hospital demand on 9/30		Est ICU demand on 9/30	
	Without Labor day spike	With Labor day spike	Without Labor day spike	With Labor day spike
Current trajectory	52	194	25	86
Schools ~10%	64	219	30	96
Schools ~20%	81	247	37	107
Schools ~30%	101	279	45	119

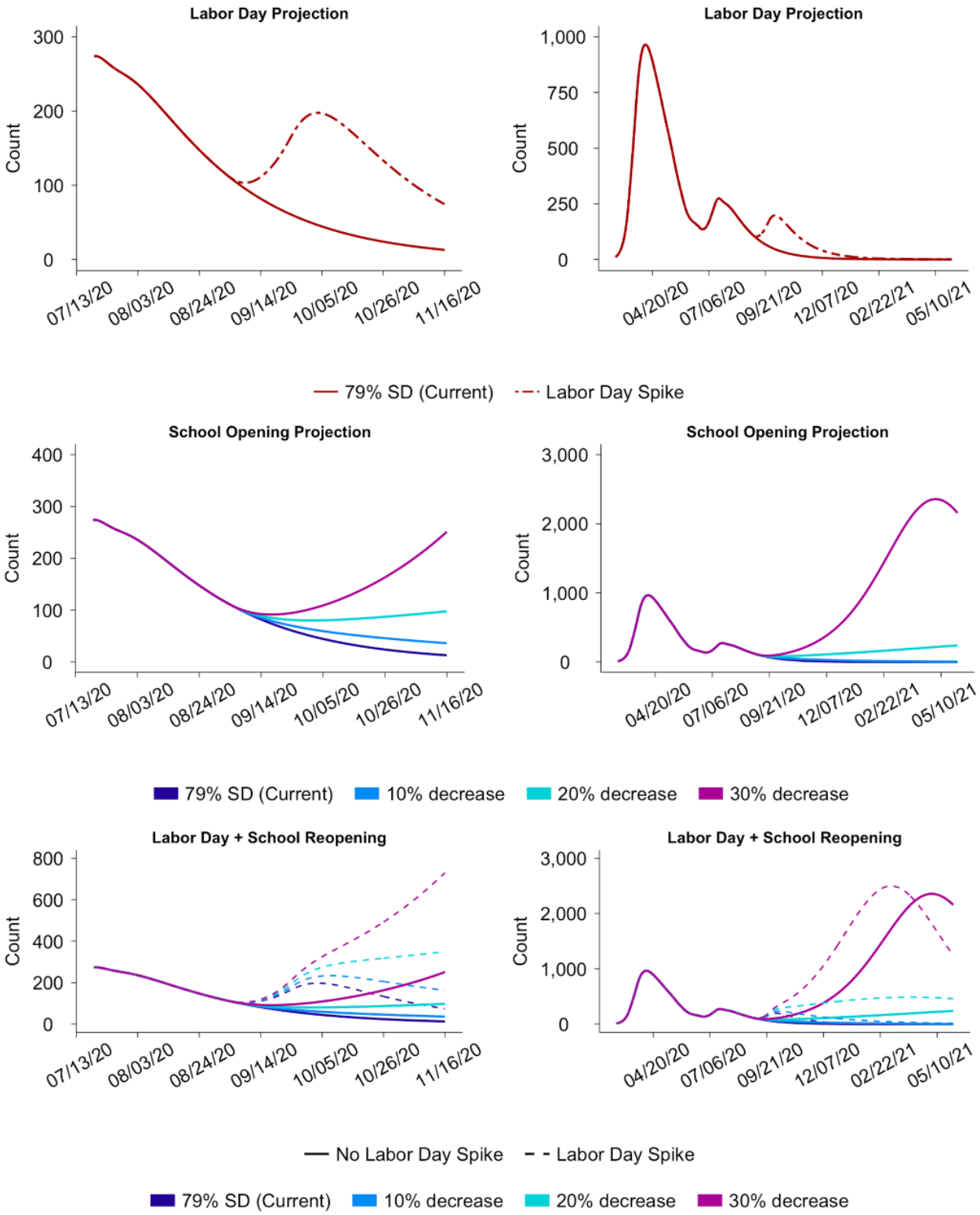
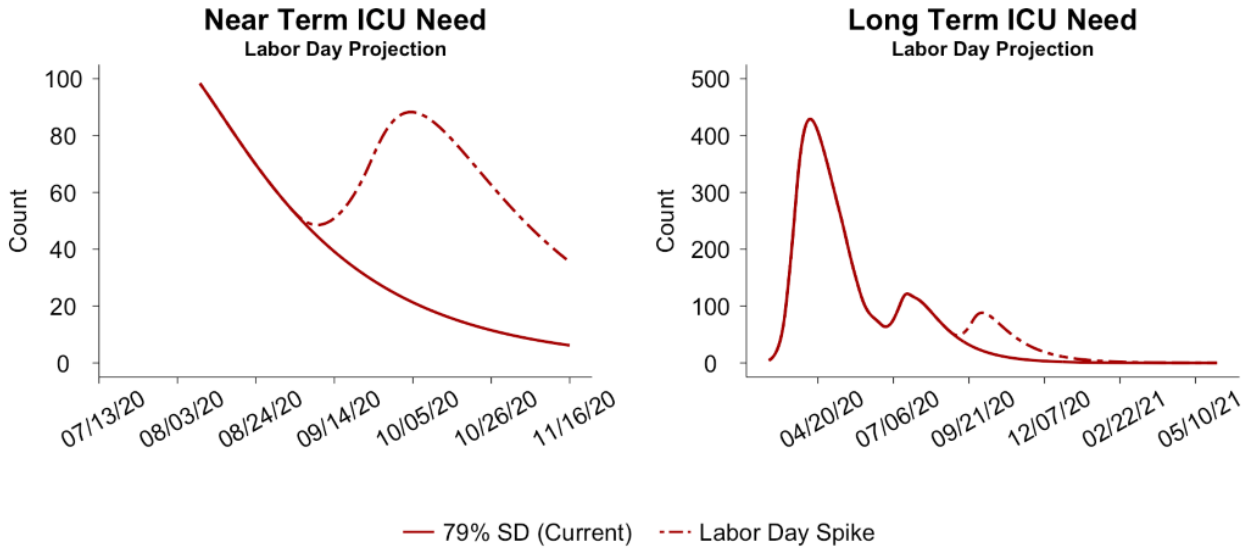
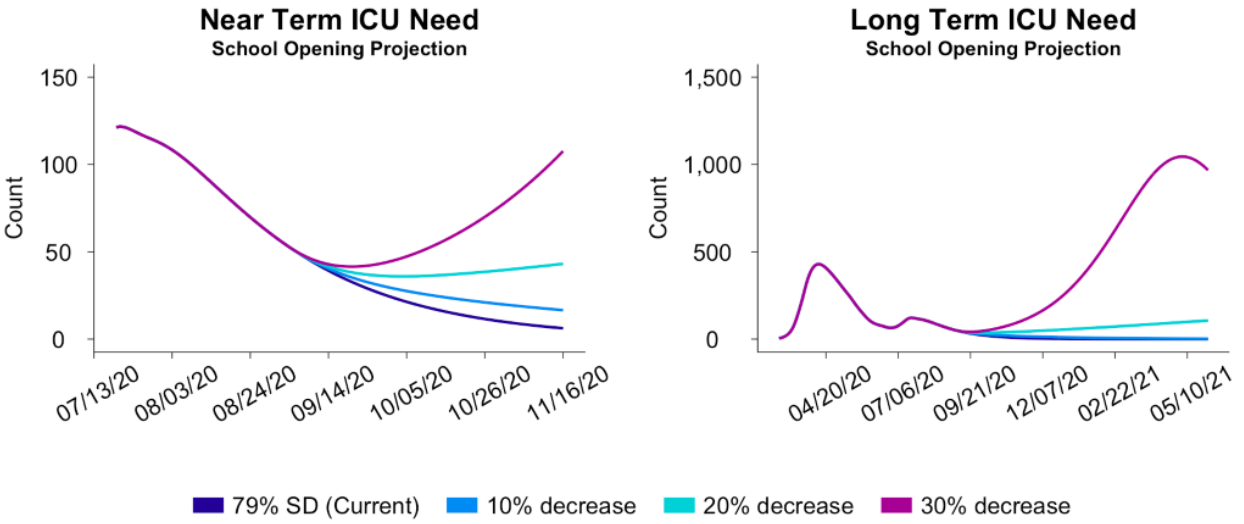


Figure 10. Projected hospital demand assuming a Labor Day increase in contacts akin to what was observed in late June/early July (top), school re-opening without a Labor Day increase in contacts (middle), and both a Labor Day increase and school opening. School opening is modelled starting 09/01 as a 10, 20 and 30% decrease in social distancing by 0 to 19 year-olds. The Labor Day scenario mirrors the increase seen around 4th of July, with an

average of 42% social distancing for three weeks beginning the Wednesday before the holiday weekend (Sep 1st – Sep 21st). In these scenarios, case isolation is assumed to remain constant and mask wearing is 90% starting 7/16, the date of the state-wide mask order.





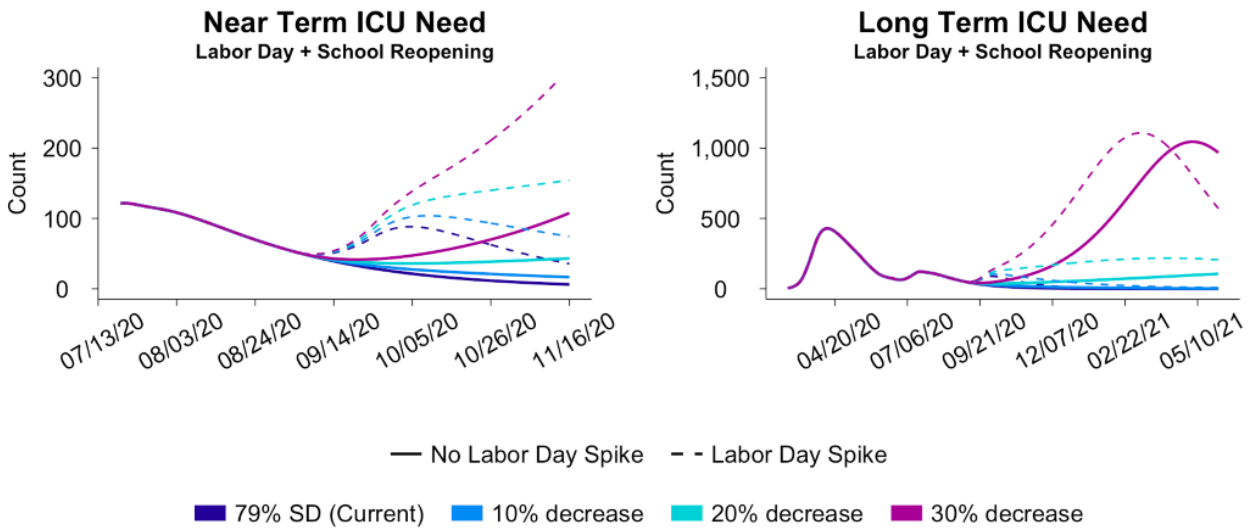


Figure 11. Projected ICU demand assuming a Labor Day increase in contacts akin to what was observed in late June/early July (top), school re-opening without a Labor Day increase in contacts (middle), and both a Labor Day increase and school opening. School opening is modelled starting 09/01 as a 10, 20 and 30% decrease in social distancing by 0 to 19 year-olds. The Labor Day scenario mirrors the increase seen around 4th of July, with an average of 42% social distancing for three weeks beginning the Wednesday before the holiday weekend (Sep 1st – Sep 21st). In these scenarios, case isolation is assumed to remain constant and mask wearing is 90% starting 7/16, the date of the state-wide mask order.

Appendix

Code for our model is available on GitHub: https://github.com/agb85/covid-19

Model simulations evaluating the potential impact of interventions can be generated using our app: https://cucovid19.shinyapps.io/colorado/. This site also includes detailed documentation of our model. The app is updated approximately weekly to reflect our most recent parameter estimates.

Appendix Table A1. Estimated model parameters based on fitting our model output of total hospitalizations to reported hospitalizations in Colorado.

	Range of possible values	Fitted value	Fit using data through
Social distancing*			
Phase 1. Estimated social distancing from mid-March until the start of the stay at home order, modeled as 3/17 - 3/25	10 – 70%	50%	06/24
Phase 2. Estimated social distancing during the state-wide stay at home order, modeled as 3/26 to 4/26	50 – 99%	79%	06/24
Phase 3. Estimated social distancing during the transition to state-wide Safer at Home, modeled as 4/27 to 05/08†	50 – 99%	80%	06/24
Phase 4. Estimated social distancing during early state-wide Safer at Home, modeled as 05/09 to 05/26†	50-99%	87%	06/30
Phase 5. Estimated social distancing during Safer at Home as more businesses re-open, 5/27-07/14†	50-99%	63%	07/27
Estimated social distancing level, 07/13 - present	30-99%	79%	08/17
Estimated current social distancing level, 07/26 - present	30-99%	79%	08/17
Mask wearing			
Percent of individuals wearing masks, 4/4 to 4/27		50%	Assumed¶
Percent of individuals wearing masks, 4/27 to present		70%	Assumed¶
Percent of individuals wearing masks, 7/16 to present		90%	Assumed
Case isolation			
Decrease in infectious - symptomatic contact rate due to self-isolation by symptomatic after March 5 (dividing by 0.57 gives proportion that self-isolate) **	0.1 - 0.8††	0.44	06/24
Case detection			
Proportion of cases detected over the last 14 days	0.0 – 1.0	42%	08/10
Transmission parameters			
The rate of infection (beta)	0.2 - 0.6††	0.48	06/24
Ratio of infectiousness for symptomatic vs. asymptomatic individuals (lambda)	1.0 - 4.0††	1.39	06/24

*The social distancing parameter estimates the percent decrease in effective contacts between susceptible and infectious individuals. This parameter accounts for social distancing policies intended to avoid contact altogether (e.g., through workplace and school closures) as well as policies and individual behaviors to reduce potential contact with the virus (e.g., maintaining at least 6 feet of distance between people outside of one's household, and handwashing).

†Social distancing estimated weekly and averaged over time period of interest.

¶Given the difficulty in disentangling the effect of mask wearing from social distancing in decreasing transmission, we cannot fit this parameter at this time. Survey data suggests levels of mask wearing in June were are approximately 70% [1]. Recent data from local public health agencies suggest mask wearing is above 90% in stores.

**Self-isolation by symptomatic cases is assumed to occur 1 day after the onset of infectiousness and decrease the 67% of contacts that typically occur outside of the home. This parameter jointly accounts for the percent of symptomatic individuals that self-isolate and the imperfect decline in contacts. Dividing the value in the table by 0.57 gives the proportion of symptomatic individuals that self-isolate.

††The range of potential parameter values for case isolation [2] and the rate of infectiousness for symptomatic vs. asymptomatic individuals [3, 4] are based on the literature, and for the rate of infection, were obtained from the MIDAS Online COVID-19 compilation of parameter estimates [5].

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