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The University of Texas at Austin

COVID-19 Transmission Risks For Reopening The University of Texas at Austin

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Summary

There are more than 50,000 students enrolled at the University of Texas at Austin (UT), with an estimated 80% from Texas, 93% from the United States, and 7% from abroad. The 2020-2021 academic year began on August 26th. The university has taken steps to reopen safely in light of four COVID-19-related risks:

> *Introduction risks*: UT students returning to Austin from other regions may arrive infected.
>
> *On-campus transmission risks*: Transmission may occur during classes and other organized UT activities.
>
> *Off-campus transmission risks*: Transmission may occur through off-campus interactions among members of the UT community.
>
> *Community amplification risks*: Transmission may spill over from the UT community into the surrounding Austin community.

In order to assist the University of Texas at Austin in safely reopening, this report addresses the last three risks. We make projections based on several scenarios for the transmission of COVID-19 among UT students and in the surrounding Austin-Round Rock metropolitan area during the Fall 2020 semester. For each scenario, we project the following quantities for August 26 - December 20, 2020: (i) the number of students infected both on and off campus, (ii) the number of total COVID-19 hospitalizations in the Austin MSA and (iii) the peak number of COVID-19 hospitalizations in Austin MSA. We assumed that there will be 27,000 UT students living in Austin during the Fall 2020

semester, with 24% of those students already living in Austin and 76% returning in mid-August from other regions throughout Texas and the world.

In summary, the projections for the August 26 - December 20, 2020 period indicate that the public health impacts of reopening UT will depend on the COVID-19 transmission rates among UT students and other Austin residents.

- Under the mildest scenario, which assumes that transmission rates among students and in Austin are lower than current estimates, we would expect around 638 students to be infected and approximately 527 cumulative COVID-19 hospitalizations in Austin. We would expect Austin hospitalizations to peak at about 157.

- Under a more severe scenario, which assumes a high transmission rate among students and a moderate transmission rate in Austin, we would expect around 19,675 students to be infected and approximately 8,188 cumulative COVID-19 hospitalizations in Austin. We would expect Austin hospitalizations to peak at about 942.

- If UT creates and enforces policies to mitigate COVID-19 transmission among its students, such as prohibiting large gatherings and providing testing, contact tracing, and isolation resources for all students, it can lower the risk of transmission spilling over into the surrounding community.

The projections below assume that transmission rates among UT students and within the city are constant through December 20, and thus do not capture potential reductions in transmission due to changes in UT or city policies, increased precautionary behavior, or the expansion of testing, contact tracing and isolation efforts.

Scenarios

To project the impact of the Fall 2020 UT reopening on the COVID-19 pandemic in Austin, we extended the Austin-Round Rock module of our *US COVID-19 Pandemic Model* to explicitly consider COVID-19 transmission among the 27,000 UT students returning to Austin. The projections assume the following initial conditions and key parameters with 27,000 students returning:

- Simulation time period: August 25 - December 20, 2020

- State of the COVID-19 pandemic on August 25:

- 0.26% of the Austin community infected (5,576 cases)
- 0.5% of UT students infected (135 cases)
- 5.8% of the Austin community previously infected (126,656 recovered or deceased)
- 5% of UT students previously infected (1,350 recovered)

All other model parameters, including asymptomatic proportion, average incubation period, and age-specific hospitalization and fatality rates are provided in the Appendix.

We consider 27 distinct scenarios, each of which is defined by the number of returning students, the transmission rate among students and the transmission rate among other Austin residents and between UT students and other Austin residents:

- UT students returning: 17,000, 22,000, or 27,000, with 24%, corresponding to 4,080, 5,280, or 6,480 students local to Austin
- Transmission among students: low, moderate, or high
- Transmission among other Austin residents and between UT students and other Austin residents: low, moderate or high

Results

Transmission among UT students

The model projections suggest that prevalence of COVID-19 among UT students will depend primarily on the student-to-student transmission rate and secondarily on the background transmission rate among other Austin residents.

As of the beginning of September 2020, the COVID-19 transmission rate in Austin is relatively low [1]. If transmission remains low, then we project that somewhere around 638 (between 362 and 1,354) students will be infected by the end of the fall semester on December 20, 2020 if the student-to-student transmission rate is also low (Figure 1). The projections increase to around 19,438 (between 14,178 and 21,692) students infected if the student-to-student transmission rate is high.

COVID-19 transmission may increase in Austin during fall 2020 as policies change, K-12 schools open, and the community adherence declines. If transmission in Austin is high, then we project that roughly 6,785 (between 1,864 and 14,212) students will be infected during the semester if the student-to-student transmission rate is low (Figure 1 and Table 1). The projections increase to between 15,469 and 23,159 students infected with a median projection of 20,746 if the student-to-student transmission rate is high.

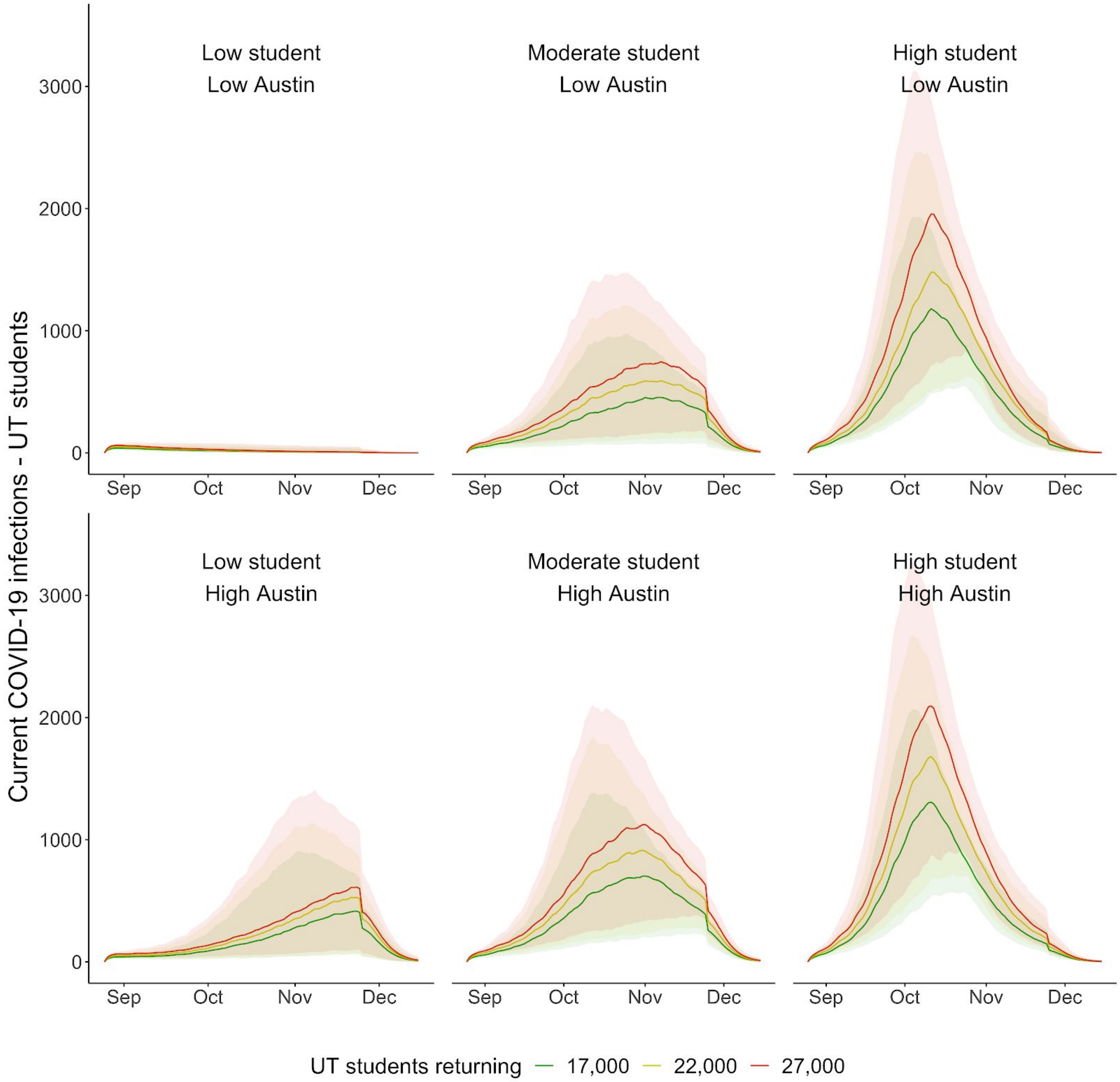

Figure 1. Projected COVID-19 cases among UT students through the end of 2020, under various scenarios for transmission in Austin and among UT students. From left to right, the graphs consider low, moderate and high levels of student-to-student transmission. These correspond to reproduction numbers ($R(t)$) of 0.8, 1.5 and 2 among UT students, respectively. From top to bottom, the graphs consider low and high levels of COVID-19 transmission in Austin. Colors indicate the number of students living in the Austin-Round Rock MSA during the Fall 2020 semester. Shading indicates 95% prediction intervals.

Table 1. Projected cumulative infections among UT students through the end of 2020 under multiple transmission levels assuming that 27,000 students are living in the Austin-Round Rock MSA. Numbers indicate median across 500 stochastic simulations; numbers in parentheses represent 95% prediction interval lower and upper bounds, respectively.

		COVID-19 Transmission in Austin		
		Low	**Moderate**	**High**
COVID-19 transmission among UT students	**Low**	638 (362, 1354)	1977 (664, 6036)	6785 (1864, 14212)
	Moderate	11082 (3543, 16717)	12223 (4159, 18218)	15799 (7016, 20777)
	High	19438 (14178, 21692)	19675 (14761, 22353)	20746 (15469, 23159)

Impacts on COVID-19 transmission throughout Austin

The projections suggest that transmission among UT students could spill over into the Austin community, leading to increasing numbers of COVID-19 hospitalizations.

For example, consider a scenario in which 27,000 UT students are in Austin and the COVID-19 transmission rate is moderate among students and low among others in Austin (Figure 2 and Table 2). We project that COVID-19 hospitalizations in Austin between August 25th and December 20th will total around 1,186, or between 513 and 974 (excluding UT students). This is approximately double the number of hospitalizations we would expect if UT mitigation policies and student behavior succeed in suppressing student-to-student transmission to a low level.

Future pandemic waves could strain the city's healthcare resources. Austin has an estimated COVID-19 hospital capacity of 1,500 beds, not accounting for potentially reduced capacity during influenza season. The projected peak number of COVID-19 hospitalizations under a scenario where student-to-student transmission remains low while Austin area transmission is moderate is 493, or 148 to 2,159 patients (Figure 3 and Table 3). However, if student-to-student transmission is high, the projection increases to a peak of 942 COVID-19 patients, or between 266 and 2,930. This implies that student-to-student transmission can amplify the strain on Austin healthcare systems and increase the risk that COVID-19 cases will exceed local resources.

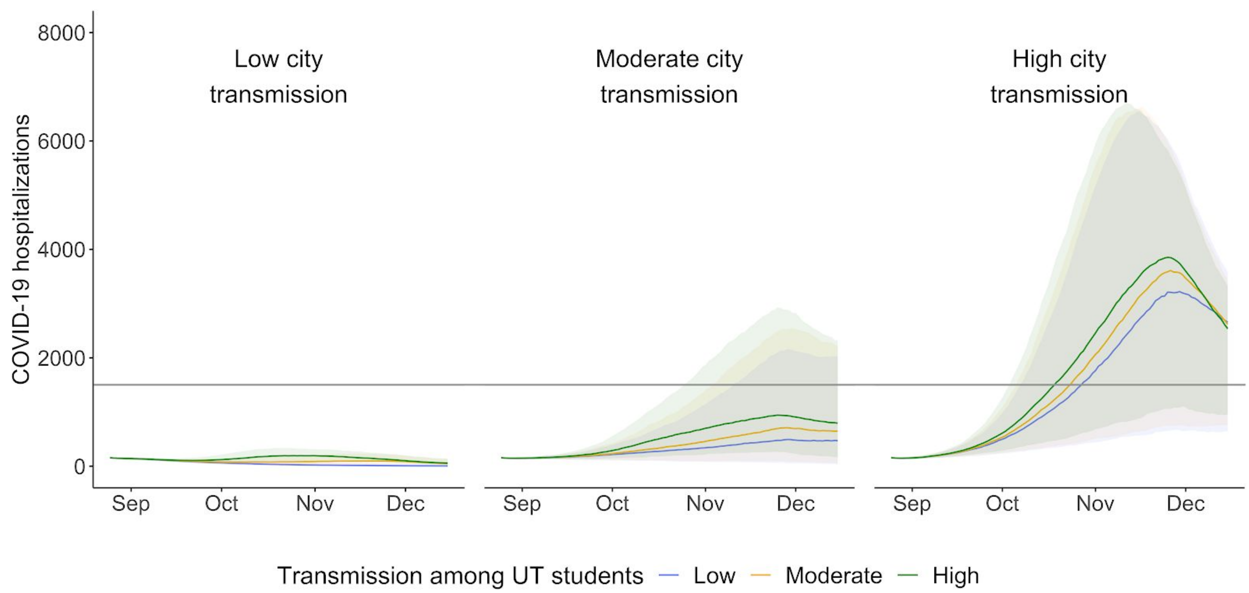

Figure 2. Projected impact of university reopening on COVID-19 hospitalizations in Austin through December 20, 2020, assuming 27,000 UT students return and community-wide transmission is low (left), moderate (middle) or high (right). Colors indicate the level of student-to-student transmission. The gray horizontal line indicates the estimated COVID-19 hospitalization capacity in the Austin MSA (1500 beds). Shading indicates 95% prediction intervals.

Table 2. Projected cumulative hospitalizations among the Austin population through the end of 2020 under multiple transmission levels with 27,000 students living in the Austin-Round Rock MSA. Numbers indicate median across 500 stochastic simulations; numbers in parentheses represent 95% confidence interval lower and upper bounds, respectively.

		COVID-19 Transmission in Austin		
		Low	**Moderate**	**High**
COVID-19 transmission among UT students	**Low**	527 (351, 974)	4604 (1156, 16049)	22992 (6010, 43070)
	Moderate	1186 (513, 2322)	6101 (1398, 18779)	25437 (6627, 43284)
	High	1826 (1048, 3039)	8188 (2699, 21869)	27271 (8742, 43766)

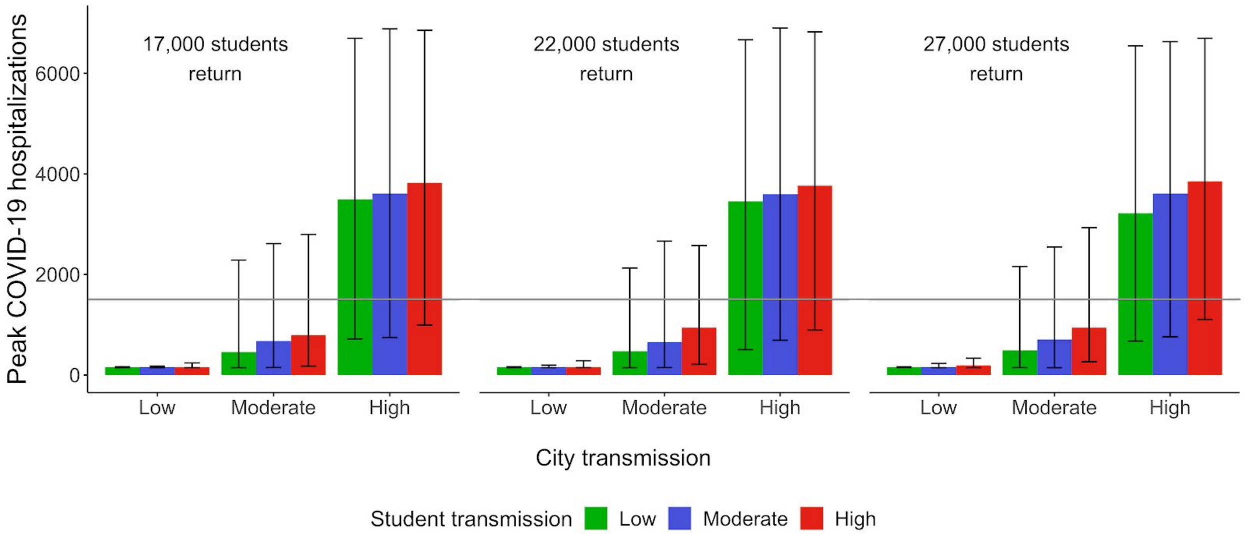

Figure 3. Projected peak COVID-19 hospitalizations in Austin, excluding UT students, through December 20, 2020, under multiple transmission levels and scenarios for the number of students in Austin. Each panel represents different numbers of university students living in the Austin-Round Rock MSA during the fall semester, while the colors represent different levels of transmission among university students when the university is open: green represents a low level of transmission; blue a moderate level; and red a high level. The gray horizontal line indicates the estimated COVID-19 hospitalization capacity in the Austin MSA (1500 beds). Columns and error bars indicate the median and 95% prediction interval across 500 stochastic simulations.

Table 3. Projected peak hospitalizations among the Austin population through the end of 2020 under multiple transmission levels with 27,000 students living in the Austin-Round Rock MSA. Numbers indicate median across 500 stochastic simulations; numbers in parentheses represent 95% confidence interval lower and upper bounds, respectively.

		COVID-19 Transmission in Austin		
		Low	**Moderate**	**High**
COVID-19 transmission among UT students	**Low**	157 (147, 166)	493 (148, 2159)	3220 (675, 6548)
	Moderate	157 (146, 231)	710 (146, 2547)	3610 (761, 6630)
	High	195 (147, 337)	942 (266, 2930)	3853 (1105, 6696)

Final Considerations

Our projections show that the return of the University of Texas at Austin students to Austin and UT campus can amplify COVID-19 transmission in Austin if there is even a moderate level of transmission among students on or off campus. Assuming that 27,000 UT students are living in Austin, the projected spillover of COVID-19 from UT into the community depends on both student-to-student and community-wide transmission rates (Figure 3). Consider the scenario where community-wide transmission is moderate. If the student-to-student transmission rate remains low, we project that peak number of COVID-19 hospitalizations in Austin will be around 493 (between 148 and 2,159), likely below our local capacity of 1,500 beds for COVID-19 patients (Table 3). However, if student-to-student transmission is high, then we would expect a significantly higher number of COVID-19 hospitalizations by December 20th and a greater chance of exceeding local capacity. If UT enacts and enforces strict control measures such as prohibiting large gatherings and providing rapid testing, contact tracing and isolation resources for all students, it can slow the spread of the virus among students and minimize spillover into the surrounding community.

We emphasize the different time course for student infections (Figure 1) and community hospitalizations (Figure 2). In the scenario of a high level of transmission among students and a moderate level of transmission in the surrounding community, student cases spike noticeably in October whereas hospitalizations climb much more slowly and peak in December. Chains of transmission that start within the UT population as early as September can gradually extend into the community leading to large numbers of cases, hospitalizations and even deaths over the course of months. The resulting lag can lead to a false sense of security regarding the spillover of risk into the community and a failure to recognize the causal links.

We also emphasize that these projections should be interpreted merely as rough guideposts to inform effective risk communication and mitigation planning. Our analyses are based on multiple assumptions about the age-specific severity of COVID-19 and the role of asymptomatic infections in the transmission of the virus. We also assume constant COVID-19 transmission rates among students and the Austin community between August 25, 2020 and December 20, 2020. Changes in policy and behavior in response to COVID-19 data and perceived risk may curtail or amplify transmission in the weeks ahead. Thus, the graphs and tables above are not intended as forecasts and do not present the full range of possibilities. Rather, they should be interpreted as plausible scenarios that highlight the potential impacts of transmission among students on the health and safety of the entire UT and Austin communities.

Appendix

COVID-19 Epidemic Model Structure and Parameters

The model structure is diagrammed in Figure S1 and described in the equations below.
For each age and risk group, we build a separate set of compartments to model the transitions between the states: susceptible (S), exposed (E), pre-symptomatic infectious (P^Y), pre-asymptomatic infectious (P^A), symptomatic infectious (I^Y), asymptomatic infectious (I^A), symptomatic infectious that are hospitalized (I^H), recovered (R), and deceased (D). The symbols S, E, P^Y, P^A ,I^Y, I^A, I^H, R, and D denote the number of people in that state in the given age/risk group and the total size of the age/risk group is
$N = S + E + P^Y + P^A + I^Y + I^A + I^H + R + D$.
The model for individuals in age group a and risk group r is given by:

$$\frac{dS_{a,r}}{dt} = -S_{a,r} \cdot \sum_{i \in A} \sum_{j \in K} (I^Y_{i,j}\omega^Y + I^A_{i,j}\omega^A + P^Y_{i,j}\omega^{PY} + P^A_{i,j}\omega^{PA})\beta\phi_{a,i}/N_i$$

$$\frac{dE_{a,r}}{dt} = S_{a,r} \cdot \sum_{i \in A} \sum_{j \in K} (I^Y_{i,j}\omega^Y + I^A_{i,j}\omega^A + P^Y_{i,j}\omega^{PY} + P^A_{i,j}\omega^{PA})\beta\phi_{a,i}/N_i - \sigma E_{a,r}$$

$$\frac{dP^A_{a,r}}{dt} = (1-\tau)\sigma E_{a,r} - \rho^A P^A_{a,r}$$

$$\frac{dP^Y_{a,r}}{dt} = \tau\sigma E_{a,r} - \rho^Y P^Y_{a,r}$$

$$\frac{dI^A_{a,r}}{dt} = \rho^A P^A_{a,r} - \gamma^A I^A_{a,r}$$

$$\frac{dI^Y_{a,r}}{dt} = \rho^Y P^Y_{a,r} - (1-\pi)\gamma^Y I^Y_{a,r} - \pi\eta I^Y_{a,r}$$

$$\frac{dI^H_{a,r}}{dt} = \pi\eta I^Y_{a,r} - (1-\nu)\gamma^H I^H_{a,r} - \nu\mu I^H_{a,r}$$

$$\frac{dR_{a,r}}{dt} = \gamma^A I^A_{a,r} + (1-\pi)\gamma^Y I^Y_{a,r} + (1-\nu)\gamma^H I^H_{a,r}$$

$$\frac{dD_{a,r}}{dt} = \nu\mu I^H_{a,r}$$

where A and K are all possible age and risk groups, ^{A} , ^{Y}, ^{PA}, ω^{PY} are the relative infectiousness of the I^A , I^Y, I^{PA}, I^{PY} compartments, respectively, β is transmission rate, $_{a,i}$ is the mixing rate between age group a, $i \in A$, ^{A} , ^{Y}, ^{H} are the recovery rates for the I^A , I^Y, I^H compartments, respectively, σ is the exposed rate, ρ^A, ρ^Y are the pre-(a)symptomatic rates, τ is the symptomatic ratio, π is the proportion of symptomatic individuals requiring hospitalization, η

is rate at which hospitalized cases enter the hospital following symptom onset, ν is mortality rate for hospitalized cases, and μ is rate at which terminal patients die.

We model stochastic transitions between compartments using the τ-leap method [2,3] with key parameters given in Table S2. Assuming that the events at each time-step are independent and do not impact the underlying transition rates, the numbers of each type of event should follow Poisson distributions with means equal to the rate parameters. We thus simulate the model according to the following equations:

$$S_{a,r}(t+1) - S_{a,r}(t) = -P_1$$

$$E_{a,r}(t+1) - E_{a,r}(t) = P_1 - P_2$$

$$P^A_{a,r}(t+1) - P^A_{a,r}(t) = (1-\tau)P_2 - P_3$$

$$P^Y_{a,r}(t+1) - P^Y_{a,r}(t) = \tau P_2 - P_4$$

$$I^A_{a,r}(t+1) - I^A_{a,r}(t) = P_3 - P_5$$

$$I^Y_{a,r}(t+1) - I^Y_{a,r}(t) = P_4 - P_6 - P_7$$

$$I^H_{a,r}(t+1) - I^H_{a,r}(t) = P_7 - P_8 - P_9$$

$$R_{a,r}(t+1) - R_{a,r}(t) = P_5 + P_6 + P_8$$

with

$$P_1 \sim \mathrm{Pois}(S_{a,r}(t)F_{a,r}(t))$$

$$P_2 \sim \mathrm{Pois}(\sigma E_{a,r}(t))$$

$$P_3 \sim \mathrm{Pois}(\rho^A P^A_{a,r}(t))$$

$$P_4 \sim \mathrm{Pois}(\rho^Y P^Y_{a,r}(t))$$

$$P_5 \sim \mathrm{Pois}(\gamma^A I^A_{a,r}(t))$$

$$P_6 \sim \mathrm{Pois}((1-\pi)\gamma^Y I^Y_{a,r}(t))$$

$$P_7 \sim \mathrm{Pois}(\pi\eta I^Y_{a,r}(t))$$

$$P_8 \sim \mathrm{Pois}((1-\nu)\gamma^H I^H_a)$$

$$P_9 \sim \mathrm{Pois}(\nu\mu I^H_{a,r}(t))$$

and where $F_{a,r}$ denotes the force of infection for individuals in age group a and risk group r and is given by:

$$F_{a,r}(t) = \sum_{i\in A}\sum_{j\in K}(I^Y_{i,r}(t)\omega^Y + I^A_{i,r}(t)\omega^A + P^Y_{i,j}(t)\omega^{PY} + P^A_{i,j}(t)\omega^{PA})\beta_{a,i}\phi_{a,i}/N_i$$

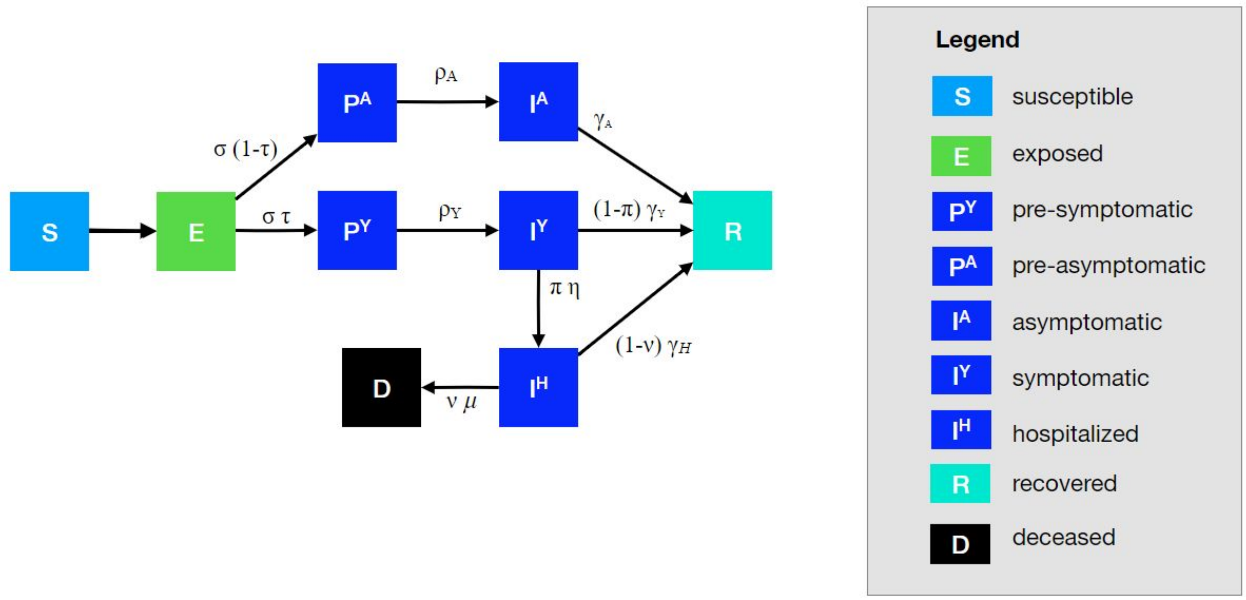

Figure A1. Compartmental model of COVID-19 transmission

Each subgroup (defined by age and risk) is modeled with a separate set of compartments. Upon infection, susceptible individuals (*S*) progress to exposed (*E*) and then to either pre-symptomatic infectious (P^Y) or pre-asymptomatic infectious (P^A) from which they move to symptomatic infectious (I^Y) and asymptomatic infectious (I^A) respectively. All asymptomatic cases eventually progress to a recovered class where they remain protected from future infection (*R*); symptomatic cases are either hospitalized (I^H) or recover. Mortality (*D*) varies by age group and risk group and is assumed to be preceded by hospitalization.

Table A1. Initial conditions, school closures and social distancing policies

Variable	Settings
Initial day of simulation	8/25/2020
Initial infection number in Austin	5,093 infected individuals across presymptomatic and infected compartments as projected on 8/14/2020 [4]
Initial infection prevalence among UT students	0.5% [5]
Initial immune number in Austin	65,445 recovered or dead individuals
Initial immune proportion among UT students	5%
UT open duration	From start of classes for fall semester 2020 (8/25/2020) to end (11/25/2020)
κ: social distancing reduction contacts in the general population	54%, 63%, 75%, corresponding to "high," "moderate," and "low" city transmission
κ_{UT}: social distancing reduction contacts in the university population	33%, 50%, 73% corresponding to "high," "moderate," and "low" UT transmission
κ_I: social distancing reduction contacts between the general and university populations	• On 8/25/2020, starting 11/26/2020: $\kappa_I = 0$ • From 8/26/2020 to 11/25/2020: $\kappa_I = \kappa$
Age-specific and day-specific contact rates	Home, work, other and school matrices provided in Tables S5.1-S5.4 • On 8/25/2020, starting 11/26/2020 *Weekday = $(1-\kappa)$*(home + work + school + other)* *Weekend = $(1-\kappa)$*(home + other)* *Weekday holiday = $(1-\kappa)$*(home + other)* • From 8/26/2020 to 11/25/2020 *Weekday* = $(1-\kappa)(home + work + school + other) + (1-\kappa_{UT})(home_{UT} + work_{UT} + school_{UT} + other_{UT}) + (1-\kappa_I)(home_I + work_I + school_I + other_I)$ *Weekend* = $(1-\kappa)(home + other) + (1-\kappa_{UT})(home_{UT} + other_{UT}) + (1-\kappa_I)(home_I + other_I)$ *Weekend Holiday* = $(1-\kappa)(home + other) + (1-\kappa_{UT})(home_{UT} + other_{UT})$

Table A2. Model parameters. Values given as six-element vectors are age-stratified with values corresponding to 0-4, 5-17, 18-25, 26-49, 50-64, 65+ year age groups, respectively.

Parameters	**Best guess - values**	**Source**
R_0	3.5	Estimated from β
δ : doubling time	3.1 days	Estimated from β
β : transmission rate	0.043	Fitted to hospitalizations data
γ^A : recovery rate on asymptomatic compartment	Equal to γ^Y	
γ^Y : recovery rate on symptomatic non-treated compartment	$\frac{1}{\gamma^Y} \sim Triangular(3.0, 4.0, 5.0)$	He et al. [6]
τ : symptomatic proportion (%)	57	Gudbjartsson et al. [7]
σ : exposed rate	$\frac{1}{\sigma} \sim Triangular(1.9, 2.9, 3.9)$	Based on incubation [8] and pre-symptomatic periods
ρ^A : pre-asymptomatic rate	Equal to ρ^Y	
ρ^Y : pre-symptomatic rate	$\frac{1}{\rho^Y} = 2.3$	He et al. [6]
P: proportion of pre-symptomatic transmission (%)	44	He et al. [6]
ω^P : relative infectiousness of pre-symptomatic individuals	$\omega^P = \frac{P}{1-P} \frac{\tau\omega^Y[YHR/\eta+(1-YHR)/\gamma^Y]+(1-\tau)\omega^A/\gamma^A}{\tau\omega^Y/\rho^Y+(1-\tau)\omega^A/\rho^A}$ $\omega^{PY} = \omega^P\omega^Y, \omega^{PA} = \omega^P\omega^A$	
ω^A : relative infectiousness of infectious individuals in compartment I^A	2/3	He et al. [9]

IFR: infected fatality ratio, age specific (%)	Overall: [0.0016, 0.0049, 0.0253, 0.105, 1.000, 3.371] Low risk: [0.000913, 0.00216, 0.0106, 0.0375, 0.252, 0.644] High risk: [0.00913, 0.0216, 0.106, 0.375, 2.52, 6.44]	Age adjusted from Verity et al. [10]
YFR: symptomatic fatality ratio, age specific (%)	Overall: [0.00281, 0.00868, 0.0444, 0.184, 1.75, 5.91] Low risk: [0.00160, 0.00379, 0.0186, 0.0658, 0.442, 1.13] High risk: [0.0160, 0.0379, 0.186, 0.658, 4.42, 11.3]	$YFR = \frac{IFR}{\tau}$
h : high-risk proportion, age specific (%)	[8.3561, 14.3375, 15.3698, 20.00, 33.02, 47.10]	Estimated using 2015-2016 Behavioral Risk Factor Surveillance System (BRFSS) data with multilevel regression and poststratification using CDC's list of conditions that may increase the risk of serious complications from influenza [11–13]
rr : relative risk for high risk people compared to low risk in their age group	10	Assumption
School calendars	Austin Independent School District calendar (2019-2020, 2020-2021) [14]	

Table A3. Hospitalization parameters

Parameters	Value	Source
γ^H : recovery rate in hospitalized compartment	[0.137, 0.137, 0.137, 0.137, 0.137, 0.101]	7.3 day-average from admission to discharge for 0-64y and 9.9 for 65+ (Austin admissions and discharge data[15,16])

YHR: symptomatic case hospitalization rate (%)	Overall: [0.0702, 0.0702, 1.49, 5.88, 16.3, 25.5] Low risk: [0.0401, 0.0306, 0.624, 2.10, 4.11, 4.88] High risk: [0.401, 0.306, 6.24, 21.0, 41.1, 48.8]	Age adjusted from Verity et al. [10]
π : rate symptomatic individuals go to hospital, age-specific	$\pi = \frac{\gamma^Y \cdot YHR}{\eta + (\gamma^Y - \eta) YHR}$	
η : rate from symptom onset to hospitalized	0.1695	5.9 day average from symptom onset to hospital admission Tindale et al. [17]
μ : rate from hospitalized to death	[0.0562, 0.0562, 0.0562, 0.0562, 0.0562, 0.0943]	17.8 day-average from admission to discharge for 0-64y and 10.6 for 65+ (Austin admissions and deaths data[15,16])
HFR: hospitalized fatality ratio, age specific (%)	[4.000, 12.37, 2.983, 3.135, 10.74, 23.16]	$HFR = \frac{YFR}{YHR}$
ν : death rate on hospitalized individuals, age specific	$\nu = \frac{\gamma^H HFR}{\mu + (\gamma^H - \mu) HFR}$	

Model modification to incorporate university students

Derivation of contact matrices

To derive contact matrices for the model, we expand the original contact matrices [18], which we assume describe contacts in the Austin Metropolitan Statistical Area at baseline (prior to the COVID-19 pandemic and with 50,000 UT students) and then adjust the resulting matrices for each scenario for the number of UT students returning. These adjustments are described in the next section, “Matrix adjustment for different numbers of returning students.”

Because we assume that original contact matrices, condensed into 6 age groups, describe contacts in the Austin Metropolitan Statistical Area at baseline, the matrices therefore include contacts by UT students, whom we assume fall into the 18-25 year old age group. We assume that there are 50,000 UT students in Austin at baseline, and that these students are included in our population estimate [19].

Table A4. AustinMSA population distribution by age and risk group.

Risk	0-4y	5-17y	18-25y	26-49y	50-64y	65y+	UT
Low	128,527	327,148	170,122	695,176	249,273	132,505	44,046
High	9,350	37,451	22,998	133,808	108,196	103,763	5,954

We denote by $C_{i,j}^{X}$ the average number of contacts a member of group i has with members of age group j at location X on any given day, where i,j ∈ {0-4, 5-17, 18-25, 26-49, 50-64, 65+}, and X ∈ {*H,W,S,O*}, representing home, work, school, and other locations respectively. Let $\tilde{C}_{i,j}^{X}$ denote the same for the expanded matrices with UT students, where in this case i,j ∈ {0-4, 5-17, 18-25, 26-49, 50-64, 65+, u}, with u representing the group of UT students and 18-25 now representing non-UT 18-25 year olds.

Because our assumed contact patterns for UT students differ from those of 18-25 year olds in the original matrices, we solve for the contribution of non-UT 18-25 year olds' average contacts $\tilde{C}_{\text{18-25},j}^{X}$ to all 18-25 year olds' average contacts $C_{\text{18-25},j}^{X}$ to maintain the underlying symmetry of the original matrices. We let p denote the proportion of all 18-25 year olds who are UT students. Because $C_{\text{18-25},j}^{X}$ is the average number of contacts 18-25 year olds have with members of group j at location X, we know that UT students' contacts contribute to this average with a weight of p, and that non-UT 18-25 year olds contribute with a weight of $1-p$. Note that the following equation does not hold for the case where $j=$18-25, which is addressed later.

$$C_{i,\text{18-25}}^{X} = \tilde{C}_{i,\text{18-25}}^{X} + \tilde{C}_{i,u}^{X}.$$

These changed contact patterns for UT students also apply to other groups' contacts with non-UT 18-25 year olds. Other groups' contacts with all 18-25 year olds $C_{\text{18-25},j}^{X}$ are a combination of other groups' contacts with non-UT 18-25 year olds $\tilde{C}_{i,\text{18-25}}^{X}$ and their contacts with UT students $\tilde{C}_{i,u}^{X}$. Thus $C_{i,\text{18-25}}^{X}$ describes i's contacts with both non-UT 18-25 year olds and UT students, and so it is the sum of i's contacts with each group:

$$C_{i,\text{18-25}}^{X} = \tilde{C}_{i,\text{18-25}}^{X} + \tilde{C}_{i,u}^{X}.$$

$C_{\text{18-25,18-25}}^{X}$ describes four types of contacts: non-UT 18-25 year olds' contacts with non-UT 18-25 year olds, non-UT 18-25 year olds' contacts with UT students, UT students' contacts with non-UT 18-25 year olds, and UT students' contacts with other UT students. By combining the logic for the previous two cases, we have:

$$C^X_{18\text{-}25,18\text{-}25} = (1-p)\cdot(\tilde{C}^X_{18\text{-}25,18\text{-}25} + \tilde{C}^X_{18\text{-}25,u}) + p\cdot(\tilde{C}^X_{u,u} + \tilde{C}^X_{u,18\text{-}25}).$$

Thus assumptions about UT students' contacts with others at each location $\tilde{C}^X_{u,j}$ and related assumptions about others' contacts with UT students $\tilde{C}^X_{i,u}$ are sufficient to solve for non-UT 18-25 year olds' contacts with others and others' contacts with non-UT 18-25 year olds in the expanded matrices:

$$\tilde{C}_{18\text{-}25,j} = \frac{C^X_{18\text{-}25,j} - p\cdot\tilde{C}^X_{u,j}}{1-p} \text{ for } j \neq 18\text{-}25,$$

$$\tilde{C}^X_{i,18\text{-}25} = C^X_{i,18\text{-}25} - \tilde{C}^X_{i,u} \text{ for } i \neq 18\text{-}25, \text{ and}$$

$$\tilde{C}^X_{18\text{-}25,18\text{-}25} = \frac{C^X_{18\text{-}25,18\text{-}25} - p\cdot(\tilde{C}^X_{u,u} + \tilde{C}^X_{u,18\text{-}25}) - (1-p)\cdot\tilde{C}^X_{18\text{-}25,u}}{1-p}.$$

Contacts at Home

We assume that UT students have the same number of home contacts as the average 18-25 year old, but that all are with other UT students. Thus UT students have no home contacts with other groups nor vice versa.

$$\tilde{C}^H_{u,u} = \sum_j C^H_{18\text{-}25,j},$$

$$\tilde{C}^H_{i,u} = 0 \text{ for } i \neq u, \text{ and}$$

$$\tilde{C}^H_{u,j} = 0 \text{ for } j \neq u.$$

See table A5.1. for the original home contact matrix and table A6.1. for the modified home contact matrix.

Contacts at Work

Full-time 18-25 year old university students in the United States work an average of 9.23 hours per week, compared to the average of 19.33 hours for all 18-25 year olds [20]. Thus full-time 18-25 year old university students work $\mu = \frac{9.23}{19.88}$ proportion of the hours of the average 18-25 year old. We assume that work contacts are proportional to hours worked such that full-time university students have μ times the work contacts of the average 18-25 year old. We also assume that all UT students work, on average, the same number of hours per week as the typical 18-25 year old full-time university student in the United States. Finally, we assume that $\pi = 50\%$ of a UT student's work contacts are with other UT students. Thus students' home contacts are described by the following equations:

$$\tilde{C}^W_{u,u} = \pi\mu\sum_j C^W_{18\text{-}25,j},$$

$$\tilde{C}^W_{u,j} = (1-\pi)\mu C^W_{18\text{-}25,,j}, \text{ and}$$
$$\tilde{C}^W_{i,u} = p(1-\pi)\mu C^W_{i,18\text{-}25}.$$

See table A5.3. for the original work contact matrix and table A6.3. for the modified work contact matrix.

Contacts at School

We assume that 18-25 year olds' contacts with 18-25 year olds and 26-64 year olds in the school matrix C^S describe only interactions between university students and other university students, and university students and faculty or staff, respectively. So the number of contacts by university students with these groups

$$\tilde{C}^S_{u,x} = \frac{C^S_{18\text{-}25,x}}{p_s}, \text{ and}$$
$$\widetilde{C}^S_{u,u} = \frac{C^S_{18-25,18-25}\, p_s}{[?]}$$

Where $x \in$ {26-49, 50-64} and $p_s = .29$ denotes the proportion [20] of 18-25 year olds in the United States who are full-time university students. We assume that UT students only have contacts with other students and faculty and staff at school, so contacts with other groups

$$\tilde{C}^S_{u,j} = 0 \text{ for } j \notin \{u, 26\text{-}49, 50\text{-}64\}$$

Finally,

$$\tilde{C}^S_{i,u} = p\frac{C^S_{i,18\text{-}25}}{p_s} \text{ for } i \in \{26\text{-}49, 50\text{-}64\}, \text{ and}$$
$$\tilde{C}^S_{i,u} = 0 \text{ for } i \in \{0\text{-}4, 5\text{-}17, 18\text{-}25, 65+\}$$

See table A5.2. for the original school contact matrix and table A6.2. for the modified school contact matrix.

Contacts in Other Locations

We assume that UT students have the same number of total contacts as the average 18-25 year old in Austin, but that $\kappa = .5$ proportion of them are with other UT students.

$$\tilde{C}^O_{u,u} = \kappa \sum_j C^O_{18\text{-}25,j},$$

$$\tilde{C}^O_{i,u} = p(1-\kappa)C^O_{i,18\text{-}25},$$
$$\tilde{C}^O_{u,j} = (1-\kappa)C^O_{18\text{-}25,j}.$$

See table A5.4. for the original other contact matrix and table A6.4. for the modified other contact matrix.

Matrix adjustment for different numbers of returning students

In order to adjust the contact matrices for our scenarios, where $n <$ 50,000 students return to Austin, we multiply others' contacts with students at location X $\tilde{C}^X_{i,u}$ by $\frac{n}{50000}$.

Initial conditions

Initial conditions for each disease compartment were estimated using our Austin projection model for August 25, 2020 on September 14, 2020 [4]. Because our Austin projection model uses 5 age groups, with 18-25 and 26-49 consolidated into 18-49, we split each 18-49 disease compartment into 18-25 and 26-49 age groups proportional to the age distribution of the Austin population.

Students in Austin

We assume that, at baseline, there are 12,000 UT students that live in Austin and thus 38,000 students that come from outside of Austin. We assume that in a simulation scenario where N students return to UT as residential students, either on- or off-campus, for the semester, then $\frac{12000}{50000} * N = .24 * N$ students will return from Austin. The other $1 - (.24 * N)$ students will return to UT from outside of Austin.

In our simulation, $.24 * N$ individuals proportionally leave the 18-25 disease compartments and become UT students when UT opens, such as on August 26, 2020. The remainder of the scenario's students are added with initial COVID-19 prevalence of 0.5% and initial immunity of 5%. When UT closes, $.24 * N$ individuals proportionally leave the UT student disease compartments and become 18-25 year olds in Austin. The remaining students are assumed to leave Austin and thus do not have any further effect on simulation results.

Original 6-age group contact matrices

Table A5.1 Home contact matrix. At baseline, daily number contacts by age group at home.

	0-4y	**5-17y**	**18-25y**	**26-49y**	**50-64y**	**65y+**
0-4y	0.5	0.9	0.2	1.7	0.1	0.0
5-17y	0.2	1.7	0.3	1.6	0.2	0.0
18-25y	0.1	0.6	1.3	0.8	0.4	0.0
26-49y	0.3	1.0	0.3	1.2	0.2	0.0
50-64y	0.2	0.7	0.5	0.3	0.6	0.1
65y+	0.1	0.7	0.2	0.8	0.3	0.6

Table A5.2 School contact matrix. At baseline, daily number contacts by age group at school.

	0-4y	**5-17y**	**18-25y**	**26-49y**	**50-64y**	**65y+**
0-4y	1.0	0.5	0.0	0.3	0.1	0.0
5-17y	0.2	3.7	0.6	0.3	0.1	0.0
18-25y	0.0	1.5	1.7	0.2	0.1	0.0
26-49y	0.1	0.4	0.2	0.2	0.0	0.0
50-64y	0.1	0.8	0.3	0.2	0.1	0.0
65y+	0.0	0.0	0.0	0.0	0.0	0.0

Table A5.3 Work contact matrix. At baseline, daily number contacts by age group at work.

	0-4y	**5-17y**	**18-25y**	**26-49y**	**50-64y**	**65y+**
0-4y	0.0	0.0	0.0	0.0	0.0	0.0
5-17y	0.0	0.1	0.2	0.3	0.0	0.0
18-25y	0.0	0.2	1.0	2.3	0.5	0.0
26-49y	0.0	0.2	0.7	4.2	1.0	0.0
50-64y	0.0	0.1	0.3	2.5	0.9	0.0
65y+	0.0	0.0	0.0	0.1	0.0	0.0

Table A5.4 Others contact matrix. Daily number contacts by age group at other locations.

	0-4y	5-17y	18-25y	26-49y	50-64y	65y+
0-4y	0.7	0.7	0.3	1.5	0.6	0.3
5-17y	0.2	2.6	0.8	1.4	0.4	0.2
18-25y	0.1	1.5	2.8	1.8	0.4	0.1
26-49y	0.1	0.4	0.5	2.3	0.6	0.2
50-64y	0.1	0.3	0.4	1.8	1.1	0.4
65y+	0.0	0.2	0.2	1.1	0.8	0.6

Updated contact matrices with subgroup for UT students[1]

Table A6.1 Home contact matrix. Daily number contacts by age group at home assuming 50,000 UT students in Austin MSA.

	0-4y	5-17y	18-25y	26-49y	50-64y	65y+	UT
0-4y	0.5	0.9	0.2	1.7	0.1	0.0	0.0
5-17y	0.2	1.7	0.3	1.6	0.2	0.0	0.0
18-25y	0.1	0.8	0.8	1.0	0.5	0.0	0.0
26-49y	0.3	1.0	0.3	1.2	0.2	0.0	0.0
50-64y	0.2	0.7	0.5	0.3	0.6	0.1	0.0
65y+	0.1	0.7	0.2	0.8	0.3	0.6	0.0
UT	0.0	0.0	0.0	0.0	0.0	0.0	3.2

Table A6.2 School contact matrix. Daily number contacts by age group at school assuming 50,000 UT students in Austin MSA.

	0-4y	5-17y	18-25y	26-49y	50-64y	65y+	UT
0-4y	1.0	0.5	0.0	0.3	0.1	0.0	0.0
5-17y	0.2	3.7	0.6	0.3	0.1	0.0	0.0
18-25y	0.0	1.9	0.6	0.1	0.0	0.0	0.0
26-49y	0.1	0.4	0.1	0.2	0.0	0.0	0.1
50-64y	0.1	0.8	0.1	0.2	0.1	0.0	0.2
65y+	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UT	0.0	0.0	0.0	0.8	0.2	0.0	5.8

[1] These contact matrices describe contact patterns at baseline, or prior to the COVID-19 pandemic. They thus describe contacts without reduction and include 50,000 UT students. For scenario-specific adjustments, see Table A1 and “Matrix adjustment for different numbers of returning students.”

Table A6.3 Work contact matrix. Daily number contacts by age group at work assuming 50,000 UT students in Austin MSA.

	0-4y	5-17y	18-25y	26-49y	50-64y	65y+	UT
0-4y	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5-17y	0.0	0.1	0.2	0.3	0.0	0.0	0.0
18-25y	0.0	0.3	0.9	2.8	0.5	0.0	0.0
26-49y	0.0	0.2	0.6	4.2	1.0	0.0	0.0
50-64y	0.0	0.1	0.3	2.5	0.9	0.0	0.0
65y+	0.0	0.0	0.0	0.1	0.0	0.0	0.0
UT	0.0	0.1	0.2	0.5	0.1	0.0	0.9

Table A6.4 Others contact matrix. Daily number contacts by age group at other locations assuming 50,000 UT students in Austin MSA.

	0-4y	5-17y	18-25y	26-49y	50-64y	65y+	UT
0-4y	0.7	0.7	0.3	1.5	0.6	0.3	0.0
5-17y	0.2	2.6	0.8	1.4	0.4	0.2	0.1
18-25y	0.1	1.5	2.8	1.8	0.4	0.1	0.3
26-49y	0.1	0.4	0.5	2.3	0.6	0.2	0.1
50-64y	0.1	0.3	0.4	1.8	1.1	0.4	0.0
65y+	0.0	0.2	0.2	1.1	0.8	0.6	0.0
UT	0.0	0.8	1.4	0.9	0.2	0.1	3.4

Estimation of age-stratified proportion of population at high-risk for COVID-19 complications

We estimate age-specific proportions of the population at high risk of complications from COVID-19 based on data for Austin, TX and Round-Rock, TX from the CDC's 500 cities project (Figure A2).[21] We assume that high risk conditions for COVID-19 are the same as those specified for influenza by the CDC.[11] The CDC's 500 cities project provides city-specific estimates of prevalence for several of these conditions among adults.[22] The estimates were obtained from the 2015-2016 Behavioral Risk Factor Surveillance System (BRFSS) data using a small-area estimation methodology called multi-level regression and poststratification.[12,13] It links geocoded health surveys to high spatial resolution population demographic and socioeconomic data.[13]

Estimating high-risk proportions for adults. To estimate the proportion of adults at high risk for complications, we use the CDC's 500 cities data, as well as data on the prevalence of HIV/AIDS, obesity and pregnancy among adults (Table A7).

The CDC 500 cities dataset includes the prevalence of each condition on its own, rather than the prevalence of multiple conditions (e.g., dyads or triads). Thus, we use separate co-morbidity estimates to determine overlap. Reference about chronic conditions[23] gives US estimates for the proportion of the adult population with 0, 1 or 2+ chronic conditions, per age group. Using this and the 500 cities data we can estimate the proportion of the population p_{HR} in each age group in each city with at least one chronic condition listed in the CDC 500 cities data (Table A7) putting them at high-risk for flu complications.

HIV: We use the data from table 20a in CDC HIV surveillance report[24] to estimate the population in each risk group living with HIV in the US (last column, 2015 data). Assuming independence between HIV and other chronic conditions, we increase the proportion of the population at high-risk for influenza to account for individuals with HIV but no other underlying conditions.
Morbid obesity: A BMI over 40kg/m^2 indicates morbid obesity, and is considered high risk for influenza. The 500 Cities Project reports the prevalence of obese people in each city with BMI over 30kg/m^2 (not necessarily morbid obesity). We use the data from table 1 in Sturm and Hattori[25] to estimate the proportion of people with BMI>30 that actually have BMI>40 (across the US); we then apply this to the 500 Cities obesity data to estimate the proportion of people who are morbidly obese in each city. Table 1 of Morgan et al.[26] suggests that 51.2% of morbidly obese adults have at least one other high risk chronic condition, and update our high-risk population estimates accordingly to account for overlap.
Pregnancy: We separately estimate the number of pregnant women in each age group and each city, following the methodology in CDC reproductive health report.[27] We assume independence between any of the high-risk factors and pregnancy, and further assume that half the population are women.

Estimating high-risk proportions for children. Since the 500 Cities Project only reports data for adults 18 years and older, we take a different approach to estimating the proportion of children at high risk for severe influenza. The two most prevalent risk factors for children are asthma and obesity; we also account for childhood diabetes, HIV and cancer.
From Miller et al.[28], we obtain national estimates of chronic conditions in children. For asthma, we assume that variation among cities will be similar for children and adults. Thus, we use the relative prevalences of asthma in adults to scale our estimates for children in each city. The prevalence of HIV and cancer in children are taken from CDC HIV surveillance report [24] and cancer research report,[29] respectively.

We first estimate the proportion of children having either asthma, diabetes, cancer or HIV (assuming no overlap in these conditions). We estimate city-level morbid obesity in children using the estimated morbid obesity in adults multiplied by a national constant ratio for each age group estimated from Hales et al.,[30] this ratio represents the prevalence in morbid obesity in children given the one observed in adults. From Morgan et al.,[26] we estimate that 25% of morbidly obese children have another high-risk condition and adjust our final estimates accordingly.

Resulting estimates. We compare our estimates for the Austin-Round Rock Metropolitan Area to published national-level estimates [31] of the proportion of each age group with underlying high risk conditions (Table A8). The biggest difference is observed in older adults, with Austin having a lower proportion at risk for complications for COVID-19 than the national average; for 25-39 year olds the high risk proportion is slightly higher than the national average.

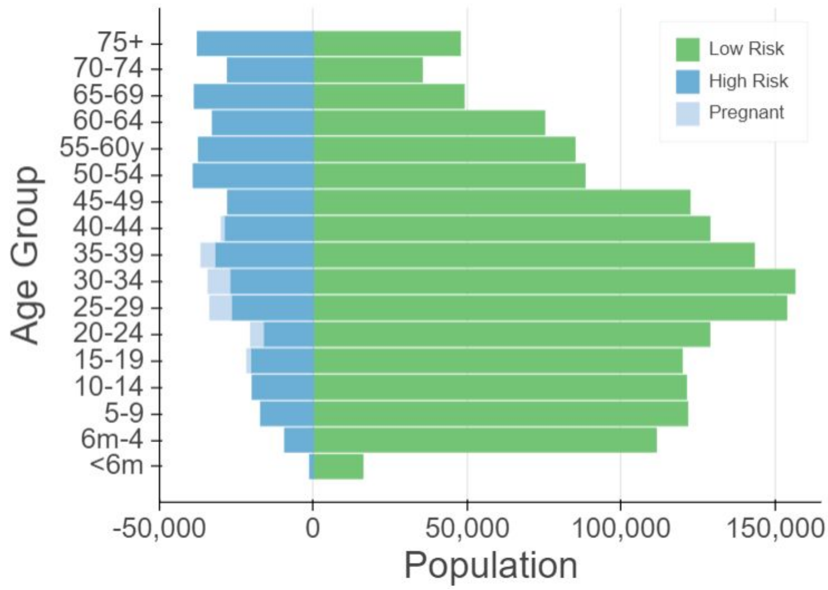

Figure A2. Demographic and risk composition of the Austin-Round Rock MSA. Bars indicate age-specific population sizes, separated by low risk, high risk, and pregnant. High risk is defined as individuals with cancer, chronic kidney disease, COPD, heart disease, stroke, asthma, diabetes, HIV/AIDS, and morbid obesity, as estimated from the CDC 500 Cities Project [21], reported HIV prevalence[24] and reported morbid obesity prevalence,[25,26] corrected for multiple conditions. The population of pregnant women is derived using the CDC's method combining fertility, abortion and fetal loss rates.[32–34]

Table A7. High-risk conditions for influenza and data sources for prevalence estimation

Condition	Data source
Cancer (except skin)	CDC 500 cities[21]
Chronic kidney disease	CDC 500 cities[21]
COPD	CDC 500 cities[21]
Coronary heart disease	CDC 500 cities[21]
Stroke	CDC 500 cities[21]
Asthma	CDC 500 cities[21]
Diabetes	CDC 500 cities[21]
HIV/AIDS	CDC HIV Surveillance report[24]
Obesity	CDC 500 cities complemented with Sturm and Hattori[25] and Morgan et al.[26]
Pregnancy	National Vital Statistics Reports[32] and abortion data[33]

Table A8: Comparison between published national estimates and Austin-Round Rock MSA estimates of the percent of the population at high-risk of influenza/COVID-19 complications

Age Group	National estimates[30]	Austin (excluding pregnancy)	Pregnant women (proportion of age group)
0 to 6 months	NA	6.8	-
6 months to 4 years	6.8	7.4	-
5 to 9 years	11.7	11.6	-
10 to 14 years	11.7	13.0	-
15 to 19 years	11.8	13.3	1.7
20 to 24 years	12.4	10.3	5.1
25 to 34 years	15.7	13.5	7.8
35 to 39 years	15.7	17.0	5.1
40 to 44 years	15.7	17.4	1.2
45 to 49 years	15.7	17.7	-
50 to 54 years	30.6	29.6	-
55 to 60 years	30.6	29.5	-
60 to 64 years	30.6	29.3	-
65 to 69 years	47.0	42.2	-
70 to 74 years	47.0	42.2	-
75 years and older	47.0	42.2	-

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