Return to work screening strategies for SARS-CoV-2 diagnostic testing

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Version 1.0 – Updated 05.19.20

Executive Summary

The goal of the Color "return to work" severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) testing protocol is to create a framework that enables the containment of coronavirus disease 2019 (COVID-19) cases so that employers are not forced to withdraw their workforce after re-introduction.

Testing of symptomatic individuals and individuals with a known exposure to COVID-19 is a key component to preventing an outbreak within the population and should be implemented across all populations.

However, testing of symptomatic individuals alone is not sufficient to contain a potential outbreak event. Proactive testing is necessary to further mitigate risk of outbreak.

When considering "return to work" SARS-CoV-2 screening, one of the most important decisions to make is how often to perform testing.

We used SEIR epidemiological models, incorporating testing and subsequent isolation of infected individuals, to determine the ideal testing cadence for screening and containment.

When no current outbreak is detected and there are low or moderate levels of community transmission, testing each individual once every three to four weeks is sufficient to detect a potential outbreak while there is still time for containment.

Once an infection is detected in the population, testing each individual once every week, combined with mitigation measures such as social distancing, personal protective equipment, and other workplace controls, can contain the outbreak in a workplace.

This framework proposes five primary testing protocols.

Testing Protocol	Testing Frequency / Cadence
1. RE-ENTRY TO WORKPLACE	Two consecutive negative diagnostic tests, taken three to four days and one to two days prior to re-entry date.
2. SYMPTOMATIC AND EXPOSURE-BASED	Test, trace, and isolate all individuals who report symptoms of COVID-19 or direct contact with an individual confirmed to be SARS-CoV-2 positive.
3. BASELINE PROACTIVE TESTING CADENCE (low/moderate community spread)	Once per month testing after initial population re-entry to work
4. ESCALATED PROACTIVE TESTING CADENCE (low/moderate community spread)	Once infected individual(s) is identified in the population, increase proactive testing cadence to once per week.
5. PROACTIVE TESTING CADENCE (high community spread or workplace exposure)	Sustained once per week testing cadence at all times.

Background

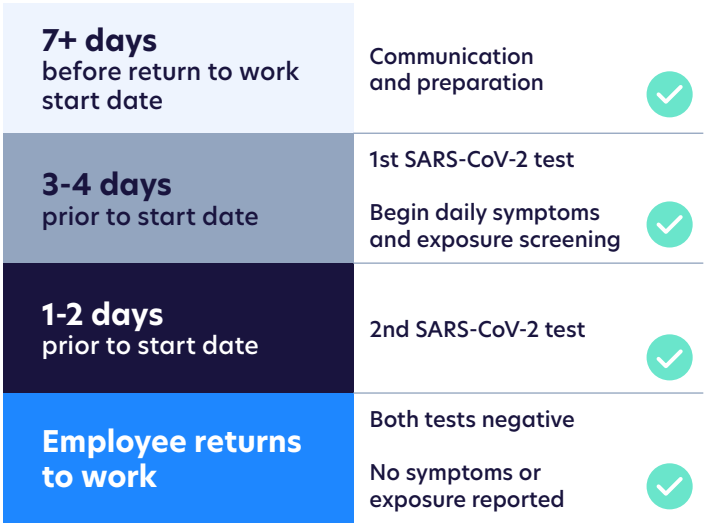
Coronavirus disease 2019 (COVID-19) is caused by the novel coronavirus known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Congregate settings, such as the workplace, provide a favorable environment for COVID-19 transmission and have been tied to several outbreaks around the world.[1,2] In addition, person-to-person transmission of COVID-19 can occur before an infected individual develops symptoms, with peak infectiousness occurring 0 - 2 days before symptom onset, and many individuals experience very mild or no symptoms.[3,4] This suggests that the use of symptomatic screening alone will be an ineffective measure to prevent outbreaks. The use of proactive testing, or surveillance testing, has been suggested as a countermeasure to identify asymptomatic individuals and prevent transmission.[5] To date, several health systems have implemented proactive testing of employees and patients to successfully identify asymptomatic individuals, preventing further transmission through early containment.[6,7] Proactive testing of asymptomatic employees can be an effective measure to safely and productively bring employees back to the workplace. However, one of the most important decisions to make is how often to perform testing. To be effective, testing must be frequent enough to catch an outbreak before it becomes a runaway event that is difficult to contain. Many factors contribute to choosing an appropriate protocol, including the exposure risks specific to the community, workplace setting, and workforce size.

Here, we outline a return-to-work protocol that addresses i) initial re-entry of individuals to the workplace, ii) ongoing symptomatic and exposure-based testing, and iii) a two-tiered proactive testing protocol to provide ongoing outbreak mitigation to maintain workplace safety and productivity. To do this, we developed a SEIR epidemiological model that simulates the disease progression and incorporates interventions such as testing and workplace controls. SEIR models are compartmental models, meaning they model the rates of change of individuals in a number of disease states, including the proportion susceptible (S) to the disease, exposed (E) to the disease, actively infectious (I), and recovered (R) from the disease. We observed these changes over time under different model assumptions in order to investigate the effect of different containment measures on disease spread.

Initial re-entry to workplace testing

In a population where the majority of the workforce has been sheltering-in-place and kept outside of the workplace (working from home), an initial re-entry to workplace testing protocol should be implemented to ensure that everyone coming back into the workplace is free from infection (Figure 1).

Figure 1. Re-entry to workplace testing protocol



An expectation should be communicated to all employees that they will take two SARS-CoV-2 diagnostic tests prior to returning to work. The first test should be administered 3 - 4 days prior to the start date, at which point daily symptom and exposure screening surveys should also be deployed. The second test should be administered 1 - 2 days prior to the start date.

Employees for whom both SARS-CoV-2 diagnostic testing results are negative, as well as no symptoms or exposures reported, are cleared to re-enter the workplace.

This protocol should be used to clear employees for initial re-entry to the workplace, as well as for any subsequent re-entry events – such as returning to work after showing symptoms or after recovery from COVID-19.

It should be noted that as the field's understanding of the accuracy, utility, and interpretation of serological tests becomes more mature, we expect that serological testing will also become an integral part of re-entry to the workplace testing.

Active symptomatic vs. asymptomatic testing in the workplace

Due to the high transmissibility of SARS-CoV-2 and congregate settings of most workplaces, the use of workplace controls and mitigation measures will be necessary to prevent widespread transmission in the workplace.

Once employees have been cleared for work, the next step is to implement screening measures to quickly detect the introduction of a new infection within this previously-cleared population.

To accomplish this, continued daily screening of symptoms and exposures must be implemented. Employees who report symptoms or exposure to a COVID-19 postive (+) individual should be removed from the workplace and undergo testing for COVID-19. Those who test positive for COVID-19 should be isolated and monitored remotely until symptoms subside, at which point they can begin re-entry to the workplace testing.

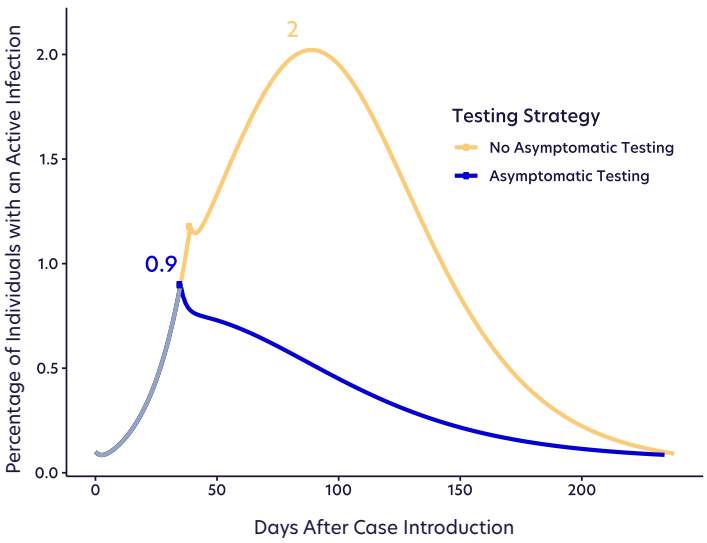
Presymptomatic and asymptomatic carriers of COVID-19 have been shown to shed high levels of SARS-CoV-2 contributing to the high transmissibility of COVID-19.[8] Furthermore, peak infectiousness has been shown to occur at or right before symptom onset in symptomatic patients, making containment measures based on symptomatic testing alone challenging.[4] Below, we designed models evaluating testing of both symptomatic and asymptomatic individuals compared to a symptomatic-only testing approach (Figure 2).

Our models suggest that in the presence of asymptomatic infections, testing of only symptomatic individuals is insufficient to prevent an outbreak (more than 1% of individuals infected at any given time), even when testing cadence is increased after outbreak detection and strong workplace controls are employed.

Proactive testing – monitoring and containment

As testing of symptomatic individuals alone is an insufficient mechanism to control and contain a potential outbreak, we next used our model to determine the cadence at which proactive testing (also known as surveillance testing) within a population can mitigate an outbreak event.

Figure 2. Effects of asymptomatic testing on epidemic progression in a population of 1000 people. This models a case where 30% of the infectious individuals have mild or asymptomatic infections and assumes increased testing cadence once the first positive is identified.

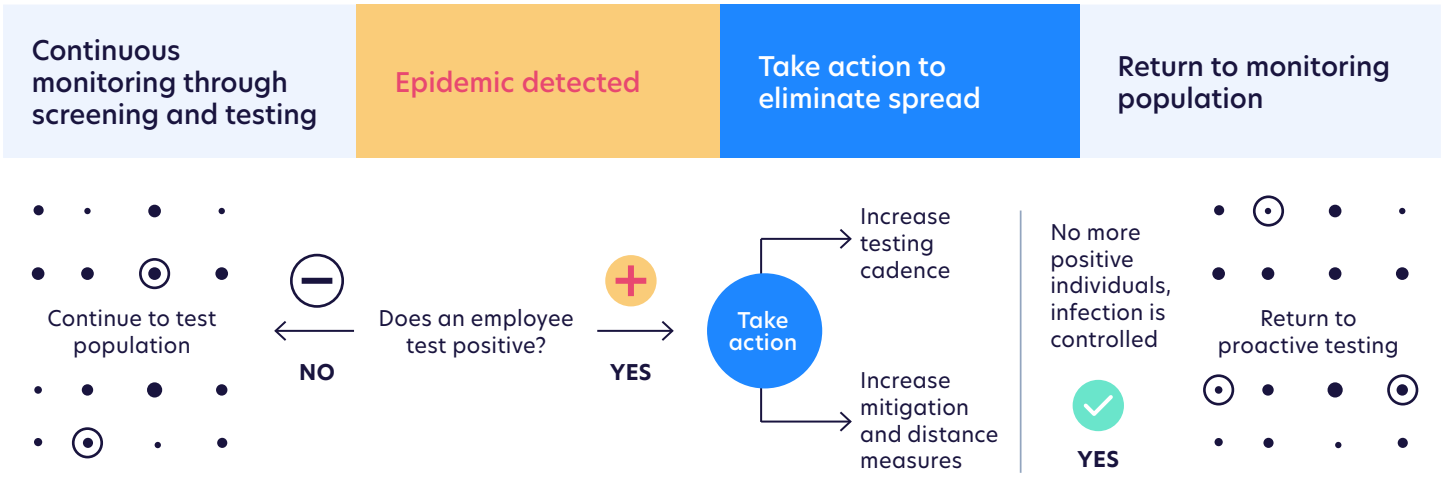


When monitoring for a disease outbreak, the goal is to identify and contain the outbreak before it can spread throughout the population. In our modeling we aimed to determine:

- At what point in the disease spread do additional workplace controls and/or other mitigation efforts need to begin, in order to ensure that a large portion of the population is not infected?
- How often do individuals need to be tested to ensure that a potential outbreak can be identified?

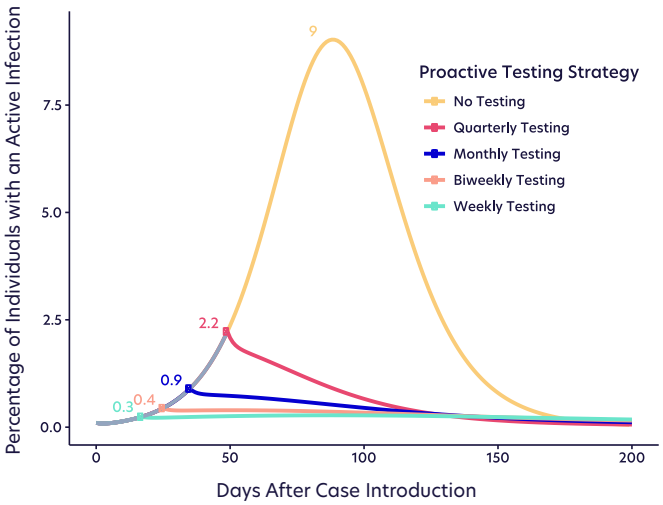
In areas with low or moderate levels of community transmission, our SEIR model suggests that a two-tiered approach of testing employees is appropriate (Figure 3).

Figure 3. Two-tiered proactive testing protocol



In this protocol, proactive testing is implemented in addition to symptomatic and exposure-based testing protocols. We recommend that proactive testing is first implemented at a baseline cadence until the first infected individual is detected, at which point testing should be increased to an escalated cadence. For employers with a mostly office-based workforce, a baseline testing cadence of once every 3 - 4 weeks, followed by an escalated cadence of once every week, can be effective in containing the spread of the virus (assuming an effective reproductive number (R_t) of 2.0 with appropriate workplace controls).

Figure 4. Baseline proactive testing cadence. This model illustrates how long (in days) after a new infection case is introduced into a population it would take to detect the outbreak given different proactive testing cadences. This figure models a population of 1000 employees in a workforce and assumes testing is increased when the outbreak is detected.



In most situations, we find that testing each individual once every 3 - 4 weeks — in addition to active monitoring and testing of symptomatic and exposed individuals — ensures (at 98% probability) that any potential outbreaks are discovered before the number of infections grows dramatically (Figure 4).

Using this strategy, we expect the first positive to be identified before an outbreak is currently infecting more than 1% of the employee population simultaneously at any given time. However, for workers in areas with high community transmission (such as an area with an active outbreak) or high exposure risk (such as frontline healthcare workers), proactive testing at a weekly cadence may be appropriate to reduce the spread.

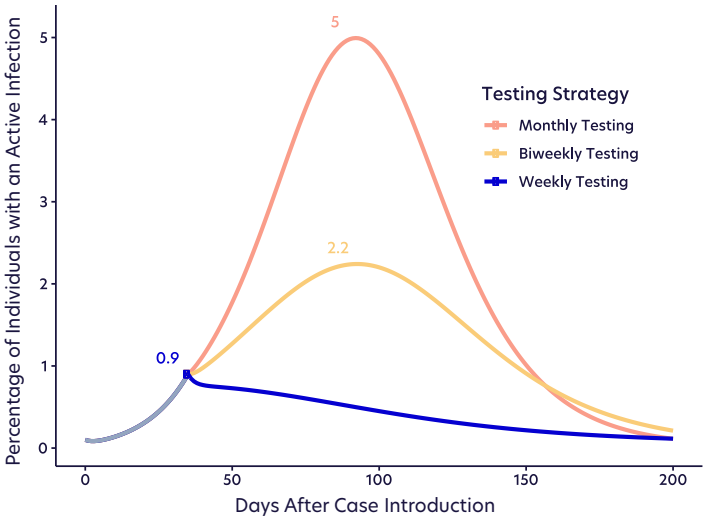
In these high risk workforces, and especially in larger workforces, new infections enter the population at a faster rate, increasing the growth and spread of the epidemic. In such populations, it would be appropriate to set the testing cadence to the escalated cadence of once per week at the outset, due to the assumption that the introduction of the first infected individual happens almost instantaneously.

Escalated proactive testing cadence

Once an individual with a SARS-CoV-2 positive result is identified in the population, the use of an escalated proactive testing cadence is an appropriate way to dramatically reduce peak concurrent infections within a workforce. Without an increase in testing cadence, our model predicts an epidemic with a peak of approximately 9% of employees infected at a given time, whereas that number can be reduced to as low as 1% through escalated proactive testing.

Once an outbreak is detected, we recommend implementing an increased testing cadence until no new positive cases have been detected for 14 days. To determine the optimal frequency of this increased cadence, we modeled the effect of increased testing combined with workplace controls (Figure 5).

Figure 5. Effects of varied outbreak testing cadences on epidemic progression once an initial case has been identified. This figure models a population of 1000 employees in a workforce and assumes that monthly proactive testing identifies the first case by day 34.



Our models suggest that a testing cadence of once every week is sufficient for controlling an outbreak when caught early (less than 1% of the population concurrently infected). Without other workplace controls and mitigation measures, however, much more frequent testing would be required to reduce outbreak impact.

Discussion

It should be noted that the models depicted are based on several core assumptions which may vary or change as our understanding of SARS-CoV-2 and COVID-19 matures. Currently, the model parameters depicted here best mimic the progression of infection in a fairly large population (n = 1000) that is able to adopt workplace control measures (R_t = 2.0).

For populations that are smaller (< 100), and where social and environmental control measures are more difficult to implement (e.g., assembly line, grocery store checkouts, front-line healthcare workers), a higher baseline proactive testing cadence should be implemented.

In addition, for populations in which the risk tolerance for infection is more stringent, such as in vulnerable populations (e.g., nursing homes), a higher baseline proactive testing cadence should also be considered.

A full list of all the assumptions used in the model parameters depicted here can be found in the appendix. As the field evolves and our understanding of COVID-19's impact in the workplace matures, we expect the model and Color's return to work protocol to evolve as well.

Conclusions

A two-phased approach allows an employer to efficiently survey a workforce for COVID-19 outbreaks and enact appropriate protocols once an outbreak is detected. Using a SEIR epidemiological model, we found that an appropriate protocol would be proactively testing each employee every 3 - 4 weeks, followed by an escalation to testing each employee every week once an outbreak is detected. This protocol also includes testing all employees, not just those with known symptoms, as many COVID-19 cases are mild or asymptomatic. Using this protocol, we model that an outbreak can be detected and controlled, with less than 1% of the workforce needing to be removed from the workplace per day.

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Appendix

Key Disease Modeling Parameters

Viral Paramenters	Value	References	Details
Effective reproductive rumber	**2.0**	Miller et. al. 2020, Sanche et. al. 2020, Zhuang et. al. 2020[9-11]	Effective reproductive number of the virus. We are assuming it is 2.0 due to workplace control measures already in place.
Recovery time	**7 days**	Woefel et. al. 2020[8]	Time after infection that an individual is no longer infectious.
Time from exposure to symptom development	**5 days**	Linton et. al. 2020, Li et al 2020, Bi et. al. 2020[12-14]	Time after exposure to development of infectiousness.
Rate of new community driven infections	**1/10,000** per day per person		
Proportion of asymptomatic and mild infections	**30%**	Nishiura et. al. 2020[15]	Proportion of infections not identified if only symptomatic individuals are tested.
Re-infection rate	**0%**		Currently, the model assumes that anyone who has recovered from infection is no longer susceptible to re-infection.