The Effectiveness of Homemade Fabric Masks at Reducing the Spread of Respiratory Infections

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Abstract

COVID-19 is caused by a virus known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which has prompted people worldwide to wear masks as a preventative measure against respiratory droplet transmission. Disposable masks are one of the most commonly accepted forms of personal protective equipment (PPE). Over time, there was a growing interest in homemade masks as alternatives. However, there are concerns surrounding which type of fabric is most effective against respiratory droplets. To assess the effectiveness of different fabric types (100% cotton, 100% polyester, an 80/20 cotton-polyester blend and disposable masks as a control), we analyzed the percent cover of water that passed through these fabrics. We hypothesized that the 80/20 cotton-polyester blend would be the least permeable to water in comparison to the other fabric types, but still more permeable in comparison to the control. These fabrics were tested by spraying water through them and recording the percent cover of water that transferred through onto a grid piece of paper. From a one-way ANOVA test, it was concluded that the different fabric types resulted in different permeabilities which aligned with our hypothesis. This suggests that different fabric types do influence permeability. Therefore, an 80/20 cotton-polyester blend is less permeable to water than 100% polyester which is less permeable than 100% cotton. However, all of the fabric types were more permeable than the disposable mask (control).

Introduction

The world outbreak of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which causes the coronavirus disease (COVID-19), has been a recent threat to human health (Cheng et al. 2020). After originating in bats (Khan et al., 2020), the virus was first recognized in an individual in Wuhan, China, and has since spread across the globe (Fauci et al., 2020). The symptoms associated with this virus include dry cough, fever, and vomiting (Yi et al., 2020). As a respiratory virus, COVID-19 is transmitted through respiratory droplets of infected individuals via their cough, sneeze, and speech (Aydin et al. 2020). As of March 2021, COVID-19 had spread to six continents, resulting in over 2.8 million deaths of those infected around the world (Statista, 2021).

To prevent further transmission of the virus, the usage of face masks as personal protective equipment (PPE) is a practice that has been implemented internationally to allow residents to safely roam in their communities. However, during the pandemic patient care provided by health care workers has increased, thus diverting the global supply chain of PPE to those professionals (Zhao et al., 2020). As a result, only a limited supply is left available for the general public (Zhao et al., 2020). As a solution, the U.S. Centers for Disease Control and Prevention have recommended the use of cloth masks in public which many countries, including Canada, have abided by (Cheng et al., 2020). These "non-medical" masks can be created from household items, such as clothing articles made out of common materials like cotton or polyester, at a cost-friendly rate (Zhao et al., 2020). Moreover, these fabric types are typically used to make clothes and thus, are readily available to individuals.

With the ongoing COVID-19 pandemic, it is crucial to test the effectiveness of different materials as face coverings to prevent health-compromising issues that can arise as a result of the virus. The purpose of this experiment is to test which common fabrics used in homemade masks: 100% cotton, 100% polyester, and an 80/20 cotton-polyester blend are the least permeable to water and in turn the most effective at reducing the spread of respiratory infections such as COVID-19. These fabric types will be compared to a disposable mask as it is considered to be the most effective in preventing droplet transmission compared to cloth masks (MacIntyre et al., 2015). According to Konda et al. (2020), fabric blends optimize the mechanical and electrostatic-based filtration effect which is more efficacious against aerosol particles compared to individual fabric types alone. Mechanical filtration effects result from the interception of particles as a result of both gravitational forces and the motion of random particles in a medium, also known as Brownian motion forces (Konda et al., 2020). Electrostatic filtration effects result from the electrostatic attraction between the fibers of fabric and particles, in this case, water spray. Additionally, the act of breathing or sneezing through a face mask involves low velocities, which is when this type of filtration effect is most efficient (Konda et al., 2020). Therefore, if the 80/20 cotton-polyester blend is the least permeable to water, then it will have the smallest percent cover of water that passes through the fabric and onto the grid paper, therefore being the most effective at reducing the spread of COVID-19 compared to fabrics made of 100% cotton or polyester. However, the 80/20 cotton-polyester blend, 100% cotton and 100% polyester will all be more permeable to water in comparison to the disposable mask.

Methods

For this experiment, our total sample size was 32. Each fabric (100% cotton, 100% polyester, and 80/20 cotton-polyester blend) had a sample size of 8. The sample size was also 8 for the EcoGuard 3-Ply disposable masks which acted as our control. A disposable mask and clothing items that were 100% cotton, 100% polyester, or an 80/20 cotton-polyester blend respectively were collected. These items had to be clean and damage-free. Each clothing item used was unique to each student depending on what they currently own. After, a spray bottle was filled with approximately one cup of water, and the nozzle was adjusted to the lowest level to produce a mist. The spray bottle used varied depending on what each student had in their homes however, the similarity of the mists produced was verified among each student via video recording. As seen in Figure 1, a standardized 10 by 10 grid was then printed on a piece of paper and taped on a wall. The spray bottle was placed inside of the clothing item and over an area of continuous fabric to ensure that the water droplets were not obstructed by stitching or logos (Figure 1). The nozzle of the spray bottle was placed five centimeters away from the grid paper (Figure 1). The spray bottle was then pumped five times onto the clothing item that was loosely hung over the nozzle and the percent cover of the water on the grid paper was recorded to one decimal place. The wet grid paper was then removed from the wall and a new one was taped onto a different section of the wall that was dry. These steps were repeated with all three types of fabrics and a disposable mask. After the pieces of fabric were air-dried and with a new disposable mask, a second trial was conducted.

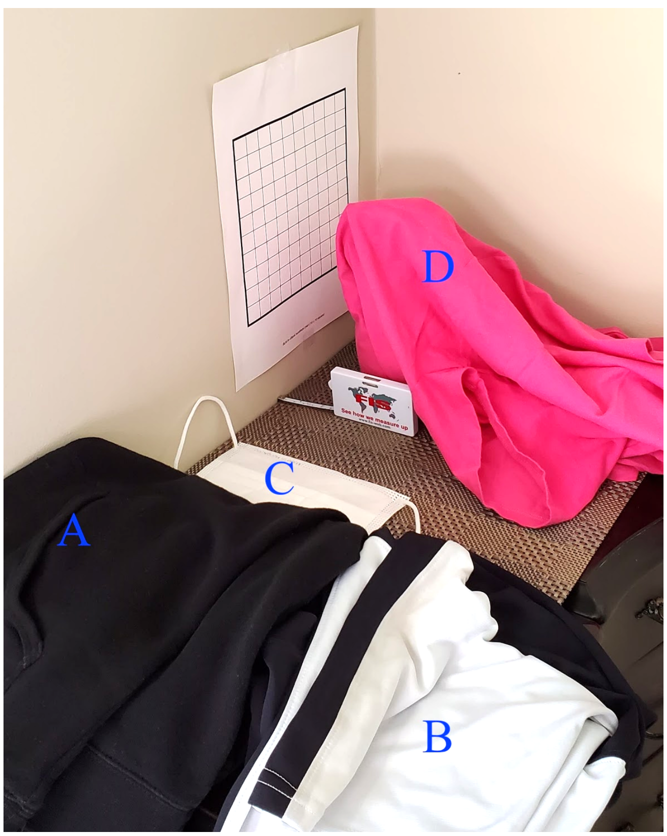

Figure 1: Experimental set-up to test the effectiveness of fabrics at reducing the spread of respiratory infections. (A) 80/20 cotton-polyester blend clothing item (n=8). (B) 100% polyester clothing item (n=8). (C) Disposable mask (n=8). (D) 100% cotton clothing item (n=8)

hung loosely around a spray bottle filled with approximately one cup of water. The spray bottle was placed five centimeters away from the 10 by 10 grid.

The data was collected from each group member and compiled on Excel. GraphPad Prism Version 9.0.2 was used to analyze the data and conduct statistical tests. A QQ plot was created and all of the data points formed a straight line with a positive slope. This relatively matched a linear regression model, thus indicating that the data was normally distributed. We conducted a one-way ANOVA to determine whether the mean water percent coverage was different among the three fabric types and disposable masks. A Tukey test was then used to determine which groups were significantly different from each other.

Results

The mean percent coverage for cotton was 16.0%, for polyester it was 11.44%, for the 80/20 cotton-polyester blend it was 5.313%, and for the disposable mask it was 0% (Figure 2). Polyester had the largest standard deviation of 2.026, then cotton with 1.309, then the blend with 1.252, and the disposable mask had the smallest standard deviation of 0 (Figure 2). There was also no overlap in the 95% confidence intervals of these means which suggests that the mean percent coverage of all four treatments are likely significantly different from one another (Figure 2).

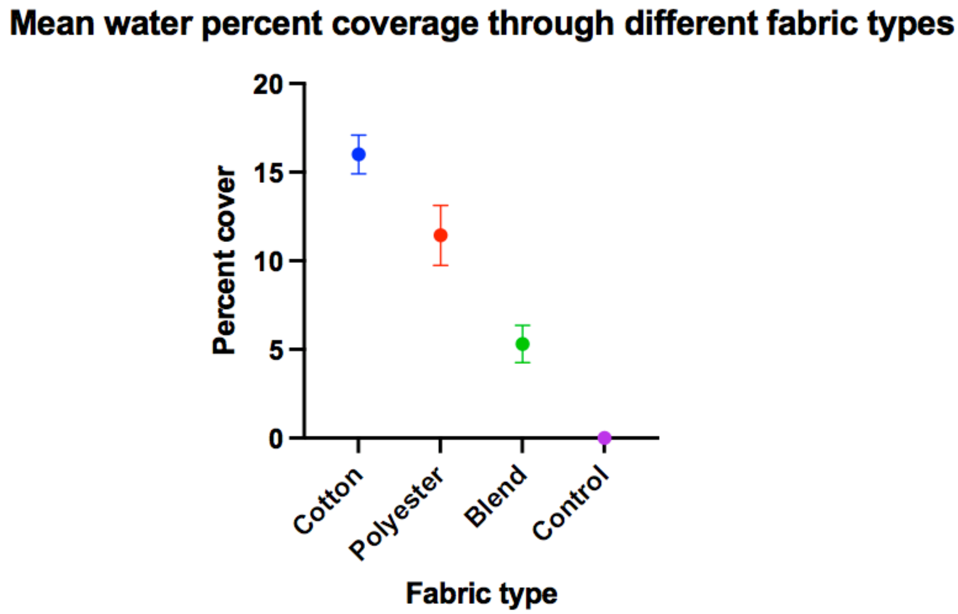

Figure 2: Mean percent coverage for each type of fabric. The blue point represents the mean percent cover from 100% cotton fabrics (n=8), the red point represents the mean percent cover from polyester fabrics (n=8), the green point represents the mean percent cover from the 80/20 cotton-polyester blend (n=8), and the purple point represents the mean percent cover from the disposable mask (n=8). The error bars represent the 95% confidence intervals. Using a one-way ANOVA, the p-value was found to be <0.0001.

In our analysis, an alpha value of 0.05 was used to determine the statistical significance as it represents a 5% risk of rejecting the null hypothesis when it is actually true. The calculated p-value from the one-way ANOVA was found to be <0.0001 which gives evidence to support that the means of the treatment groups were significantly different from one another. Furthermore, all Tukey HSD p-values were found to be significant and <0.0001 when comparing all treatments (Table 3). The Tukey test results suggest that the four treatment groups' means were significantly different from one another.

Discussion

Our objective of this experiment was to determine which fabric made of 100% cotton, 100% polyester, or an 80/20 cotton-polyester blend would be the least permeable to water and in turn, a model for the most effective homemade mask to prevent the spread of respiratory infections. Analysis of the data collected shows that there are statistically significant differences between the means of the percent cover of the different mask materials. Our p-value of the ANOVA analysis was less than alpha (0.05), which means we can conclude that using different mask materials will result in different percent covers. Furthermore, the mean percent cover value of the 80/20 cotton-polyester blend was the lowest of the fabric types. This aligned with our hypothesis where we stated that the 80/20 cotton-polyester blend would be the least permeable to water and have the smallest percent cover of liquid that passes through the fabric compared to the 100% cotton and 100% polyester fabrics, however, would still be more permeable in comparison to the disposable mask. It was also determined that fabrics made of 100% polyester are less permeable than fabrics made of 100% cotton. Therefore, we can reject our null hypothesis that there would be no statistically significant difference between the percent cover of water of each fabric type and disposable mask. The rejection of our null hypothesis may be due to the optimization of the mechanical and electrostatic-based filtration effect that results from the combination of fabrics, specifically polyester and cotton, compared to the use of an individual fabric type (Konda et al., 2020). When maximized by the combination of different fabric types, the mechanical and electrostatic-based filtration effect offers protection against aerosol particles (Konda et al., 2020).

The results of this experiment pose limitations. This experiment utilized household spray bottles that produced droplets approximately 100 μm in size (Lovén et al., 2019). However, respiratory droplets which are associated with COVID-19 are reported to be much smaller, approximately less than 5 μm (Fennelly, 2020). Additionally, the velocities of coughing and sneezing are reported to be approximately 10 m/s and 5 m/s respectively (Li et al, 2020), whereas the speed of a standard household spray bottle is much slower in comparison (Lovén et al., 2019). For future studies, spray bottles that produce similar-sized droplets that travel at comparable velocities as those associated with respiratory infections such as COVID-19 may be used for a better understanding of the efficacy of homemade fabric masks.

Sources of variation and error can be due to an inaccurate calibration of the spray bottles used. The experiment was replicated among four students whom each had different spray bottles. Although confirmation of the mist produced was verified via video recordings, there was still a chance that this could have caused sources of variation. Students also used their own fabrics and may have used clothing articles that were worn more or not as tightly woven as others which are not recommended to be used as homemade cloth masks by the Government of Canada (2021). These differences would have also altered the permeability of the fabric type and therefore, our results. It is also possible that students placed the fabric closer or further from the nozzle than others which could have altered the recorded percent cover. Moreover, confounding variables such as the thread count of the fabrics were not considered in this experiment. Thread count can alter the permeability of the fabric as a higher thread count causes the fabric to be less permeable (CBC, 2020). Due to this effect, our results may have been inaccurate. Furthermore, as the percent cover was recorded to one decimal place, variation from rounding up or down was also present. The water droplets may have also not transferred onto the grid paper despite passing through the fabrics or were too small to identify, reducing the percent cover reported in the data.

Future studies can improve this study by using the same clothing articles and spray bottles throughout the entire experiment as well as incorporating the use of a computer program to standardize percent cover recordings. Additionally, the use of food colouring can be used to assist in the identification of smaller droplets of water. To better test these fabrics' permeability against water, future studies can also examine the effect of different thread counts to confirm that the fabric efficiency results were not due to such confounding variables.

Conclusion

The goal of this study was to investigate which fabric type would be the least permeable to water and therefore, the most effective at reducing the spread of respiratory infections such as COVID-19 compared to disposable masks. Our results indicate that there are statistically significant differences between the mean percent cover of the three types of fabric and the disposable mask control. This means we reject our null hypothesis and support our hypothesis that the 80/20 cotton-polyester blend is less permeable to water than 100% cotton and 100% polyester fabrics, but more permeable than disposable face masks. Therefore, it is suggested that a blend of cotton and polyester is the most effective fabric to be used as homemade masks to reduce the spread of COVID-19.

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Appendix

Table 1: Raw data of the three fabric types and disposable masks. The sample size for each fabric and disposable mask was 8**.**

Trial	Cotton	Polyester	80/20 Blend	Disposable Mask
1	16.0%	15.0%	6.5%	0.0%
2	18.0%	12.5%	6.0%	0.0%
3	15.0%	10.0%	4.5%	0.0%
4	17.0%	11.0%	5.0%	0.0%
5	14.0%	8.0%	3.0%	0.0%
6	15.0%	12.0%	5.5%	0.0%
7	17.0%	11.0%	5.0%	0.0%
8	16.0%	12.0%	7.0%	0.0%

Table 2: Raw data of the three fabric types and disposable masks. The sample size for each fabric and the disposable mask was 8**.**

Source	Sum of squares SS	Degrees of freedom	Mean square MS	F ratio	p-value
Treatment	1175	3	391.7	212.2	<0.0001
Error	51.69	28	1.846		
Total	1227	31			

Table 3: Tukey HSD results comparing fabrics against other fabrics and control. The sample size for each fabric and the disposable mask was 8. All differences were significant.

Treatment pairs	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD Significance
Cotton vs. Polyester	9.498	< 0.0001	Significant
Cotton vs. Blend	22.25	< 0.0001	Significant
Cotton vs. Control	33.31	< 0.0001	Significant
Polyester vs. Blend	12.75	< 0.0001	Significant
Polyester vs. Control	23.81	< 0.0001	Significant
Blend vs. Control	11.06	< 0.0001	Significant

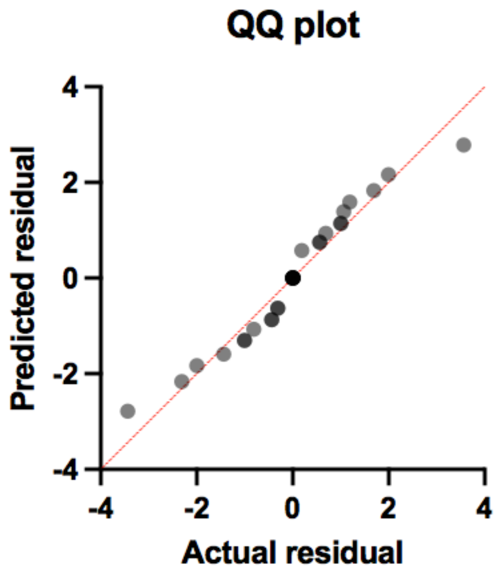

Figure 3: A quantile-quantile (QQ) plot displaying normal distribution. A straight line that relatively matches a linear regression model is formed by the points, indicating that both sets of quantiles come from the same distribution. Therefore, the data is normally distributed.