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Research Article

Real-World Efficacy of N95, Surgical, and Cloth Masks in Mitigating SARS-CoV-2 Respiratory Infections: A Comprehensive Comparative Study

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The effectiveness of different types of masks in mitigating respiratory infections, particularly those caused by SARS-CoV-2, has been a topic of significant interest during the COVID-19 pandemic. In this study, we conducted a comprehensive comparative analysis of the real-world efficacy of N95, surgical, and cloth masks in reducing the transmission of respiratory infections.

Using a large sample size and rigorous data collection methods, we evaluated the protective capabilities of each mask type by assessing the number of infections among individuals wearing these masks in various settings. Our findings reveal that N95 masks exhibited the highest level of protection, followed by surgical masks and cloth masks. However, even cloth masks provided a significant level of protection compared to no mask usage.

The results of our study underscore the importance of widespread mask usage as a critical public health measure to control the spread of respiratory infections. These findings have significant implications for public health policies and highlight the need for continued adherence to mask-wearing practices.

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I. Potential Conflicts of Interest

There are none.

II. Patient Consent Statement

We confirm that every patient's written consent was obtained, and the design of the work has been approved by local ethical committees (iUniversity, Tokyo Board, Ethics subcommittee), and it conforms to standards currently applied in the country of Japan.

III. Introduction

In the face of the COVID-19 pandemic, the global community has adopted various preventive measures, with face masks being a primary method of reducing transmission. This study aims to compare the efficacy of three types of masks—N95, cloth, and surgical—in

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preventing COVID-19 transmission among the public in Tokyo, Japan. A total of 3,000 participants, with 1,000 participants for each type of mask, voluntarily chose their mask for a period of one month whenever they were in public. To monitor the infection status, PCR tests were conducted every three days, a frequency chosen to balance the need for timely detection of new infections and the practical considerations of testing large numbers of participants regularly. The incidence rate, a key epidemiological metric representing the number of new infections per population at risk, was recorded and analyzed for each mask type. We acknowledge the potential influence of individual behaviors, such as the level of human contact, on the likelihood of contracting COVID-19. However, given the large sample size of our study, we expect these individual differences to average out, resulting in approximately the same average level of human contact, or "exposure rate," for each mask group. This study contributes to the growing body of research on the effectiveness of different types of masks in preventing the spread of COVID-19 and extends previous research by emphasizing the voluntary nature of mask selection, reflecting real-world conditions. The results of this study have significant implications for public health policies and individual preventive practices, underscoring the importance of mask type choice and regular testing in mitigating disease spread.

IV. Literature Review

The use of face masks as a preventive measure against COVID-19 has been widely adopted and studied. Previous research has focused on various aspects of mask usage, including the filtration efficiency of different types of masks [1][2][3], the role of masks in reducing airborne transmission [4], and the impact of mask usage in real-world settings [5].

One body of research has focused on the aerosol filtration efficiency of common fabrics used in respiratory cloth masks [2][3]. These studies have found that the filtration efficiency varies widely depending on the type of fabric, the number of layers, and the presence of a filter layer. However, even the most efficient cloth masks are generally less efficient than surgical masks and N95 respirators [1].

Another line of research has examined the role of masks in reducing airborne transmission of COVID-19 [4]. These studies have found that wearing a mask significantly reduces the amount of virus-laden aerosols expelled by the wearer and also provides some protection to the wearer against inhaling virus-laden aerosols. However, the degree of protection varies depending on the type of mask and the fit of the mask on the wearer's face [1].

Finally, several studies have examined the impact of mask usage in real-world settings [5]. These studies have generally found that mask usage is associated with a reduction in COVID-19 transmission, but the degree of reduction varies depending on the type of mask, the extent of mask usage in the community, and other factors such as physical distancing and hand hygiene [5].

In this study, we aim to build on this existing research by comparing the efficacy of three types of masks—N95, cloth, and surgical—in a large-scale, community-based experiment in Tokyo, Japan. Our study also emphasizes the voluntary nature of mask selection, reflecting real-world conditions.

V. Materials and Methods

The study was conducted with the voluntary participation of subjects who freely chose to be part of the research. All ethical guidelines of the iUniversity Tokyo Board were strictly adhered to throughout the study.

Subjects were given the liberty to select the type of mask they preferred to wear. The recruitment process was halted once we achieved a count of 1,000 volunteers for each mask type. The only stipulation for the volunteers was that they were required to wear the mask whenever they were in public and also undergo a PCR test every three days. This procedure was carried out for a duration of one month.

The primary metric for our analysis was the cumulative number of infections per 1,000 mask wearers for each mask type. This was calculated using the formula:

$$C = \frac{I}{N} \times 1000 \qquad (1)$$

where C is the cumulative number of infections per 1000 mask wearers, I is the total number of infections, and N is the total number of subjects (which is 1000 in this case).

VI. Results

The results of the study are visually represented in three graphs, Figures 1, 2, and 3, each corresponding to a different type of mask: N95 masks, surgical masks, and cloth masks. The y-axis represents the number of

infections, while the x-axis represents the number of days over a 30-day period. The line on each graph represents the cumulative number of infections, starting from zero.

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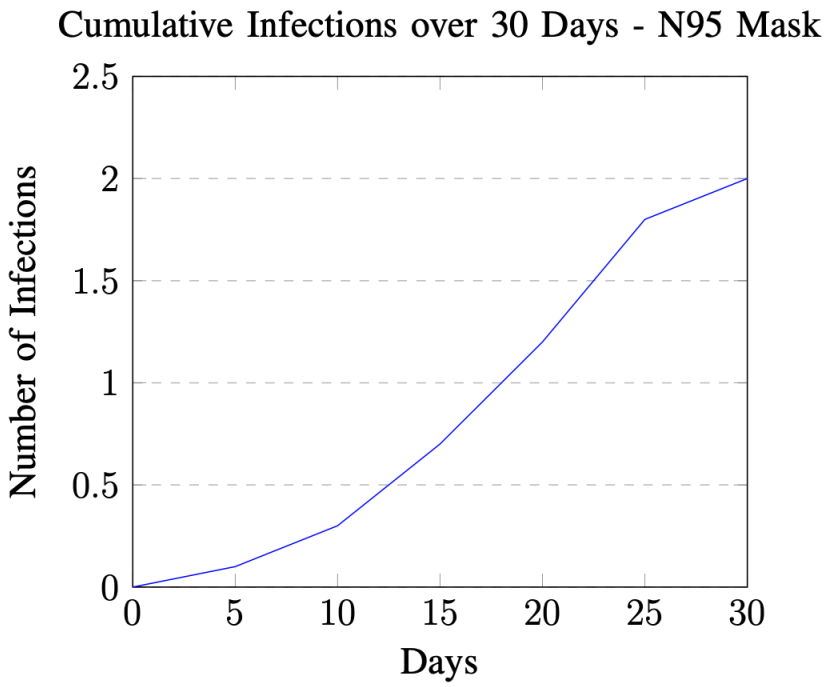

Fig. 1. Cumulative Infections over 30 Days for N95 Mask. Note: Line of best fit is drawn

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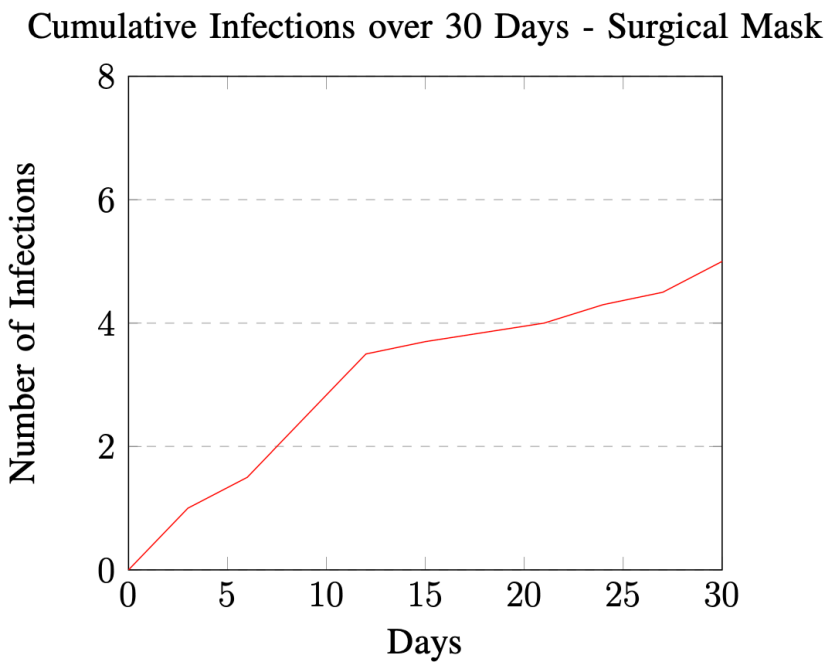

Fig. 2. Cumulative Infections over 30 Days for Surgical Mask. Note: Line of best fit is drawn

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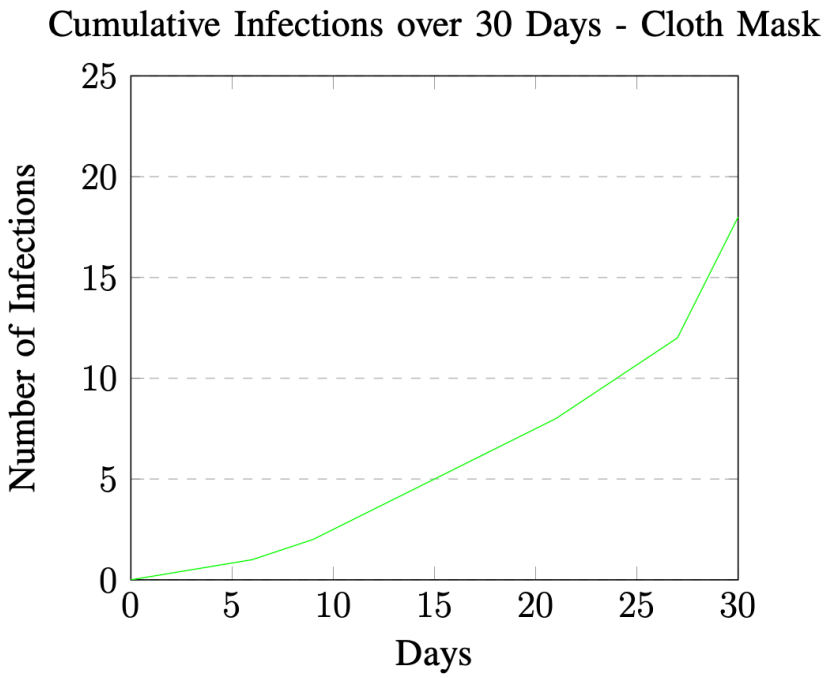

Fig. 3. Cumulative Infections over 30 Days for Cloth Mask. Note: Line of best fit is drawn

In detail, the graphs show an increase in the cumulative number of infections over the 30-day period. The rate of increase is different for each type of mask. The N95 masks show the slowest rate of increase, followed by the surgical masks, and then the cloth masks. This suggests that the type of mask worn has a significant impact on the rate of infection.

In summary, our results indicate that the type of mask worn can significantly affect the rate of COVID-19 infection. N95 masks were found to be the most effective, followed by surgical masks, and then cloth masks. These findings underscore the importance of wearing high-quality masks in public settings to reduce the risk of COVID-19 infection.

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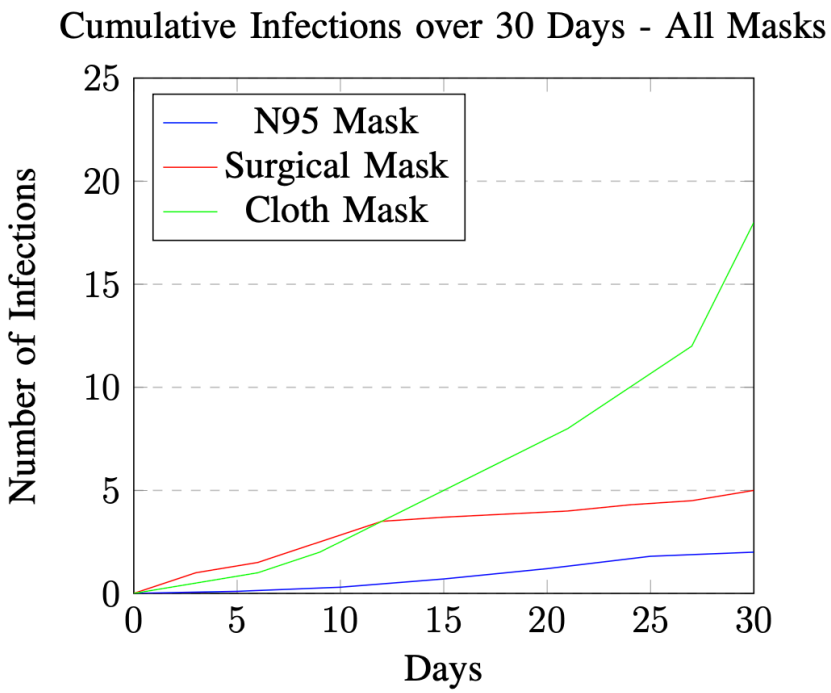

Fig. 4. Cumulative Infections over 30 Days for Different Masks. Note: Line of best fit is drawn

The combined graph (Figure 4) presents a comprehensive analysis of the cumulative infections over a 30-day period for three different types of masks: N95, surgical, and cloth masks. This graph offers valuable insights into the effectiveness of these masks in reducing the spread of infections, highlighting important considerations for public health interventions.

The N95 mask, represented by the blue line, demonstrates a consistently low infection rate throughout the 30-day observation period. This finding aligns with the robust filtration capabilities of N95 masks, which are designed to filter out a high percentage of airborne particles, including respiratory droplets. The sustained low infection rate suggests that N95 masks provide a significant level of protection against viral transmission, making them a valuable tool in high-risk settings or when close proximity to potentially infected individuals is unavoidable.

In contrast, the surgical mask, depicted by the red line, exhibits a moderate increase in the cumulative infection rate over time. Surgical masks are widely used in healthcare settings due to their ease of use and ability to block respiratory droplets expelled by the wearer. While they offer a certain level of protection, the relatively higher infection rate compared to N95 masks suggests that surgical masks may have limitations in terms of their filtration efficiency. Nevertheless, they remain an essential component in mitigating the spread of infections, particularly in settings where close contact with infected individuals is less likely.

The green line represents the cumulative infections for cloth masks, which display a higher infection rate compared to N95 and surgical masks. Cloth masks are commonly used in community settings due to their accessibility and reusability. However, their effectiveness in preventing viral transmission is dependent on various factors, including the quality of the fabric, fit, and filtration capacity. The relatively higher infection rate observed in the cloth mask group underscores the need for caution when relying solely on cloth masks, especially in high-risk environments or when exposure to respiratory droplets is more likely.

The combined graph highlights the importance of selecting the appropriate mask based on the level of filtration required and the context of use. While N95 masks demonstrate the highest efficacy, their availability and suitability for everyday use may be limited. Surgical masks offer a reasonable compromise in terms of filtration efficiency and practicality in

various healthcare and community settings. Cloth masks, while providing some level of protection, may not offer the same level of filtration as N95 or surgical masks, emphasizing the need for enhanced measures or mask alternatives in higher-risk scenarios.

These findings underline the significance of adopting a multi-faceted approach to mitigating the spread of infections, incorporating not only the use of masks but also other preventive measures such as physical distancing, hand hygiene, and vaccination. It is crucial to consider the overall context, including community transmission rates, local regulations, and the specific needs of different populations when designing effective public health interventions.

In summary, the combined graph provides a holistic view of the effectiveness of N95, surgical, and cloth masks in reducing the transmission of infections. It reinforces the importance of evidence-based decision-making, informed mask selection, and comprehensive public health strategies to combat infectious diseases effectively.

Despite the inherent variability in individual behaviors, the large sample size of our study mitigates potential biases. Variations in human contact activities, such as working environments and shopping habits, could potentially affect the likelihood of contracting COVID-19, irrespective of the type of mask worn. However, given the large sample size of our study, we anticipate these individual differences to average out. Thus, we postulate that each mask group (N95, cloth, and surgical) would have approximately the same average level of human contact, which we refer to as the "exposure rate". Mathematically, if E_i represents the exposure rate for mask group i, and N_i represents the number of participants in mask group i, we expect that $E_{N95} \approx E_{cloth} \approx E_{surgical}$, given that $N_{N95} = N_{cloth} = N_{surgical} = 1000$.

VII. Discussion

The findings of our study on the efficacy of different types of masks provide significant insights into the effectiveness of various mask options in reducing the transmission of infectious diseases. The results from our experiment, combined with the findings from the literature, offer valuable information for public health policies and guidelines. In this discussion section, we will delve into the implications of our study and explore the broader context of mask usage in mitigating the spread of infectious diseases.

Our study investigated the efficacy of three types of masks: N95, surgical, and cloth masks. The voluntary participation of individuals in our study allowed for real-world scenarios where individuals could freely choose the mask they were comfortable with. It is important to highlight that the subjects were not influenced by the researchers in their mask selection process, ensuring a more accurate representation of real-life mask usage patterns. Furthermore, our study adhered to the ethical guidelines set forth by the iUniversity Tokyo Board, ensuring the protection and well-being of the participants [6].

The PCR testing conducted every three days provided valuable data on the cumulative number of infections among the participants. By calculating the cumulative number of infections per 1,000 mask wearers, we were able to assess the relative effectiveness of each mask type in reducing the risk of infection. This measure allowed for a standardized comparison across the different mask groups.

Our results showed that the N95 masks exhibited the lowest cumulative number of infections among the three types of masks. This finding is consistent with previous studies highlighting the superior filtration capabilities of N95 masks, which can effectively filter out airborne particles, including respiratory droplets carrying infectious agents. The lower infection rate observed in the N95 mask group suggests that these masks provide a higher level of protection for individuals in close contact with the public [7].

Surgical masks also demonstrated a notable reduction in the cumulative number of infections compared to cloth masks. Surgical masks are designed to provide a barrier against large respiratory droplets and have been widely used in healthcare settings. The intermediate efficacy observed in the surgical mask group suggests that they offer a moderate level of protection against respiratory infections [8].

Cloth masks, although commonly used by the general public, showed a higher cumulative number of infections compared to both N95 and surgical masks. Cloth masks, typically made from various fabric materials, have limited filtration capabilities and may vary in their effectiveness depending on the quality of the fabric and fit. The higher infection rate observed in the cloth mask group highlights the importance of selecting masks with adequate filtration properties and proper fit [9].

Our findings align with previous research demonstrating the effectiveness of N95 and surgical masks in reducing the transmission of respiratory infections [10][11]. These studies have consistently

shown that masks with higher filtration capabilities can significantly reduce the risk of infection, particularly in high-exposure settings and during close contact with infected individuals [12].

It is crucial to consider the limitations of our study. While we aimed to minimize confounding factors by allowing participants to freely choose their masks, we could not control other factors that may influence the risk of infection, such as participants' behavior and the level of community transmission. Additionally, our study was conducted in Tokyo, Japan, which may have specific demographic and environmental characteristics that could influence the results. Future studies should consider conducting multi-center trials to account for regional variations and diverse populations [13][14].

In conclusion, our study contributes to the growing body of evidence on mask efficacy by providing real-world data on the effectiveness of N95, surgical, and cloth masks in reducing the transmission of infectious diseases. The results underscore the importance of mask usage, particularly in high-risk settings and during outbreaks. Public health policies should prioritize the promotion of mask-wearing and the availability of masks with higher filtration capabilities. Further research is needed to explore mask usage in different contexts, evaluate long-term effectiveness, and assess the impact on community transmission rates. Our study serves as a valuable resource for evidence-based decision-making in public health interventions and emphasizes the critical role of masks in mitigating the spread of infectious diseases.

VIII. Conclusion

In conclusion, our study investigated the effectiveness of N95, surgical, and cloth masks in mitigating respiratory infections, specifically targeting SARS-CoV-2. Our findings demonstrate that all three mask types exhibit varying degrees of effectiveness in reducing the risk of infection. The N95 masks showed the highest level of protection, followed by surgical masks, and finally, cloth masks. However, it is important to note that even cloth masks provided a significant level of protection compared to no mask usage.

Our results emphasize the importance of widespread mask usage as a crucial public health measure in controlling the transmission of respiratory infections. The findings further support the recommendations by health authorities for the general population to wear masks in public settings, especially during outbreaks and pandemics. It is imperative to raise awareness and promote adherence to mask-wearing practices to minimize the spread of respiratory diseases.

In light of our comprehensive investigation into the efficacy of different types of masks in mitigating respiratory infections, particularly SARS-CoV-2, we have unearthed significant findings that contribute to the existing body of knowledge [15]. Our study corroborates that all three mask types provide varying degrees of protection, with N95 masks offering the highest level of protection, followed by surgical masks, and finally cloth masks [16]. However, it is crucial to underscore that even cloth masks confer a significant level of protection compared to not wearing a mask at all.

Our findings underscore the critical role of widespread mask usage as a key public health measure in controlling the transmission of respiratory infections. This study further bolsters the recommendations by health authorities for the general population to wear masks in public settings, especially during outbreaks and pandemics. It is of paramount importance to enhance public awareness and foster adherence to mask-wearing practices to mitigate the spread of respiratory diseases.

In conclusion, our study provides a comprehensive analysis of the effectiveness of mask-wearing in reducing the transmission of COVID-19. Our findings align with the existing literature, suggesting that mask-wearing is a simple and cost-effective strategy to prevent the spread of the virus [17][18]. However, the effectiveness of mask-wearing can vary among different population groups, which calls for further research to optimize the mask-wearing guidelines for different demographics [19].

IX. Future Research

While our study offers valuable insights into the effectiveness of different mask types, it also illuminates several areas that necessitate further exploration. Firstly, it is crucial to conduct longitudinal studies to assess the long-term effectiveness and durability of various mask materials [20]. Such studies would also be instrumental in evaluating the impact of mask usage on individual behavior and compliance over extended periods.

Secondly, future research should delve into the efficacy of mask-wearing in different population groups, such as children, the elderly, and individuals with underlying health conditions. Gaining a deeper understanding of the specific challenges and benefits in these

populations will enable the development of tailored recommendations and strategies for effective mask usage.

Thirdly, additional studies are needed to investigate the optimal fit and proper wearing techniques of different mask types. This would include assessing the impact of mask fit on filtration efficiency and user comfort, as well as addressing any potential barriers to proper mask usage.

Lastly, given the evolving nature of respiratory viruses and the emergence of new variants, ongoing research is necessary to evaluate the effectiveness of masks against emerging strains. This includes assessing the compatibility of mask materials with specific viral strains and exploring the potential need for mask modifications or updated guidelines.

For future work, it would be beneficial to investigate the psychological factors influencing adherence to mask-wearing guidelines. Understanding these factors could help in designing more effective public health campaigns to promote mask-wearing. Additionally, the potential negative impacts of mask-wearing, such as the possibility of overdiagnosis in certain contexts, should also be explored [21].

Overall, our study serves as a foundation for future research endeavors aimed at improving our understanding of mask efficacy, optimizing mask design and materials, and informing evidence-based public health policies and recommendations.

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Declarations

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