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Assessment of effectiveness of optimum physical distancing phenomena for COVID-19

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ABSTRACT

Currently, COVID-19 is a global pandemic that scientists and engineers around the world are aiming to understand further through rigorous testing and observation. This paper aims to provide safe distance recommendations among individuals and minimize the spread of COVID-19, as well as examine the efficacy of face coverings as a tool to slow the spread of respiratory droplets. These studies are conducted using computational fluid dynamics analyses, where the infected person breathes, coughs, and sneezes at various distances and environmental wind conditions and while wearing a face-covering (mask or face shield). In cases where there were no wind conditions, the breathing and coughing simulations display 1–2 m physical distancing to be effective. However, when sneezing was introduced, the physical distancing recommendation of 2 m was deemed not effective; instead, a distance of 2.8 m and greater was found to be more effective in reducing the exposure to respiratory droplets. The evaluation of environmental wind conditions necessitated an increase in physical distancing measures in all cases. The case where breathing was measured with a gentle breeze resulted in a physical distancing recommendation of 1.1 m, while coughing caused a change from the previous recommendation of 2 m to a distance of 4.5 m or greater. Sneezing in the presence of a gentle breeze was deemed to be the most impactful, with a recommendation for physical distancing of 5.8 m or more. It was determined that face coverings can potentially provide protection to an uninfected person in static air conditions. However, the uninfected person's protection can be compromised even in gentle wind conditions.

I. INTRODUCTION

Throughout history, mankind has always been faced with plagues and illnesses that have threatened the well-being of society.[1] It has always been the aim of scientists, engineers, and researchers to work toward creating innovative solutions to overcome diseases and other issues.[2] Most recently, the world is in the midst of combating COVID-19, a global outbreak.[3] COVID-19 is a zoonotic disease caused by a new strain of coronavirus that began in December 2019. Symptoms from the virus include fever, shortness of breath, nausea, congestion, and a multitude of others.[4] Similar to other pathogenic respiratory coronaviruses such as severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome (MERS), the effects of COVID-19 can be fatal, given its 3% mortality rate.[5] The virus can also cause severe, long-lasting health complications such as inflammation of the heart, referred to as myocarditis and pericarditis. While cases of myocarditis are uncommon among young people, it can still occur.[6] Presently, cases of the virus have been reported in more than 200 countries, with outbreaks occurring in hospitals, old age care facilities, prisons, and hospitals.[7]

During the preliminary stages of COVID-19 research, it was believed that human to human transmissions of the virus was relatively limited and posed no imminent threat. However, as further research on the virus continued, it was established that the virus was being transmitted from human to human.[5] As recent as April 2020, scientists were able to determine that the primary mode of transmission of the virus is attributed to respiratory droplets when the unprotected individuals are in close proximity with an infected person.[8–10] Additional evidence suggests that the virus can be found in blood and human stool and can exist on surfaces.[8]

In order to stop and mitigate the transmission of COVID-19, health care professionals recommend practicing hand hygiene, maintaining physical distancing, wearing masks and face coverings, and using cleaning or disinfectant supplies.[11] Of the methods listed, wearing a mask and other face coverings is the most logical method to stop

This is attributed to the velocity at which the droplets were ejected. Sneezing is released at a 35 m/s, more than double that of coughing, and substantially greater than breathing. Based on this, particles released from sneezing pose a greater risk with regard to the distance they are able to travel.

Figure 8 displays the change in the position of particles when breathing, coughing, and sneezing over a 1 s time interval in still air. The particle position was used as a measure to determine the furthest distance a respiratory droplet was able to reach within that time frame when two people stand facing each other. As expected, the final particle position of breathing was substantially smaller, only 0.33 m, whereas coughing and sneezing were 1.76 m and 2.77 m, respectively. The 2.77 m particle position exceeds the commonly used physical distancing recommendation of 2 m. Therefore, a new minimum safe distance recommendation of 2.77 m can be made when sneezing in static air.

Given that sneezing displayed the most volatile response from the simulation in regard to the particle position, the impact that preventative measures would have on sneezing was also examined. In order to do this, the previous sneezing scenario, as shown in Figs. 7 and 8, was used to compare sneezing while wearing an N95 mask to sneezing while wearing a face shield. A pictorial representation of these three scenarios is captured in Fig. 9.

As shown in Fig. 9, wearing a face-covering is a highly effective strategy in mitigating the spread of respiratory droplets if the uninfected individual is standing across from the infected individual. In

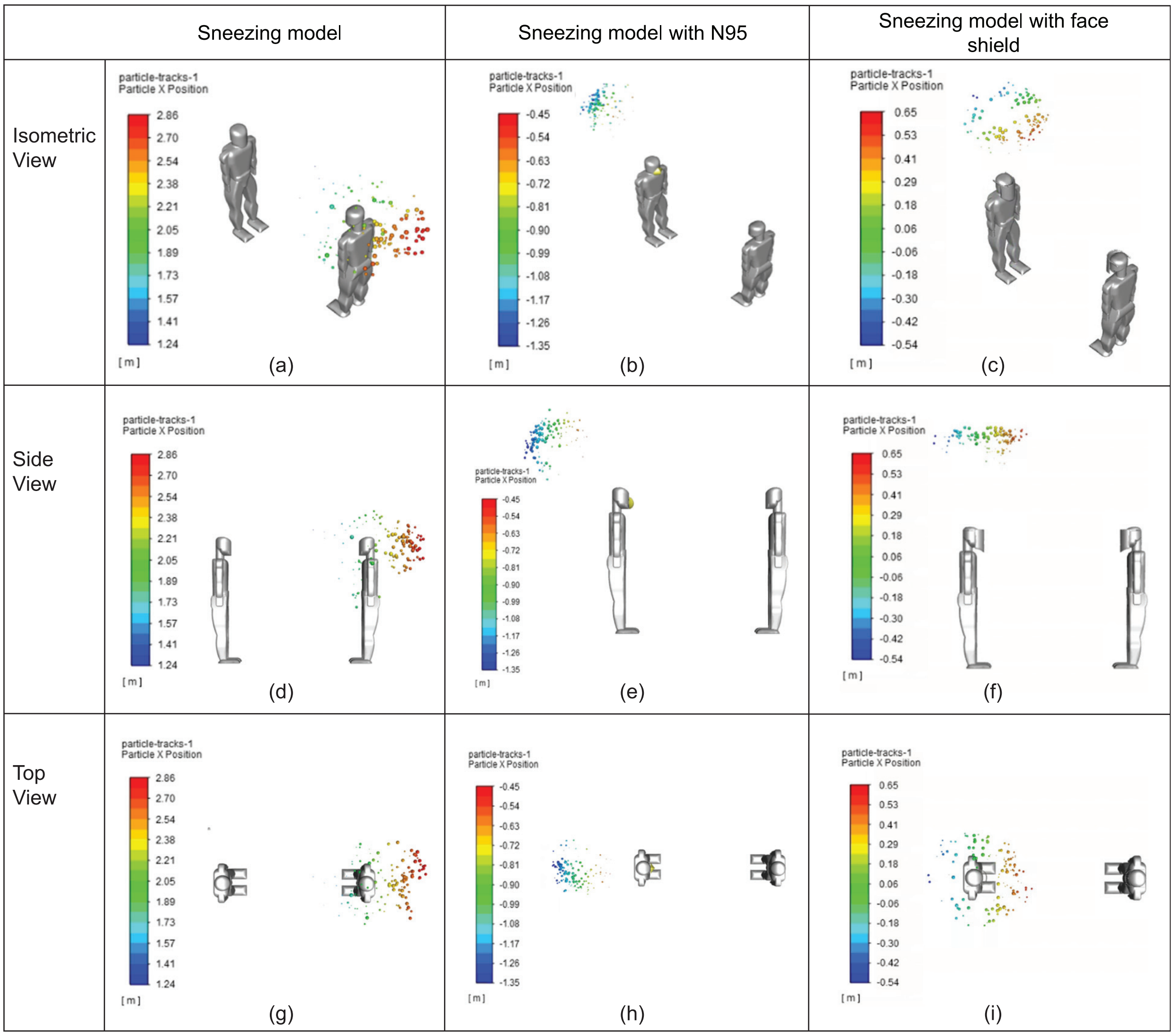

FIG 9. Comparison between sneezing and sneezing while wearing a face-covering at different views: (a) sneezing model (isometric view), (b) sneezing model with N95 (isometric view), (c) sneezing model with face shield (isometric view), (d) sneezing model (side view), (e) sneezing model with N95 (side view), (f) sneezing model (side view), (g) sneezing model (top view), (h) sneezing model with N95 (top view), and (i) sneezing model with face shield (top view).