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Evaluation of Six-Minute Walk Test (6MWT) Performance with and without a Facemask

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ABSTRACT

Introduction: During viral outbreaks, including the most recent coronavirus (COVID-19) pandemic, the use of personal protective equipment is recommended to prevent the spread of any highly contagious pathogen. When comparing performance measures with and without wearing a surgical mask (SM) or an N95 mask when completing the Six-Minute Walk Test (6MWT) among older community-dwelling adults, limited research is available. This was a prospective, randomized, and counterbalanced repeated measures design with three testing conditions (no mask (NM), SM, and N95 mask). The purpose of this study was to compare Six-Minute Walk Distance (6MWD), heart rate (HR), respiratory rate (RR), oxygen saturation (S_pO_2), rating of perceived exertion (RPE), and rating of perceived dyspnea (RPD) when performing the 6MWT with and without the use of a SM and an N95 mask. **Methods:** Thirty-six community-dwelling adults (17 males, 19 females), ranging from 50 to 83 years of age, completed a familiarization 6MWT and three separate 6MWTs. All testing was performed outside on a 30-meter long, flat corridor. Before being tested, subjects completed the PAR-Q+, ACSM Exercise Pre-participation Health Screening Questionnaire, COVID-19 Screening Questionnaire, the Duke Activity Status Index Questionnaire (DASI). They had their temperature, height, weight and blood pressure measured. A two-way analysis of variance (ANOVA) with repeated measures was used to assess differences between walking conditions across time for 6MWD, HR, RR, S_pO_2 , RPE, and RPD. If there was a significant F ratio, Bonferroni posthoc tests were used to assess pairwise comparisons. Alpha was set at $p < .05$ to achieve statistical significance. **Results:** No significant difference was found in 6MWD between walking conditions. HR, RR, and RPE significantly increased across time regardless of walking condition, but there was no significant difference between conditions. Overall, S_pO_2 significantly decreased from resting ($97.0\% \pm .2$) to immediate post-exercise ($95.7\% \pm .3$), and then returned to baseline ($97.3\% \pm .2$) 1-minute into recovery. No significant difference was found between conditions. The 6MWT performed with the N95 mask elicited significantly higher RPD scores when compared to both the NM and the SM conditions. **Conclusions:** Wearing a SM or an N95 mask had no significant effect on 6MWD, HR, RR, RPE, and S_pO_2 in older community-dwelling adults when performing the 6MWT. Wearing the N95 mask was associated with significantly higher RPD scores when completing the 6MWT. The increased perception of breathlessness may be attributed to a tighter face seal of the N95 mask, increased breathing resistance, higher temperature/humidity levels, and carbon dioxide trapping inside the N95 mask.

Key Words: Masks, Older Community-dwelling Adults, Performance Measures, Submaximal Exercise.

Introduction

During viral outbreaks, including the most recent coronavirus (COVID-19) pandemic, the use of personal protective equipment (i.e., facemasks) is recommended to prevent the spread of any highly contagious pathogen^{1,2,3}. As essential businesses and clinical hospital settings slowly resume normal business operations and patient care appointments, extra precautionary measures, including the use of protective facemasks, are recommended¹. Health care workers typically wear N95 masks due to the recommended filter medium from respiratory droplets and aerosols. Due to the increased demand and low supply of the N95 masks, the general public primarily uses either a cloth or surgical mask (SM) to prevent airborne droplets' transmission². When comparing performance measures with and without wearing a SM or an N95 mask when completing the 6MWT among older community-dwelling adults, limited research is available.

Cardiopulmonary exercise testing (CPET) is the gold standard for determining cardiorespiratory fitness (CRF). A higher CRF, relative to age, indicates a higher survival rate⁴⁻⁷. However, a CPET requires technical resources and trained personnel to conduct the test. Most health insurance companies do not reimburse for a CPET unless the test is medically necessary for diagnostic purposes. Thus, submaximal exercise testing has become a widely accepted alternative to a CPET, as these tests are quick, safe, inexpensive, and do

not require maximal effort. One of the first submaximal assessments, the Harvard Step test, was developed by Lucien Brouha in 1943, and several modifications of the step test evolved over the next few decades⁸⁻¹¹.

Balke and Cooper introduced submaximal running/walking tests to estimate functional capacity. They found that predicted maximal oxygen consumption (VO_{2max}) values were highly correlated and comparable to those obtained from a CPET^{12,13}. McGavin used the Cooper 12-minute run/walk test to identify disabilities in pulmonary patients diagnosed with chronic bronchitis^{14,15}. However, Butland found that some pulmonary patients had difficulty performing the 12-minute submaximal assessment but had similar results when completing a 6MWT. He concluded that the 6MWT might be more appropriate in a clinical population¹⁶.

The 6MWT measures the total distance walked on a flat 30-meter corridor in a 6-minute timeframe using a standardized protocol¹⁷. It has become one of the most widely used functional tests to assess functional capacity and predict morbidity and mortality rates in patients with pulmonary disease, cardiovascular disease, and congestive heart failure^{4,16,18,19, 20}. Solway reviewed walk tests. They found that patients were able to tolerate the 6MWT better than other walking tests and found that it was highly correlated with performing activities of daily living²¹. Harada also found the 6MWT to be a

reliable and valid measure of mobility among community-dwelling adults²².

Due to the COVID-19 virus pandemic, extra preventative measures have been put into place to prevent the spread of this virus, including the use of a facemask. However, limited research has been conducted on the physiological responses and exercise performance when wearing a facemask²³⁻³¹. More research is needed to identify if wearing a facemask significantly affects performance measures when completing the 6MWT.

The purpose of this study was to compare Six-Minute Walk Distance (6MWD), heart rate (HR), respiratory rate (RR), oxygen saturation (S_pO_2), rating of perceived exertion (RPE), and rating of perceived dyspnea (RPD) when performing the 6MWT with and without the use of a SM and an N95 mask.

Methods

Participants

Thirty-six community-dwelling adults (17 males, 19 females), ranging from 50 to 83 years of age, were recruited as participants. Participants were recruited by word of mouth and by placing flyers within the community. Sample size estimation using Cohen's techniques indicated that a minimum of 34 participants would be needed to detect a 5% difference in 6MWD with a power of .80 and an alpha level of .05³². It was decided to use 36 participants

to ensure a counter-balanced testing order for all conditions.

Questionnaires

Potential participants completed the Physical Activity Readiness Questionnaire (PAR-Q+) and ACSM Exercise Pre-participation Health Screening Questionnaire before data collection to identify current or chronic symptoms or medical conditions that would exclude participants from the study^{33,34}. Participants were included if they could tolerate walking for 6 minutes without chest pain/pressure, excessive shortness of breath (SOB), pain in the back, legs, or neck that would limit the assessment's completion. Participants were excluded if they were experiencing unstable angina, had a myocardial infarction within the past month, had a history of chronic obstructive pulmonary disease, had a resting heart rate greater than 120 bpm, resting systolic blood pressure greater than 180 mm Hg, and a resting diastolic blood pressure greater than 100 mm Hg. Participants were also excluded if they had any problems with dizziness, fainting, blackouts, or were a current smoker.

Data collection was performed outside on a 30-meter long, flat corridor located under the stadium bleachers at Veteran's Memorial Field at the University of Wisconsin – La Crosse. Data collection was completed from October 1-28, 2020. The outside temperature ranged from 36.6 to 55.4 degrees Fahrenheit. The sheltered stadium provided protection from

inclement weather conditions, and only one testing session needed to be rescheduled due to a thunderstorm with high wind speeds.

A verbal explanation of the test was given to the participants with the opportunity to ask questions. Participants then provided written informed consent. Approval from the Institutional Review Board for the Protection of Human Participants at Rocky Mountain University and the University of Wisconsin – La Crosse was obtained before testing (IRB Protocol # 2008051-02).

Familiarization session

All participants who met the inclusion criteria attended a familiarization session, where they completed a COVID-19 Screening Questionnaire, the Duke Activity Status Index Questionnaire (DASI), and had their temperature, height, and weight assessed³⁵. After resting for 10 minutes, blood pressure (BP) was taken using a calibrated sphygmomanometer and a stethoscope. Participants then performed a practice 6MWT following ATS guidelines. Before the test, they were given standardized guidelines on how to complete the test¹⁷.

Testing

Participants returned for testing at least 48 hours after the familiarization 6MWT and repeated the COVID survey and temperature check. Participants completed three separate 6MWTs (no mask (NM), SM, and an N95 mask). The SM used was a 3-Layer Disposable Surgical Face Mask and

the N95 mask used was a Powecom KN95 Face Mask. The order of test administration was randomly assigned and counter-balanced to eliminate any order effect. There were 60 minutes of rest between each walk to minimize any effect of fatigue¹⁷. Reflective tape was placed at the start/finish line and every 3 meters of the walking course. Two cones identified the turnaround points. A stopwatch was used to monitor time. Halfway along the walking course, a chair was placed against the wall if a subject needed to rest. During each test, the manufacturers' instructions were verbally reviewed for each of the masked conditions, and the standardized verbal prompts were given to participants each minute of the 6MWT.

The following measurements were taken during the familiarization 6MWT and for all testing conditions. Heart rate and RR were continuously monitored using a Zephyr Bio Harness 3 (Zephyr Technology, Annapolis, MD). Oxygen saturation was monitored at rest, immediate post-walk, and at 1-minute post-walk using a pulse oximeter (Pulse Oximeter CMS50D+, Contec Medical Systems Col, Ltd). Rating of perceived exertion and RPD was assessed at rest, every minute during the walk, and at the end of the walk test using large Borg 6-20 scales and modified Borg dyspnea scales, which were placed at each of the two pivot areas³⁶⁻³⁹. An iPad was used to record each 6MWT to determine 6MWD and calculate walking pace. All data were recorded on standardized worksheets, assigned a code

for confidentiality purposes, and entered into an Excel document for analysis.

Statistical analyses

SPSS for Windows (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp) was used for statistical analysis. Data were screened for accuracy, completeness, and normality. Standard descriptive statistics were used to summarize participants' characteristics and the responses to testing. Initially, all variables were analyzed with a three-way analysis of variance (ANOVA) (condition x time x gender) with repeated measures. Because there were no differences between men and women between conditions or across time, data were collapsed across gender. Subsequently, a two-way ANOVA with repeated measures was used to assess differences between walking conditions across time for 6MWD, HR, RR, S_pO_2 , RPE, and RPD. If there was a significant F ratio, Bonferroni posthoc tests were used to assess pairwise comparisons. Alpha was set at $p < .05$ to achieve statistical significance. All data are presented as mean \pm standard deviation.

Results

Thirty-eight participants were recruited for this study, but two participants did not complete the study due to rhythm abnormalities that did not transmit reliable data when using the Bio Harness monitor. Data for RR (two males with body weight \geq 103 kg) and HR (one female with body weight of 53.5 kg) were not used due to unreliable testing results. Physical characteristics of the participants who completed the study are presented in Table 1. Participants ranged from 50-83 years of age. The men were significantly younger, taller and heavier than the women, and had a higher mean BMI and estimated VO_{2max} scores. Estimated VO_{2max} values were calculated using the multiple regression equation from Porcari et al.⁴⁰. Responses from the PAR-Q+ and ACSM health screening questionnaire revealed six participants had a history of cardiovascular disease, nine participants took prescribed medications for hypertension and hyperlipidemia, four participants used prescribed inhalers for asthma, one participant had obstructive sleep apnea, and two participants had seasonal allergies.

Table 1. Descriptive characteristics of the subjects.

| | Women (n=19) | Men (n=17) | Total Group (N=36) |
|--------------------------|-----------------|------------------|-----------------------|
| Age (years) | 69.1 \pm 10.3 | 63.3 \pm 10.5* | 66.3 \pm 10.7 |
| Height (cm) | 160.2 \pm 6.7 | 177.4 \pm 5.8* | 168.3 \pm 10.7 |
| Weight (kg) | 64.1 \pm 11.1 | 88.1 \pm 13.8* | 75.5 \pm 17.3 |
| BMI (kg/m ²) | 25.0 \pm 4.4 | 28.0 \pm 3.9* | 26.4 \pm 4.4 |
| VO_{2max} (mL/kg/min) | 28.5. \pm 3.1 | 32.8 \pm 1.1* | 30.5 \pm 2.4 |

*Significantly different than females ($p < .05$).

Data for 6MWD are presented in Figure 1. There was no significant difference in 6MWD between conditions. Data for HR, RR, RPE, and RPD are presented in Figures 2-5, respectively. Values for HR, RR, and RPE significantly increased across time, however, there was no significant difference between testing conditions. Rating of perceived dyspnea values also significantly increased across time, but

values for the N95 mask were significantly greater than the other two conditions starting at minute 2. Data for S_pO_2 are presented in Figure 6. Overall, S_pO_2 significantly decreased from rest ($97.0\% \pm .2$) to immediately post-exercise (IPE) ($95.7\% \pm .3$) and then returned to baseline resting values ($97.3\% \pm .19$) at 1-minute of recovery. However, there was no significant difference between conditions.

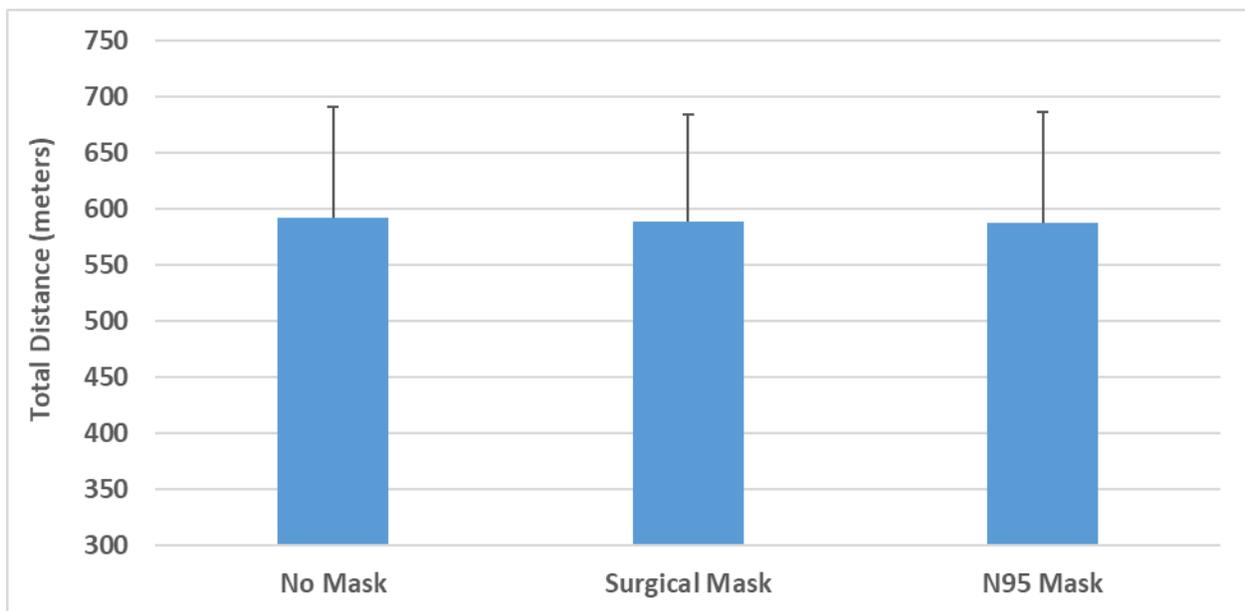


Figure 1. Average Six-Minute Walk Distance (6MWD) for each testing condition.

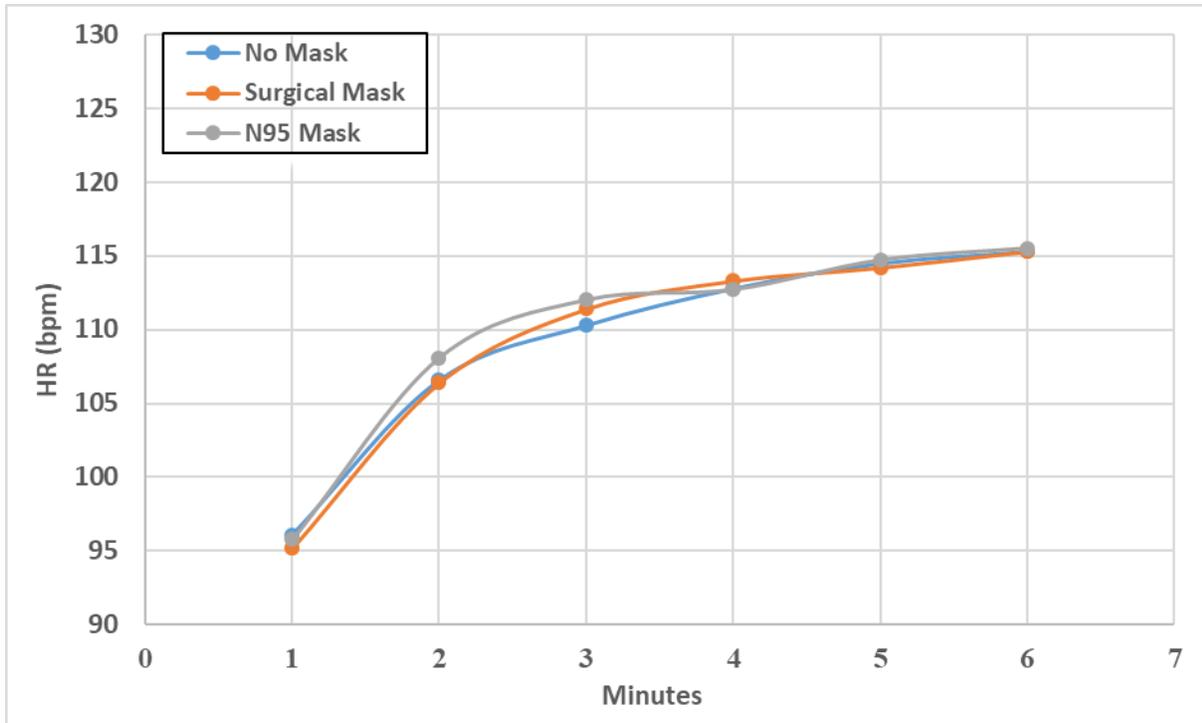


Figure 2. Average heart rate (HR) during each testing condition.

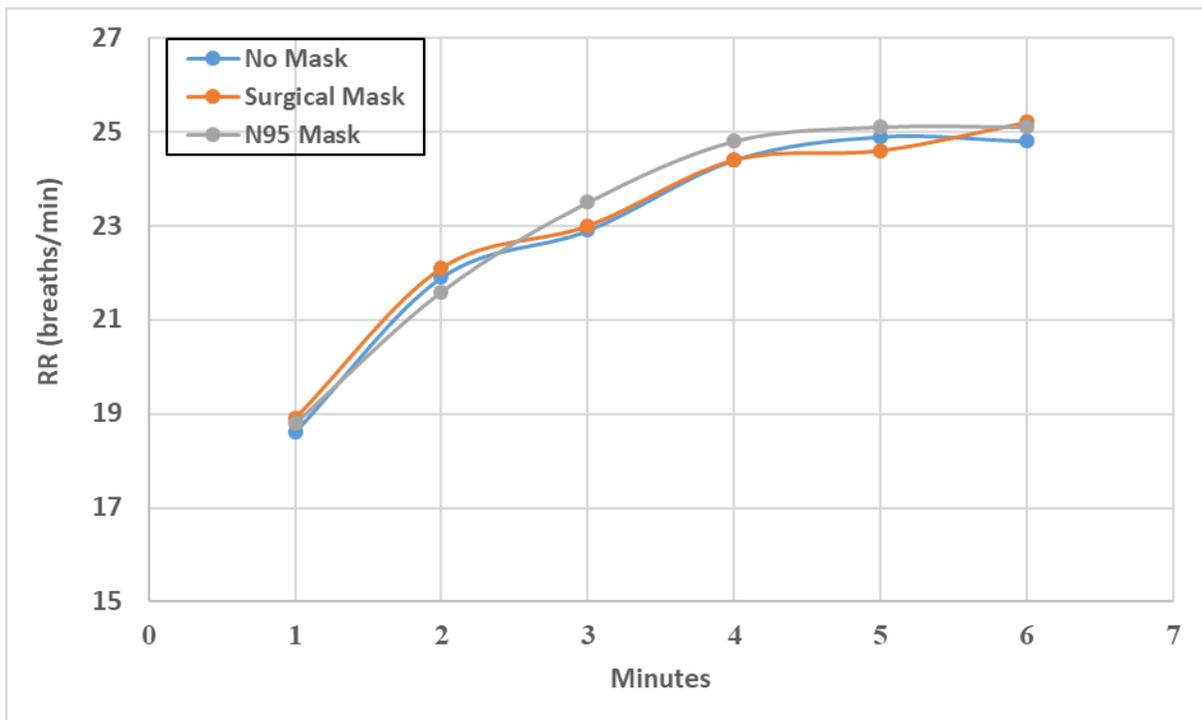


Figure 3. Average respiratory rate (RR) during each testing condition.

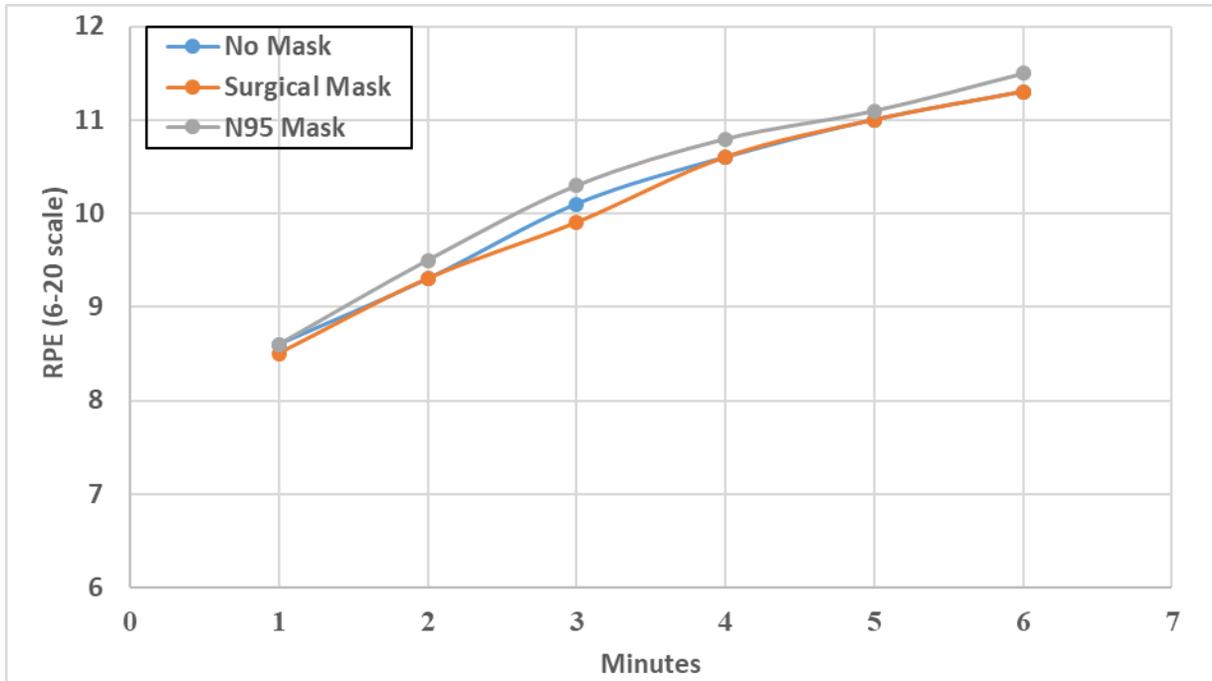


Figure 4. Average Rating of Perceived Exertion (RPE) during each testing condition.

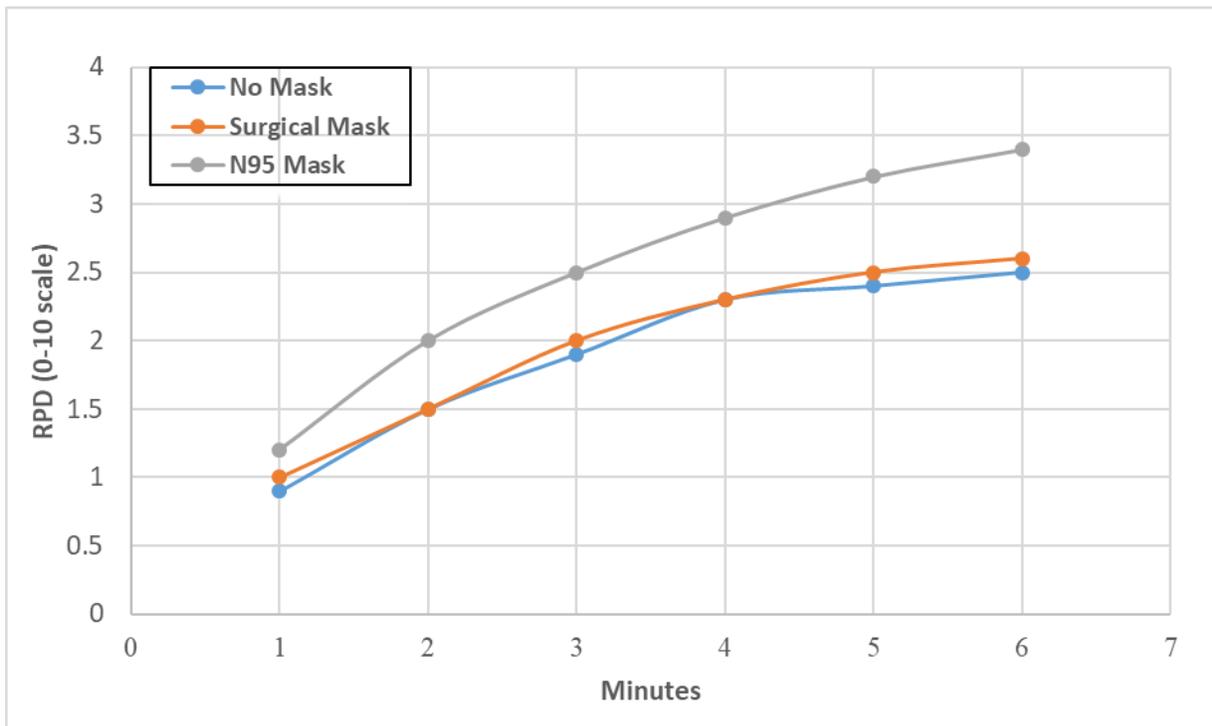


Figure 5. Average Rating of Perceived Dyspnea (RPD) during each testing condition.

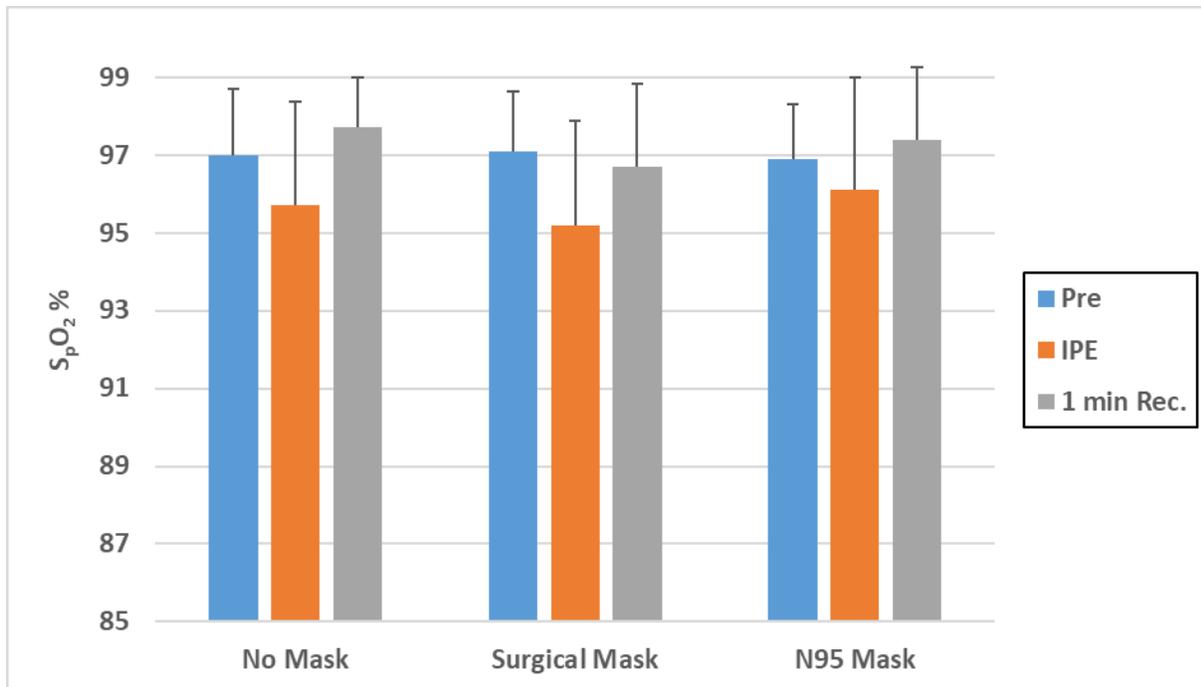


Figure 6. Average oxygen saturation (S_pO_2) during each testing condition. Pre = Resting, IPE= Immediate Post Exercise, 1 min Rec. = 1 minute Recovery.

Discussion

Performance Measures

The 6MWT is a commonly used test to evaluate CRF in older adults, especially in a clinical setting^{5,6,7}. The main purpose of this study was to determine if wearing a facemask would impact 6MWD. The results from our study found no significant difference in 6MWD between testing conditions. Distance averaged 592.9, 589.5, and 588.1 meters for the NM, SM, and the N95 conditions. The average total distance from our study fell within the reported normative reference values (400 to 700 meters) for healthy community-dwelling adults⁴¹⁻⁴⁸.

We found no significant difference in HR, RR, or S_pO_2 between conditions, but RPD was significantly greater when wearing the N95

mask than both the NM and the SM conditions. Rating of perceived dyspnea scores peaked during the last minute of the 6MWT with mean RPD scores of 3.4 ± 1.3 (N95 mask) compared to both the NM (RPD 2.5 ± 1.3) and the SM (RPD 2.6 ± 1.3) conditions. Our results are similar to those of Person, who investigated if wearing a SM affected walking distance when completing the 6MWT on 44 healthy participants. Participants in their study performed a familiarization 6MWT followed by two randomly performed 6MWT (NM and SM). No significant difference was found in 6MWD, HR, and S_pO_2 , but there was a clinically meaningful and significant difference found with RPD. The participants' perceived shortness of breath was significantly higher when wearing the SM than not wearing the mask. Person did not

measure RR or evaluate the N95 mask. When comparing these two studies, no significant difference was noted when comparing RPD scores between the NM and SM conditions in our study. Still, Person did find a significant difference in RPD scores in their study²⁹.

Our study results are also similar to those of Roberge et al. They evaluated the effects of wearing NM compared to wearing an N95 mask among health care workers. The participants in Roberge's study performed two testing conditions that were equivalent to realistic clinical work rates (1-hour of walking at 1.7 mph and 2.5 mph, respectively). They also found no significant difference in HR, RR, or S_pO_2 while wearing a mask. A notable difference between the two studies is that the mean walking speed reported in the current study ranged from 3.6 to 3.7mph, higher than the walking speeds in Roberge's study³⁰.

Shaw et al. and Epstein et al. evaluated the effects of wearing a mask when performing maximal exercise. They found no significant difference in HR, RR, BP, RPE, S_pO_2 , and time to exhaustion between mask conditions. Both of those studies were performed on young healthy adults^{25,31}.

Fikenzer et al. performed one of the first studies to evaluate the effects of wearing a mask on pulmonary function measurements and maximal exercise capacity. In contrast to the current study results, the N95 group had a 13% reduction in VO_{2max} and a 23%

reduction in maximal ventilation compared to the NM group²⁶. The changes are consistent with the results of Lee and Wang, who demonstrated increased airway resistance and work of breathing from mask usage²⁷. When comparing the N95 to the NM condition, Fikenzer et al. found a non-significant increase in cardiac workload, suggesting the myocardium compensates for the decreased pulmonary measurements. Our study did not assess pulmonary function measurements or stroke volume, but we found no significant HR or RR change, regardless of mask condition. Another key difference between our study and the study by Fikenzer et al. was that the 6MWT is a submaximal test, and they used a maximal test. More research is needed on the effects of mask-wearing and exercise capacity in older community-dwelling adults and individuals with impaired myocardial function.

Predictors of Dyspnea

Facemasks form an enclosed loop to inspired and expired air. Theoretically, individuals are rebreathing their own exhaled carbon dioxide (CO_2), which may decrease the partial pressure of oxygen (O_2) and increase the partial pressure of CO_2 . The three main predictors of exertional dyspnea include work of breathing, hypoxia, and hypercarbia^{3, 49}. Work of breathing is the energy used for inhalation and exhalation and can be calculated by measuring changes in pulmonary pressures and inspired and expired lung volumes⁵⁰. Hypoxia occurs when the concentration of O_2 in the arterial

blood is lower than normal. Signs and symptoms of hypoxia may include SOB, increased RR, increased HR, headache, restlessness, dizziness, and in severe cases confusion^{49,51}. Exercise also increases O₂ demand and may trigger hypoxemia.

Our study did find a significant decrease in oxygen saturation from rest (S_pO₂ 97.0% ± .2) to immediate post-exercise (S_pO₂ 95.7% ± .3) regardless of the mask condition. At 1-minute of recovery, oxygen saturations returned to baseline (S_pO₂ 97.3% ± .2). These results were consistent regardless of condition. Our findings are similar to an observational study performed on 53 surgeons wearing SMs while performing surgery²⁴. Their study found S_pO₂ decreased from 98% before surgery to 96% after surgery (1-4 hours in duration). Both the current study and the study by Beder et al., found S_pO₂ levels that were still within normal limits at all times making hypoxia an unlikely explanation for the observed increase in RPD during the N95 mask condition.

Hypercarbia is an increase in CO₂ in the blood. It is typically found in patients diagnosed with chronic lung diseases. In apparently healthy individuals, the body usually compensates from hypercarbia with an increase in RR. Signs and symptoms of hypercarbia include SOB, headaches, dizziness, fatigue, drowsiness, confusion, and flushing of the skin^{49,51,52}. Fikenzler et al. suggested that when wearing an N95 mask, the elevated airway resistance from the

mask increases the work of the respiratory muscles leading to an increase in O₂ consumption. This increased work of breathing stimulates sympathetic induced vasoconstriction affecting cardiac output. The increased breathing resistance may prolong inspiratory ventilation, causing a prolonged negative intrathoracic pressure²⁶. Epstein et al., Sinkule et al. and Smith found that prolonged usage of an N95 mask was associated with a build-up of CO₂ levels in the body^{3,25,53}. This CO₂ buildup leads to increased breathing, shifting the blood to more acidic levels³. The authors concluded that participants with obstructive lung disease should proceed with caution before attempting any type of physical activity while wearing a mask^{3,25,26, 53}. Our study did not evaluate end-tidal CO₂ levels, but the increase in end-tidal CO₂ may explain the increased perceived dyspnea scores found in our study.

Possible reasons for the increased perceived breathlessness may also be explained by the findings from Li et al. In their study, the participants perceived the N95 mask to be significantly more uncomfortable than the SM due to the higher heat and humidity within the mask, and the increased breathing resistance and itchiness experienced when wearing the N95 mask²⁸. Fikenzler et al. also found that the N95 mask was perceived as extremely uncomfortable compared to NM and SM conditions. Factors reported to explain this overall feeling of discomfort included the tight seal of the N95

mask, increased breathing resistance, and increased heat build-up within the mask²⁶.

Limitations

One limitation of the current study was that we used a convenience sample, which may not represent the general population of older community-dwelling adults. For instance, the participants in this study had above average estimated CRF levels based on the DASI questionnaire and the Porcari 6MWT regression equation; thus, the results of this study may not apply to sedentary or deconditioned older community-dwelling adults^{35,40}. Another limitation is that we only evaluated performance measures during a 6-minute timeframe. More research is needed on the effects of mask wearing and exercise capacity in older community-dwelling adults for an extended period (> 10 minutes), in sedentary populations, and in individuals with impaired myocardial or pulmonary function.

Conclusion

Wearing a SM or an N95 mask had no significant effect on 6MWD, HR, RR, RPE, and SpO₂ in older community-dwelling adults when performing the 6MWT. Wearing the N95 mask was associated with significantly higher RPD scores when completing the 6MWT. The increased perception of breathlessness may be attributed to a tighter face seal of the N95 mask, increased breathing resistance, higher temperature/humidity levels, and the trapping of CO₂ inside the N95 mask.

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