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RESEARCH ARTICLE

Individual performance analysis of maximal and submaximal exercise testing with different face masks

Syeda Rida Batool[1], Suman Sheraz[1], Maria Naeem[1], Aisha Razzaq[1], Arshad Nawaz Malik[1]

ABSTRACT

Background: COVID-19 pandemic brought drastic changes in every domain of life, including Facemask compulsion. Performance testing is universal practice but its approach with facemasks lacks guidelines.

Objective: The research aimed to investigate the effects of different masks on performance during submaximal (6MWT) and maximal test performance (Bruce Treadmill testing).

Methods: In a randomized crossover design (Riphah/RCRS/REC/01087), 66 healthy individuals (mean age 32.64 ± 12.7 years) performed 6MWT and Bruce tests under three conditions: no mask, surgical mask, N95 mask. Performance parameters (6MWD, Bruce time), predicted maximum Oxygen consumption (VO_2 max), rate of perceived exertion (RPE), and hemodynamic responses were measured. Subjective perceptions of discomfort and exhaustion were also recorded.

Results: Submaximal performance showed no significant change in walking distance ($p = 0.128$, $\eta p^2 = 0.032$) or VO_2 max ($p = 0.511$, $\eta p^2 = 0.039$). Bruce test duration significantly declined with N95 ($p < 0.001$, $\eta p^2 = 0.127$) and surgical masks ($p = 0.046$), with predicted VO_2 max significantly reduced in the N95 condition ($p < 0.001$, $\eta p^2 = 0.130$). Post-test SpO_2 ($p < 0.001$, $\eta p^2 = 0.392$), breathing rate ($p = 0.002$, $\eta p^2 = 0.195$), and RPE ($p < 0.001$, $\eta p^2 = 0.317$) were significantly affected with mask use. Heart rate and blood pressure remained unchanged ($p > 0.05$, $\eta p^2 \leq 0.041$).

Conclusion: Mask-associated performance declined during maximal testing, particularly with N95, which significantly reduced test duration and predicted VO_2 max while submaximal performance remained unaffected. Post-exercise measures were altered in both masked groups, heart rate and blood pressure remained stable.

Keywords: Exercise capacity, face masks, maximal exercise testing, performance

Clinical Trial Number: NCT05150613

DOI: http://doi.org/10.33897/fujrs.v5i2.449

Introduction:

Facemasks have become integral tools in infection control strategies, particularly amidst the COVID-19 pandemic. Designed with different protective purposes, facemasks serve to prevent splash and droplet contact, while respirators are specifically engineered to offer respiratory protection from aerosols.(1) These facial protective devices include different medical and non-medical standards, including NIOSH-certified N95 respirators and surgical masks, commonly utilized by healthcare professionals, as well as fabric-based non-medical masks made from various materials such as cotton, gauze, polypropylene, and silk.(2,3)

Exercise testing represents a widely adopted protocol for evaluating cardiopulmonary function, especially in assessing exercise capacity and predicting health-related outcomes across diverse populations. This procedure provides comprehensive insights into the functional performance of the cardiovascular, ventilatory, and skeletal systems, enabling the evaluation of undiagnosed exercise tolerance, exertional symptoms, performance capacity, and impairments. (4,5) Both submaximal and maximal exercise protocols, such as the 6 Minute Walk Test and the Bruce protocol, are globally practiced to deliver cost-effective and easily implementable outcomes.(6–9)

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Received: October 22nd, 2024; **Revision 1:** May 30th, 2025; **Revision 2:** June 23rd, 2025.

Acceptance: July 18th, 2025.

How to Cite: Batool SR, Sheraz S, Naeem M, Razzaq A, Malik AN. Individual performance analysis of maximal and submaximal exercise testing with different face masks. Foundation University Journal of Rehabilitation Sciences. 2025 July;5(2):89-99.

Amid concerns regarding the dyspneic effects of face masks during exercise, various experimental protocols have been conducted to elucidate their impact on respiratory mechanics and other parameters. While increased dyspneic perception has been noted with mask utilization, literature reviews suggest that the effects on respiratory mechanics during physical exertion are often minimal.(10) Studies examining the effects of medical masks, including surgical and N95 masks, on maximal cardiopulmonary exercise capacity have shown mixed results, indicating potential reductions in ventilation, oxygen uptake, and subjective exertion perception.(11,12)

A recent study by Massimo Mapelli et al. (2021) investigated the parametric differences associated with different face masks during rest and maximal exercise. Despite concerns, no negative impacts were observed among the participants. The study revealed significant differences in lung function measures across various mask conditions, with forced vital capacity and forced expiratory volume in one second (FEV1) decreasing in the order: no mask > surgical mask > FFP2 masks.(13)

While previous research has explored the effects of face masks on exercise performance, knowledge gaps persist regarding the individualized response to mask use during exercise testing. Factors such as mask tolerance, respiratory health, and baseline fitness level may influence performance outcomes. Therefore, this study aims to evaluate the impact of surgical and N95 facemasks on individual performance outcomes during submaximal and maximal exercise testing.

Methods:

All the procedures performed in the study were in accordance with the ethical standards of the Riphah ethical review board with reference # Riphah/RCRS/REC/01087**.** Informed consent was filled by all the participants prior to the study.

A randomized 3-way crossover study protocol, undertaking 3 testing groups (Group A; No mask, Group B; Surgical mask, Group C; N95 mask) was followed. The potential subjects were recruited from Aiwan-e-Tijarat-o-Sanat Hospital Trust (Karachi) (staff and local visitors) and both testing procedures were conducted at Aiwan-e- Tijarat-o- Sanat Physiotherapy Department (Karachi).

The required sample size was calculated using OpenEpi (Version 3.01) for comparing two independent means with a two-sided confidence level of 95% and power of 80%. Based on an expected mean difference of 1.666 between groups, with standard deviations of 2.2667 (Group 1) and 2.2833 (Group 2), and assuming a 2:1 allocation ratio (Group 2:Group 1), the estimated sample size was 22 participants for Group 1 and 44 for Group 2, totaling 66 participants and a total of 198 tests were conducted in randomized order.

The study included healthy adults over 18 who were physically fit and willing to consent, while excluding those with cognitive impairments, contraindications to exercise, limitations on mask wearability, Long COVID, or symptomatic/laboratory-diagnosed COVID-19. Eligible participants were assessed for pre-set criteria and provided informed consent. Random allocation of the participating individuals was done through the sealed envelope method to assign the testing order. 3 sealed envelopes containing codes A (no mask), B (surgical mask) and C (N95 mask) were used to decide the testing sequence by the primary researcher. The testing results were concealed to prevent anticipation bias, with the masks examined for defects and proper fit confirmed. Participants were instructed to avoid meals for 2 hours and exercise for 24 hours before testing. Upon arrival, demographic data and pre-participation information were collected via a screening questionnaire.

In the 6-Minute Walk Test, participants were debriefed individually and assigned to a sequence (no mask, surgical mask, or N95). Baseline metrics (heart rate, SpO2, respiratory rate, blood pressure, and RPE) were recorded before the test. Participants walked a marked 30-meter walkway for 6 minutes, with periodic measurements taken at 2, 4, and 6 minutes. HR and SpO2 were monitored via hospital-issued standard pulse oximeter, and subjective dyspnea was assessed. The total distance covered was recorded along with vitals. Encouragement was given, and discomfort and exhaustion scales were evaluated during a 30-minute recovery before the maximal procedure.

The Bruce protocol involves a hospital- issued callibrated treadmill test with stages: warm-up (1.7 mph at 0% incline), performance period with increasing speed and incline, and cool-down (1.7 mph at 0% incline). Baseline data (heart rate, SpO2, respiratory rate, blood pressure, RPE) were recorded after a safety briefing. Vitals and RPE were reassessed at each stage transition (1.7 mph at 10% incline to 5.0 mph at 18% incline). Post-test, vitals and termination criteria were noted, with perceived discomfort and exhaustion assessed. To minimize the potential for carryover effects such as fatigue or training adaptation, a minimum 48-hour washout period, as suggested by American College of Sports Medicine (ACSM) guidelines for high-intensity sessions for untrained individuals, was maintained between testing sessions. (14) Each participant underwent three sessions, totaling 198 tests for 66 participants.

The primary outcome measures were 6MWT (VO2 max, Walking distance) and Bruce protocol (VO2 max, Test Duration and Termination Criteria). The secondary outcomes were Vitals, Rate of Perceived exertion (RPE), Discomfort Perception using Discomfort scale published by Y. Li et al(15) and Exercise Exhaustion using Hecimovich-Peiffer-Harbaugh Exercise Exhaustion Scale (HPHEES).(16) Formula-based VO2 max was predicted from the recorded parameters of 6MWT. The formula used employed baseline data (weight, age and RHR) and distance covered in 6 minutes (r = 0.49).(17) For Bruce protocol, the VO2max was predicted using Bruce test duration For Women (r = 0.91), VO2 Max = 4.38 x T – 3.9. For men (r = 0.97), VO2 Max = 14.8 – (1.379 x T) + (0.451 x T2) – (0.012 x T3).(18,19)

Statistical analysis was conducted using SPSS version 22, with results presented via descriptive and inferential statistics. Continuous variables were expressed as mean ± SD, while categorical parameters were shown in frequency (percentage). Normality of distribution was assessed using Shapiro-Wilk's test (p-value >0.05 indicated normal distribution). Parametric comparisons were made using one-way repeated measure ANOVA, with sphericity corrections applied using Greenhouse-Geisser or Huynh-Feldt adjustments. Bonferroni comparisons analyzed pairwise group differences, with partial eta squared (ηp^2) calculated for effect size. For non-parametric data, outliers were adjusted to ensure normal distribution, and comparisons were made using Friedman's test followed by Wilcoxon signed-rank analysis. Kendall's W was used to calculate effect size for non-parametric data. Results were displayed using tables and graphs, with statistical significance set at p-value <0.05.

Results:

The sample included 66 participants, predominantly females (n=40), with a mean age of 32.64 ± 12.7 years. Reported demographics included weight (60.76 ± 11.17 kg), height (162.4 ± 9.2 cm), and BMI (23.08 ± 4.0 kg/m²). All participants had clearance through the Get Active Questionnaire, with a mean activity level of 4257.58 ± 2419.9 steps/day. Most participants were nonsmokers (74.2%), with 16.7% active smokers and 9.1% passive smokers, and active smokers had a mean consumption of 2.05 ± 6.1 packs/month. The preferred type of mask was surgical (63.6%), with equal preference for cloth and no mask (18.2% each), and the average daily mask wear was 3.19 ± 3.3 hours.

The post-trial average 6MWD was clinically reduced in the N95 group, but variations were non-significant. Table 3 summarizes 6MWT procedural metrics. Pretrial indices showed non-significant differences in heart rate, respiratory rate, oxygen saturation, and blood pressures (Table 1).

Table 1. Post Trial Statistics for 6MWD and VO_2 max

Post-Trial Data (6MWT)								
	No Mask	**Surgical Mask**	**N95 Mask**	**ANOVA (p-value: <0.05)**	**NM* vs SM***	**NM* vs N95**	**SM* vs N95**	**ηp2**
6MWD *(meters)	495.30 ± 57.4	495.09 ± 57.9	493.35 ± 57.3	0.128	1.000	0.302	0.328	0.032
VO_2max (ml/kg/min)	38.51 ± 6.5	38.50 ± 6.5	38.46 ± 6.5	0.128	1.000	0.302	0.328	0.032

**NM: No mask, SM: Surgical Mask, 6MWD: 6-minute walk distance, ηp2= Partial Eta squared*

Repeated measure ANOVA indicated non-significant heart rate differences initially, but at test conclusion, the heart rate was higher in the Surgical Mask group, followed by N95, with no difference between SM and N95. Oxygen saturation declined in masked groups during 6MWT, with the greatest drop in N95 at test end, though changes between SM and N95 were non-significant. RPE scores showed significant dyspnea increases from 2 to 6 minutes, especially in the N95 group. A steady rise in breathing frequency was noted across all groups, with masked groups significantly higher than NM, and N95 highest overall. Systolic and diastolic pressures showed no significant post-procedural variations between groups, though pressures were slightly higher in the SM group (Table 2).

Table 2. Six-Minute Walk Test—Summary of pre-trial, staged, and post-trial vitals (n = 66)

Variables		No Mask	Surgical Mask	N95	ANOVA (*P-value* <0.05)	NM* vs SM*	NM* vs N95	SM* vs N95	ηp2
HR (BPM)*	Pre-Test	83.14 ± 10.3	82.41 ± 7.7	82.02 ± 9.5	0.374	0.946	0.641	1.000	0.015
	2-min	107.70 ± 7.9	109.70 ± 7.9	109.17 ± 8.3	0.058	0.054	0.824	1.000	0.043
	4- min	122.38 ± 9.2	124.58 ± 8.6	124.41 ± 8.9	0.080	0.150	0.126	1.000	0.038
	Post-Test	124.45 ± 10.9	128.59 ± 10.9	127.65 ± 9.9	0.004	0.010	0.017	1.000	0.082
SpO_2* (%)	Pre-Test	99.09 ± 0.9	99.26 ± 0.8	99.27 ± 0.8	0.616	0.261	0.264	0.973	0.007
	2-min	98.55 ± 1.3	98.55 ± 1.3	98.41 ± 1.2	0.683	0.761	0.308	0.414	0.006
	4-min	99.27 ± 0.9	98.17 ± 1.4	98.36 ± 1.3	<0.001	<0.001	<0.001	0.495	0.174
	Post-Test	98.68 ± 1.2	98 ± 1.5	97.97 ± 1.6	0.004	0.004	0.010	0.876	0.083
RPE (0-10)*	Pre-Test	0	0	0	-	-	-	-	-
	2-Min	0.16 ± 0.2	0.11 ± 0.2	0.17 ± 0.3	0.388ǂ	0.317	0.694	0.127	0.014
	4- min	0.26 ± 0.3	0.31 ± 0.3	0.59 ± 0.4	<0.001	0.209	<0.001	<0.001	0.353
	Post-Test	0.62 ± 0.3	0.69 ± 0.5	0.96 ± 0.7	<0.001	0.153	<0.001	<0.001	0.158
RR (BPM)+	Pre-Test	15.97 ± 1.8	15.58 ± 1.9	16.35 ± 1.9	0.057	0.577	0.751	0.069	0.043
	Post-Test	24.38 ± 3.1	26.09 ± 3.3	27.70 ± 3.9	<0.001	<0.001	<0.001	0.001	0.316
SBP (mmHg)*	Pre-Test	111.79 ± 5.8	112.14 ± 5.3	110.71 ± 4.6	0.273	1.000	0.679	0.216	0.020
	Post-Test	118.67 ± 8.2	120.61 ± 7.1	118.44 ± 9.1	0.063	0.110	1.000	0.193	0.042
DBP (mmHg)*	Pre-Test	70.79 ± 5.1	71.09 ± 4.6	70.20 ± 4.4	0.545	1.000	1.000	0.766	0.009
	Post-Test	75.79 ± 4.9	76.42 ± 4.8	74.76 ± 4.5	0.108	1.000	0.547	0.068	0.034

**NM=No mask, SM=Surgical Mask, HR(BPM)=Heart Rate in Beats Per Minute, RR(BPM)=Respiratory Rate in Breaths Per minute, SBP(mmHg)=Systolic Blood Pressure in Millimeter Mercury, DBP(mmHg)=Diastolic Blood Pressure in millimeter Mercury, RPE=Rate of Perceived Exertion, SpO2= Oxygen Saturation, ηp2= Partial Eta squared*

Post-procedure analysis of Bruce performance time showed a significant decline in the N95 group, followed by SM, but no significant difference between the masked groups according to Bonferroni analysis. VO2 max values were significantly reduced with the N95 mask. (Table 3)

Table 3. Post Trial Statistics for Termination Criteria, Bruce Test Duration and Bruce VO_2 max

Post-Trial Vitals				
		No Mask (N%)	Surgical Mask (N%)	N95 (N%)
Termination Criteria	Exhaustion	46 (69.7%)	25 (37.9%)	16 (24.2%)
	HR max	9 (13.6%)	5 (7.6%)	6 (9.1%)
	CNS Signs	3 (4.5%)	17 (25.8%)	23 (34.8%)
	High RPE	8 (12.1%)	19 (28.8%)	21 (31.8%)

**HR max=Heart Rate Maximum, CNS=Central Nervous System, RPE=Rate of Perceived Exertion*

Test termination was based on subjective exhaustion, CNS signs, high RPE, and HR max, with exhaustion being the main criterion for NM and SM trials. (Table 4)

Table 4. Bruce protocol—Summary of pre-trial, staged, and post-trial vital

Variables (n = 66)		No Mask		Surgical Mask		N95		ANOVA (P-value <0.05)	NM* vs SM*	NM* vs N95	SM* vs N95	ηp2
	Stage/Time	**N**	**Mean ± SD**	**N**	**Mean ± SD**	**N**	**Mean ± SD**					
HR (BPM)*	Pre-Test	66	82.53 ± 11.0	66	84.62 ± 10.6	66	82.88 ± 9.0	0.107	0.201	1.000	0.327	0.034
	3-Min	66	108.56 ± 15.9	66	112.27 ± 17.9	66	112.67 ± 14.8	0.027	0.139	0.054	1.000	0.054
	6-Min	62	130.85 ± 13.9	64	134.27 ± 15.5	63	137.54 ± 15.1	<0.001	0.019	<0.001	0.045	0.184
	9-Min	43	145.51 ± 13.3	40	149.95 ± 12.7	41	154.88 ± 13.0	<0.001	0.124	<0.001	0.018	0.256
	12-Min	14	162.36 ± 12.2	11	160.27 ± 14.3	11	169.82 ± 15.3	0.982	1.000	1.000	1.000	0.004
	15-Min	3	183.33 ± 8.9	2	186.50 ± 2.1	3	180.67 ± 10.5	-	-	-	-	-
	Post- Test	66	165.70 ± 15.2	66	167.29 ± 15.5	66	167.45 ± 16.6	0.415	0.780	0.797	1.000	0.013
SpO_2* (%)	Pre-Test	66	99.50 ± 0.8	66	99.24 ± 0.8	66	99.55 ± 0.7	0.013	0.015	0.561	0.010	0.066
	3-Min	66	98.95 ± 1.5	66	98.55 ± 1.3	66	98.12 ± 1.8	0.004	0.005	0.002	0.192	0.085
	6-Min	62	98.65 ± 1.2	64	97.55 ± 1.3	63	97.87 ± 1.6	<0.001	<0.001	0.012	0.162	0.207
	9-Min	43	98.09 ± 1.8	40	97.39 ± 1.2	41	98.00 ± 1.4	0.047	0.112	0.990	0.039	0.090
	12-Min	14	98.43 ± 1.1	11	97.50 ± 1.2	11	97.90 ± 0.9	0.307	0.059	0.655	0.726	0.295
	15-Min	3	99 ± 0	2	97.50 ± 0.7	3	96.67 ± 0.6	0.156	0.180	0.102	0.317	0.929
	Post- Test	66	98.73 ± 1.4	66	97.41 ± 1.5	66	97.38 ± 1.7	<0.001	<0.001	<0.001	0.989	0.392
RPE* (0-10)	Pre-Test	66	0	66	0	66	0	-	-	-	-	-
	3-Min	66	0.26 ± 0.3	66	0.48 ± 0.6	66	0.77 ± 1.1	<0.001	<0.001	<0.001	0.036	0.265
	6-Min	62	1.18 ± 0.9	64	1.72 ± 0.96	63	1.90 ± 1.1	<0.001	<0.001	<0.001	0.121	0.262
	9-Min	43	2.51 ± 1.1	40	3.18 ± 1.2	41	3.46 ± 1.2	<0.001	<0.001	<0.001	0.077	0.396
	12-Min	14	3.75 ± 0.9	11	4.27 ± 1.3	11	4.54 ± 1.4	1.000	0.496	0.414	0.564	0
	15-Min	3	5.33 ± 0.6	2	5.5 ± 2.1	3	6 ± 1	0.607	1.000	0.157	0.317	0.250
	Post- Test	66	4.98 ± 1.6	66	5.91 ± 1.3	66	6.30 ± 1.3	<0.001	<0.001	<0.001	0.014	0.317
RR (BPM)*	Pre-Test	66	15.73 ± 1.8	66	16.06 ± 1.9	66	15.74 ± 1.9	0.522	0.856	1.000	1.000	0.010
	3-Min	66	21.00 ± 2.4	66	22.20 ± 2.1	66	22.71 ± 3.0	<0.001	<0.001	<0.001	0.541	0.171
	6-Min	62	28.61 ± 3.8	64	30.41 ± 4.6	63	30.29 ± 4.5	<0.001	<0.001	0.019	1.000	0.109
	9-Min	43	36.51 ± 5.3	40	37.58 ± 6.4	41	39.00 ± 5.8	0.001	0.192	0.002	0.070	0.195
	12-Min	14	42 ± 5.1	11	42.18 ± 5.5	11	44.45 ± 6.9	0.429	0.457	1.000	1.000	0.191
	15-Min	3	43.67 ± 4.7	2	43.50 ± 4.9	3	45.67 ± 8.5	-	-	-	-	-
	Post- Test	66	43.94 ± 7.2	66	45.24 ± 7.9	66	46.92 ± 7.1	0.002*	0.316	0.003	0.131	0.182
SBP (mmHg)*	Pre-Test		114.88 ± 7.5		114.55 ± 6.2		114.52 ± 5.6	0.856	1.000	1.000	1.000	0.002
	Post-Test		140.62 ± 14.8		138.62 ± 15.7		137.29 ± 13.9	0.067	0.526	0.095	0.920	0.041
DBP (mmHg)*	Pre-Test		74.39 ± 4.9		72.33 ± 4.7		73.33 ± 5.9	0.022*	0.021	0.402	0.597	0.057
	Post-Test		80.05 ± 6.1		79.32 ± 5.8		79.30 ± 6.8	0.543	0.935	1.000	1.000	0.009

**NM=No mask, SM=Surgical Mask, HR(BPM)=Heart Rate in Beats Per Minute, RR(BPM)=Respiratory Rate in Breaths Per minute, SBP(mmHg)=Systolic Blood Pressure in Millimeter Mercury, DBP(mmHg)=Diastolic Blood Pressure in millimeter Mercury, RPE=Rate of Perceived Exertion, SpO2= Oxygen Saturation, ηp2= Partial Eta squared*

Table 4. Bruce protocol—Summary of pre-trial, staged, and post-trial vital

Baseline measures showed no discrepancies, but higher heart rates were noted in the N95 group during staged progressions. Saturation drops were more profound in masked groups, especially the N95 group. RPE started at 0 for all participants, rising significantly in masked groups, highest in the N95 group. Respiratory rates, initially similar across groups, rose significantly more in masked groups, with higher post-trial differences in the N95 group. Diastolic variations were noted pre-trial between NM and SM groups, but post-procedural indices showed no significant differences across all groups.

Figure 1 highlights the subjective perceptions of mask-associated discomfort for 6MWT test adaptations. Ten components of perceived discomfort were analyzed separately to yield procedural differences. (Fig 1)

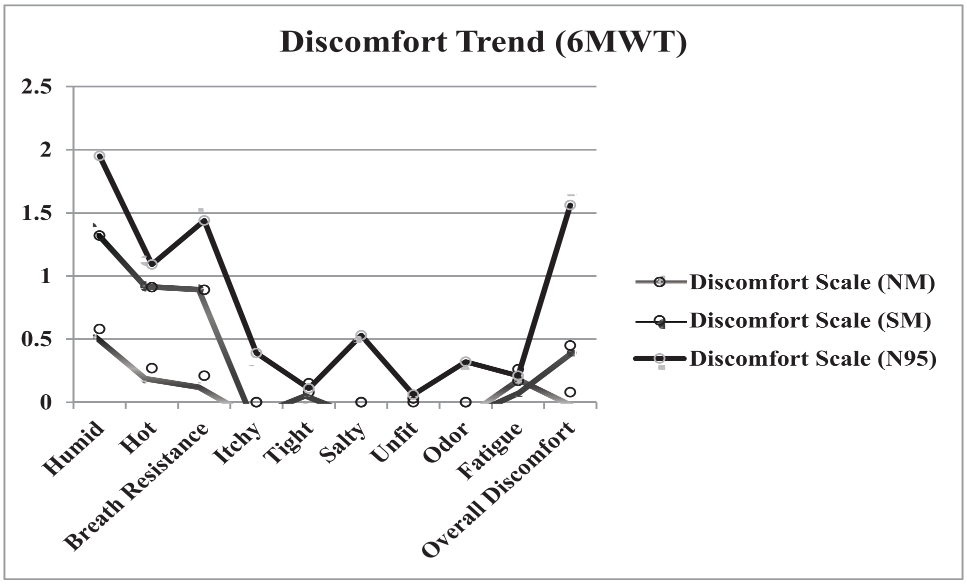

Figure 1. Temporal changes in the means of components of perceived discomfort with different facemasks (6MWT)

Figure 2 highlights the data for Bruce protocol-associated discomfort variations of the three groups. 8 out of 10 components differed significantly during masked conditions. However, the N95 trials showed a marked rise in humidity level, perceived hotness, breath resistance, itchiness, getting salty, unfitness level, perception of odor and overall discomfort. (Fig 2)

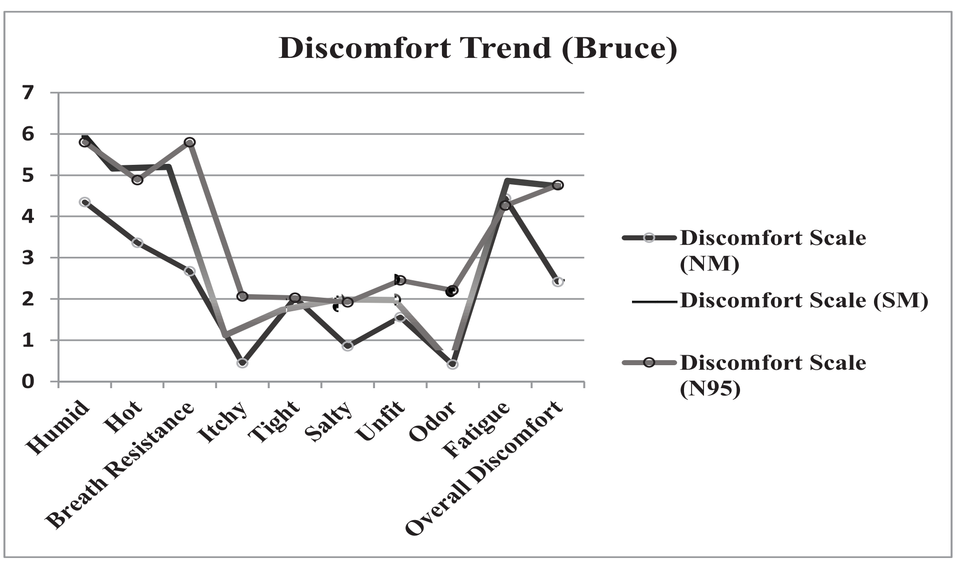

Figure 2: Temporal changes in the means of components of perceived discomfort with different facemasks (Bruce)

For components of Hecimovich Peiffer Harbaugh Exercise Exhaustion Scale (HPHEES), the total scores showed a significant change in post-performance exhaustion values for six-minute walk test. Individual component analysis showed a significant reduction in post-exercise refreshment levels, energy depletion (physical) and metal cloudiness in the masked group. Refreshment level and mental cloudiness were lowest in the N95 group. Similarly, participants walking with N95 masks were more physically drained in comparison, while running capacity was only reduced in the N95 category compared to both groups. (Fig 3)

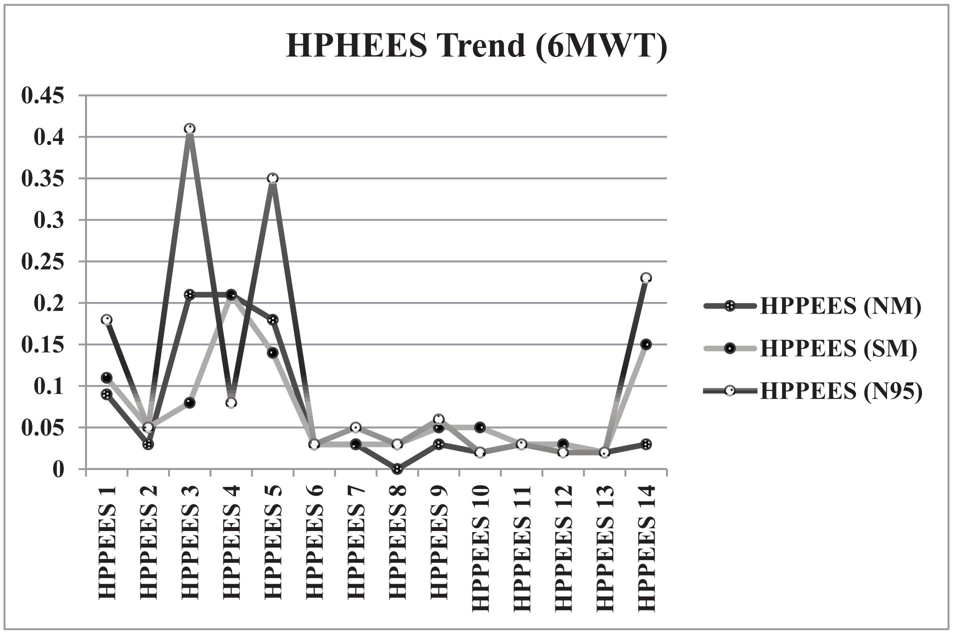

Figure 3: Temporal changes in the means of components of exhaustion with different facemasks (6MWT)

Figure 4 highlights the components of HPHEES for Bruce testing. Following statistical analysis, the HPHEES total scores varied across groups. Following Bonferroni, significant pairwise comparisons existed between NM vs SM. (Fig 4)

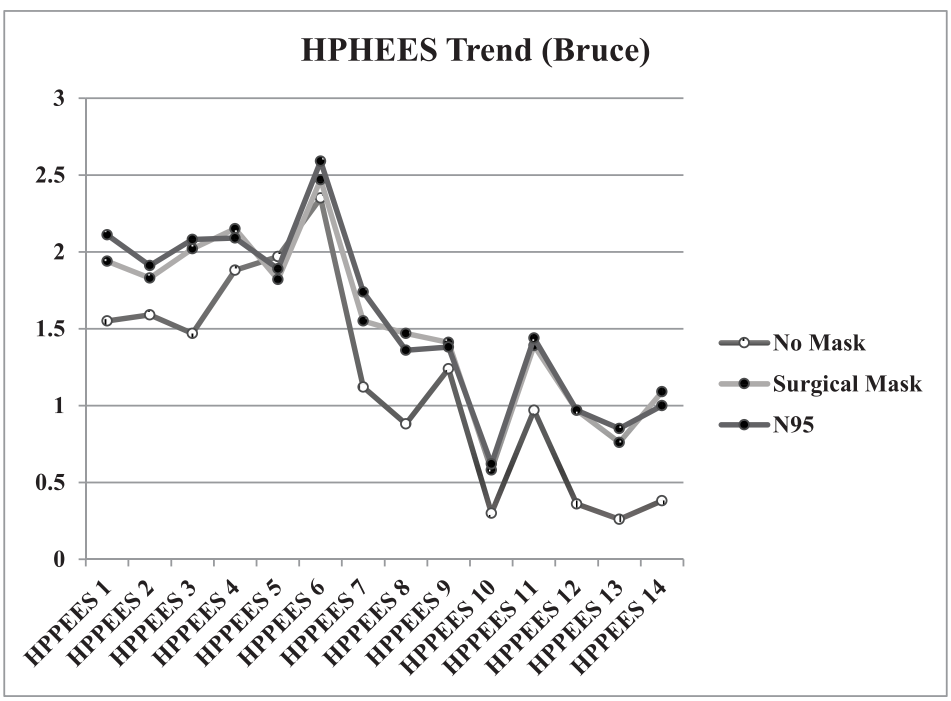

Figure 4: Temporal changes in the means of components of post exercise exhaustion with different facemasks (Bruce)

Discussion:

Our randomized cross-over study assessed the mask-related effects on the procedural performance of submaximal and maximal exercise tests commonly used in cardiopulmonary rehabilitation settings. The analyzed results reported the impact on hemodynamic parameters (HR, RR, SpO_2, BP), exercising capacity (exhaustion time, 6MWD) and perceptual factors (RPE, subjective questionnaires) for both protocols. Although the test adaptations negatively impact the exercise parameters of maximal testing, affecting the exercise capacity and hemodynamic stability of the participating individuals, the outcomes for submaximal were minimal alternations in physiological parameters. Furthermore, subjective perception to mask utilization was deemed uncomfortable, especially to the component of breath resistance and refreshment levels which were the most affected parameter for acute onset of exhaustion scoring, especially in N95 masks. 6MWT is a commonly utilized performance test.

With changes in the traditional mode of practice owing to the COVID-19 prevalence, our analysis with protective respirators reported no change in the walking distance of the sample population. These findings were consistent with the ones reported in the literature. Our distance averaged between 495.3, 495.09, and 493.35 for NM, SM and N95, which fell under the described normative values (400-700 meters).(20–22) Although the measure of six-minute walk distance allows screening of individual functional status, parameters of hemodynamic responses support testing performance.

RPE is a standard measurement in 6MWT and as per ATS recommendations should be scored subjectively by participants over time.(23) Our findings reported a significant increase in RPE ratings with N95 utilization. Similar findings were reported in the literature. Radtke et al. reported an increase in perceived dyspnea in the N95 group (3.4 ± 1.3) in comparison with NM (2.5 ± 1.3) and SM (2.6 ± 1.3).(24) Our results also reported a drop in saturation in all groups from the baseline.

Studies analyzing the effect of respiratory protective devices on ventilatory volumes have concluded a change in pulmonary parameters owing to the resistance offered to breathe via face masks.(25) Consequently, exertional dyspnea is dependent upon hypoxia, hypercarbia and breathing effort.(26,27) Theoretically, our findings correspond to mask associated increased breathing effort along with identified saturation decline to affect levels of perceived exertion.

Periodic analysis showed surgical masks largely, N95 affect the heart rate, breathing frequency and saturation during maximal exercise in healthy adults. Contrary to our findings, Fabricio et Al. reported a significant decrease in mask-associated breathing frequency with sequential bouts of physical activity.(28) Driver et al. also reported a significant fall in breathing frequency of the masked individuals during a graded treadmill test.(29) However, consistent to our findings Café et al. reported an apparent decrease in saturation in masked participants during physical exertion.(12) Similarly, high RPE as reported by our sample also correlates with the findings of Fabricio et al. who reported a rise in RPE in the masked group (19.6% and 15.3% MES during two bouts of TNT) compared to no mask.(28)

Our findings report, that the negative perceptions of discomfort are marked in masked groups, with higher severity analyzed in the N95 group. Apart from the psychological factors (claustrophobia and anxiety), the literature supports thermoregulatory changes of the inspired air as well as perceptions of humidity, hotness, breath resistance and overall discomfort all influence perception of exertion and cause exercise intolerance. In our study apart from the aforementioned components, other negative perceptions were also reported in Bruce incremental test to be significantly associated with general comfortability leading to a cumulative effect on test performance. These findings are consistent with the reports of Fikenzer et al. who also reported severe subjective discomfort associated with mask wearability, especially in the components of hotness, resistance to breathing, tightness and global discomfort.(11)

In the study done in 2022, where they investigated the effects of surgical face masks on perceived exertion during submaximal tests in children, the surgical facemask did not alter the various aspects of dyspnea during a submaximal effort, it did raise children's perceived exertion. Moreover, using a facemask during a moderately intense exercise did not affect any of the cardiorespiratory indices or the performances. Ultimately, the youngsters were able to do a brief submaximal activity without the facemask getting in the way. While according to our research, using N95 significantly increased RPE scores than the SM groups.(30)

In a study done by Lilly Chui in 2023, when compared to the no mask condition, the surgical and N95 masks reduced inspiratory flow, minute ventilation, and inspiratory duration from rest to peak exertion. During rest, warm-up, and maximal exercise, oxygen intake (VO2) and oxygen pulse (VO2/HR) declined in both the surgical and N95 mask settings (compared to no mask). Even Nevertheless,in our study, both masked groups had a significant decrease in saturation compared to the non-masked group. The N95 group experienced the largest post-procedure SpO2 decrease. (31)

To our knowledge, no previous studies used the Hecimovich-Peiffer Exercise Exhaustion Scale to evaluate the post-exercise acute onset of exhaustion. However, our results are in accordance with our subjective findings of discomfort and exercise intolerance, as participants reported mask-associated elevation in overall exhaustion scores.

The present study recruited healthy, sedentary adults, which limits the generalizability of findings to populations such as elderly individuals, children, or those with cardiopulmonary or metabolic conditions. The lack of age and clinical diversity restricts the application of results to disease-specific settings. Future studies should include more diverse or clinical populations to explore mask-associated performance changes across health conditions and age groups.

The VO2max was predicted using formulae and no direct calculations could be performed due to lack of resources. Further recommendations are made to test VO2max using direct calculations.

While sample size was estimated based on expected changes in Bruce protocol duration, the statistical power for secondary outcomes, especially in submaximal testing, may have been insufficient to detect small effects. This limitation should be addressed in future work.

The changes observed in SpO_2 and estimated VO_2 max are discussed in light of proposed physiological mechanisms, such as mask-induced airflow resistance and thermal effects. However, due to the absence of direct gas exchange analysis or spirometry, these mechanisms remain uncertain. Future investigations should utilize direct physiological measurements such as respiratory gas exchange and spirometry to confirm these effects.

This study assessed only the acute effects of mask wearability on cardiopulmonary performance. Therefore, the findings do not account for adaptation to long-term mask use. Future longitudinal studies are needed to examine whether repeated exposure leads to adaptation or attenuation of mask-related effects.

Conclusion:

To conclude, physiological adaptations were tolerable in masked individuals performing 6MWT and no post-performance adverse effects were reported. Hence, need-based utilization of both surgical and N95 masks can be encouraged in infective conditions to limit pathological spread. For Bruce maximal testing, surgical masks can be used with caution due to the increased incidence of mask-associated CNS signs. However, N95 associated difference in Bruce testing were substantial to limit maximal performance.

Disclaimer: This manuscript is a part of a post-graduate research study for the MS-Cardiopulmonary Physical Therapy program held in Riphah College of Rehabilitation and Allied Health Sciences, Islamabad.

Conflict of interest: None to declare.

Source of funding: None to declare.

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Malik AN: Final critical review and approval of the manuscript