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Effects of Surgical Mask Use on Peak Torque, Total Work and Interest Fatigability during Isokinetic Strength Testing

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Abstract

The purpose was to investigate if relative to a condition with no mask does wearing a surgical mask during resistance exercise in healthy individuals warrant early exercise termination, limit peak torque or total work performed alter physiological or psychological response. Our methods consisted of a cross-over design in which 20 participants completed isokinetic strength testing on 2 separate days, once with no mask and once with a surgical mask. For each leg 3 sets comprised of 5 repetitions set to 60° per second of an isokinetic, concentric knee extension and flexion, followed by 90 sec recovery. After completing 3 sets on initial leg, testing was set up for second leg. Physiological parameters (peak torque, total work, HR peak, oxygen saturation, psychological responses breathing discomfort and rate of perceived exertion) were investigated. The results revealed that the mean oxygen saturation was greater while wearing a surgical mask than with no mask 98.1 ± 0.60, 97.6 ± 0.94 respectively ($p=0.038$). Additionally, the breathing discomfort scores were higher while wearing a surgical mask, when compared to no mask 3.3 ± 2.41 and 2.0 ± 1.95, respectively ($p=0.015$). There were no additional differences ($t<1.531$, $p>0.202$) found between conditions, with the level of significance set for the study ($p<0.05$). In conclusion wearing mask during resistance exercise increases breathing discomfort but does not otherwise negatively impact peak force, exercise capacity, perceived effort, nor physiologic measures of exertion.

Keywords: Resistance training; Exercise; COVID; Weightlifting; Gym

Introduction

The coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome [1-3]. Coronavirus 2 (SARS-CoV-2) is highly transmittable from person-to-person when an infected individual coughs, sneezes, or talks while within at least 6 feet (1.8 m) of a neighboring individual [4]. Research has demonstrated that surgical face masks significantly reduced detection of both influenza virus RNA in respiratory droplets and coronavirus RNA in aerosols, with a trend toward reduced detection of coronavirus RNA in respiratory droplets [5]. According to the Centers for Disease Control and Prevention (CDC) as illustrated in Figure 1, an uninfected person wearing a surgical mask can be infected if within 6 feet of an infected person wearing a surgical mask for 60 minutes. The duration of exposure needed to become infected is reduced if only one individual is wearing a surgical mask, or if neither is wearing a mask to 30 minutes and 15 minutes respectively [6]. Guidelines set forth by the CDC state that if an individual is fully vaccinated against COVID-19, they can participate in many of the activities that they had before the pandemic as vaccination reduces the risk of infection and prevents severe illness and death should a vaccinated person become infected with COVID-19. Unvaccinated people should get vaccinated and continue masking until they are fully vaccinated. To maximize protection from variants of COVID-19 and prevent possibly spreading the virus to others, the CDC also recommends that fully vaccinated people should wear a mask indoors in public in areas of substantial or high transmission [7]. With the emergence of variants, such as the highly transmissible Omicron, following these guidelines remains prudent currently and could be necessary in the future.

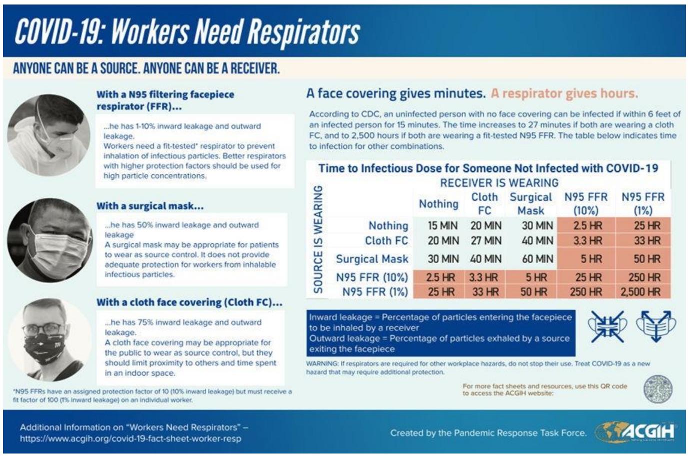

Figure 1: Centers for disease control and prevention. Your guide to masks: How to select, poperly wear, clean, and store masks.

Currently, the CDC identifies age ≥ 65, BMI ≥ 30, diabetes, smoking, chronic obstructive pulmonary disease, heart conditions, or an immunocompromised state as risk factors for severe illness from COVID-19 [8-10]. Potentially compounding these risk factors are findings that the environment created by the pandemic (e.g., restrictions relating to fitness facilities, efforts to avoid groups) may have promoted increases in sedentary behavior and decreases in physical activity [2,3,11,12]. Research conducted by Barkley et al., revealed that university cancellation of face-to-face courses due to the pandemic increased sedentary behavior in a sample of university students and employees, but only decreased physical activity in individuals who were the most active pre-cancellation. This suggests that pandemic-related restrictions and closure related to facilities such as gyms may disproportionately impact a more active population. This is of concern as increased sedentary behavior and reduced physical activity may, over time, exacerbate these known risk factors for severe illness from COVID-19 (e.g., obesity, diabetes). Increasing the prevalence of risk factors may then result in greater disease severity and contribute to overloading our healthcare systems [13]. It is still recommended that adults of all ages should achieve 150 min-300 min of moderate or 75 min-150 min of vigorous (or an equivalent combination) physical activity per week, along with at least 2 days per week of muscle strengthening activities [14]. However, it is important to note that increased viral shedding that occurs during elevated ventilatory rates observed during exercise within a shared space, such as gyms or fitness studios may increase the rate of transmission [1,15,16]. Unfortunately, evidence-based guidelines have not yet been developed to guide universal mask use during indoor exercise in a community setting like gyms or fitness studios. Previous work from our research group has demonstrated that the subjective experience of high breathing resistance should not be overlooked as being potentially impactful to reducing how well individuals are able to tolerate vigorous-to-peak intensity running while wearing a face mask. We previously conducted a randomized crossover trial, in which 20 recreationally active men and women performed a graded Exercise Stress Test (EST) under each of the experimental conditions: No mask, N95, and cloth mask. We found that performing a graded exercise stress test while wearing either a cloth mask or N95 respirator resulted in lower estimated peak oxygen consumption (eV̇ O2peak) from peak workload and heart rates as compared with no mask. Regardless of experimental condition, no participant demonstrated a clinical indication requiring test termination (e.g., light-headedness, confusion, ataxia, or angina) prior to voluntary cessation associated with the achievement of peak exhaustion. We initially conducted univariate comparisons of physiological responses to EST, which consistently demonstrated exercise tolerance was the highest during the EST and no mask trial. However, after controlling for breathing resistance there were no longer any significant differences between conditions. Leading us to conclude that breathing discomfort was the primary factor in EST termination, rather than an actual physiological limitation during exercise [17].

In addition to our work there have been other studies evaluating how exercise capacity can be impacted by wearing a mask during peak cardiovascular exercise and the results are equivocal. Some studies conclude that surgical face mask use results in a significant reduction in exercise capacity and $\dot{V}O_2$ max [18-21]. Conversely, other groups did not identify significant reductions in exercise capacity or $\dot{V}O_2$ max [17,22-25]. It is important to note that all of the studies that identified significant reduction in exercise capacity and $\dot{V}O_2$ max were conducted while placing a spirometry mask over the face masks during the cardiopulmonary exercise testing. However, there were some studies that failed to demonstrate a significant reduction in exercise capacity and $\dot{V}O_2$ max despite having a spirometry mask over the surgical face mask. Additionally, studies that were conducted without placing a spirometry mask over the surgical mask did not identify a significant reduction in $\dot{V}O_2$ max. Furthermore, a systematic review and meta-analysis conducted by Shaw et al. on the impact of wearing a mask during exercise concluded that face masks can be worn during exercise with no influences on performance and minimal impacts on physiological variables [26]. Since most cardiovascular and resistance training conducted within gyms and fitness facilities is submaximal exercise, a more applicable study conducted by Lassing et al., revealed that surgical face masks increase airway resistance and heart rate during submaximal cycling exercise, but perceived exertion and endurance performance were unchanged [27]. These disparate findings highlight the need for additional research examining the potential impact of mask wearing upon individual responses to and the perception of physical activity. While there is a need for additional research examining the impact of mask wearing on physical activity this may be particularly true for resistant-based exercise. To our knowledge, only two studies have evaluated the acute effects of face mask use on physiological responses and strength performance. A study comprised of 14 individuals with sarcopenia found that wearing a surgical mask or a Filtering Face Piece (FFP2) respirator during a resistance training session resulted in similar strength performance and physiological responses than the same exercise without a mask in persons with sarcopenia [28]. The second study conducted by Rosa et al., evaluated 17 recreational weightlifters performing four randomized bouts of bench press consisting of 70% of one-Repetition Maximum (1RM) and 50% 1RM, both performed with and without a N95 respirator. Each bench press session was separated by 72 hours and comprised of four sets with 2 min of recovery between sets. The bench press exercise was performed until concentric failure in all conditions, with the eccentric phase controlled for two seconds and the concentric phase performed at the highest possible voluntary speed. After comparing the average of four sets of 70% 1RM, maximum propulsive velocity was significantly reduced while wearing a N95 respirator. However, there was no significant effect of condition on total volume performed (set × load × repetition), oxygen saturation (SpO_2), Rating of Perceived Exertion (RPE), or Heart Rate (HR). Conversely, when analyzing the average of 4 sets of 50% 1RM, RPE was significantly increased and SpO_2 significantly reduced in the mask condition, but there was no significant difference in maximum propulsive velocity, total volume performed (set × load × repetition), or HR between conditions [29]. To date, there is no study that evaluates the effects of surgical mask use during resistance exercise in an active healthy population.

The purpose of the present study was to address the following questions: Relative to a condition with no mask does wearing a surgical mask during resistance exercise in healthy individuals (1) Yield clinically relevant indications warranting early exercise termination (e.g., angina, ataxia, cyanosis, significant dyspnea, or hypoxemia), (2) Limit peak torque, (3) Limit total work performed, (4) Alter physiological (HR or SpO_2) or psychological responses (RPE or breathing discomfort) during resistance exercise. We hypothesized that surgical masks covering the nose and mouth worn during resistance exercise would significantly increase the level of discomfort during exercise but will not limit exercise capacity as determined by peak torque generated within each set and total work performed during testing session, nor would masking cause any increased frequency of clinical indications for exercise termination. To our knowledge this is the first study to assess the effects of wearing a surgical mask during resistance exercise in an active healthy population.

Methods

Experimental approach to the problem

This was a prospective study conducted using a randomized-control crossover design where participants completed a resistance exercise protocol utilizing a biodex system 4 (Biodex Medical Systems Inc., Shirley, New York) and advantage V5 software (Biodex Medical Systems Inc., Shirley, New York), with a standard leg attachment to replicate a bout of lower-body exercise. Participants performed an isokinetic resistance exercise protocol under two different conditions completed in a randomized order, once without a mask and once while wearing a surgical mask. Study participants were asked which leg they prefer to kick a ball with to identify their dominant leg for data collection purposes, and were instructed to abstain from vigorous aerobic or lower extremity resistance training 48 hours prior to testing [30]. Isokinetic testing can be used to provide valid, reliable, objective measure of a muscular performance and offers significant clinical controls to simulate a resistance training workout. The lever arm speed measuring muscular output by the participant can be adjusted depending on the desired number of repetitions or duration test performed [31]. Various skeletal muscle metabolic systems could be stressed depending on the effort and duration of time under tension, making it an efficient and reliable method for the assessment of muscle performance under various environmental conditions,including wearing a mask during a resistance training workout.

Subjects

We recruited healthy recreationally active men and women N=20 (n=11 female) currently employed by the cleveland clinic. All participants completed the protocol with no adverse events, and their physical characteristics are summarized in Table 1. Participants were solicited *via* flyers posted throughout the medical campus. Voluntary participation of individuals external to the cleveland clinic was prohibited due to institutional policies mandating COVID-19 related human-to-human research could not involve unnecessary onsite medical testing or research procedures at any cleveland clinic facility apart from studies utilizing exclusively cleveland clinic employees. Relative and absolute clinical criteria that were referenced in order to determine whether any resistance exercise protocol required immediate termination due to safety related concerns came directly from joint recommendations written by the American heart association, American college of cardiology, and American college of sport medicine [32]. Study inclusion criteria required potential participants be apparently healthy without history of any chronic disease (including absence of exercise induced asthma), demonstrate no orthopedic or medical limitation that could interfere with exercise participation, and ability to independently provide verbal and written informed consent. Informed consent was obtained by either the Primary Investigator (PI) or Co-Investigator (CoI), and need for medical clearance determined based on American College of Sports Medicine's (ACSM) 2015 pre-participation guidelines [33]. Each study participant provided voluntary verbal and written informed consent prior to participating in any aspect of this study. This study was approved by the cleveland clinic institutional review board.

	Female (n=11)			**Male (n=9)**		
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**
Age (Years)	39.0	± 11.4	24-54	37.1	± 13.5	25-60
Weight (kg)	70.5	± 10.8	55.6-90.9	81.9	± 16.5	59.5-109
Height (cm)	25.4	± 1.3	23.3-27.6	28.2	± 1.4	26.4-30.3
BMI (kg/m2)	26.1	± 4.7	20.8-33.8	30.3	± 4.3	19.3-30.3

Table 1: Physical characteristic of study participants.

Testing protocol

Testing took place on two separate days with seven to ten days between tests, and the time of day was kept consistent for each test. Study personnel verbally encouraged participants throughout the testing to provide a maximal effort, encouraging them to "push, push, push" and "pull, pull, pull" during knee extension and knee flexion, respectively [17,24,34]. Throughout each testing session, participants were monitored continuously using pulse oximetry to measure HR and SpO_2 following each set throughout the resistance exercise testing protocol. Within the immediate post-exercise recovery following completion of the last set of each testing sessions, rating of perceived exertion (RPE; Borg scale, (6-20) and the subjective experience of breathing discomfort while wearing or not wearing a surgical mask was evaluated using a perceptions of mask discomfort scale instrument [35]. Figure 1 shows the rating scales used by the participants. Participants were asked to reply to the question ‘‘How uncomfortable was your breathing during exercise?’’ by rating on a scale ranging from 0-10, with 0 representing ‘‘comfortable’’, 5 representing ‘‘uncomfortable’’ and 10 representing ‘‘very uncomfortable’’ (Figure 2).

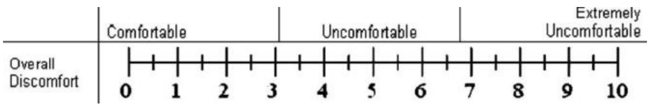

Figure 2: Scale of measuring subjective perception of breathing discomfort.

Session began with a warm-up protocol which was broken down into two phases (general warm-up and tempo warm-up): The general warm up consisted of a general cardiovascular warm up for 10 minutes on a cycle ergometer, gradually increasing pace to a moderate power output between 80-100 watts, followed by low-intensity dynamic stretching exercises for the hamstrings and quadriceps [36]. Study participants were placed in the sitting position on the biodex dynamometer, with the center of the knee joint aligned with the center of the dynamometer's power shaft, and the seat back adjusted to provide adequate lumbar support. Range of motion was set for each individual participant. End range flexion and extension stopping points were determined based on the comfort level of the participant, but were matched between limbs.

The anatomical reference point was set at a knee angle of 90°, with full knee flexion to 90. The ankle pad of the dynamometer was placed above the participants' lateral malleolus, with shoulder and lap belts secured. A tempo warm-up was performed on each leg prior to testing of each leg, and consisted of three sub-maximal efforts, and one maximal effort to become accustomed to the tempo of the machine. Participants were instructed to perform one repetition of knee flexion and extension at 25%, 50%, 75% and 100% of maximal effort with no rest between each repetition. This enabled the exerciser to get a feel for the effort level required to apply sub maximal and maximal effort at the various speeds. Following the tempo warm-up, resting HR and SpO_2 were recorded.

For each leg, participants performed three sets of maximal effort, for 15 repetitions at 180° per second of an isokinetic, concentric knee extension and flexion. Each set was followed by a 90 second period of recovery. After completing all three sets on the initial leg, testing was set up for second leg.

Statistical analysis

Differences in mask condition (mask *vs.* no mask) on physiological parameters comprised of parametric data including peak HR (HR peak), SpO_2, and total work were analyzed using paired sample t-tests. Non-parametric data from psychometric variables including RPE (6-20) and breathing discomfort scores (0-10) were analyzed utilizing Wilcoxon signed-rank test. Two-tailed significance was determined using $\alpha \leq 0.05$. Analyses were performed using SPSS version #27 statistical software. There were 20 participants enrolled, which was determined through a power analysis from normative data as previously published for males aged 30-39 with an average power of 284+21.1 Watts during Isokinetic testing at 180°per second (26). Given this average power, detecting a Minimal Clinically Important Difference (MCID) of 10% for isokinetic testing of knee extension and flexion would require 14 subjects to achieve a power of 0.80 given a priori alpha pf 0.05.

Results

Table 2 presents the differences between the surgical mask and no mask conditions on HRpeak, SpO_2, total work knee extension, total work knee flexion, total work combined knee extension and flexion, RPE, and breathing discomfort score. A paired sample t-test revealed that mean SpO_2 was significantly greater when performing resistance exercise while wearing a surgical mask, than with no mask 98.1 ± 0.60, 97.6 ± 0.94 (t=2.236, p=0.038) with a medium effect size, d=0.503. A wilcox signed rank test revealed that breathing discomfort scores were significantly higher when performing resistance exercise while wearing a surgical mask when compared to no mask 3.31 ± 2.41 and 1.95, respectively z=-2.44, p=0.015 with a medium effect size, d=0.571. There were no additional significant differences (t<1.531, p>0.202) found between conditions for any of the remaining dependent variables: HR peak, RPE, total work knee extension, total work knee flexion, total work combined knee extension & flexion, peak torque for knee extension or knee flexion.

Variable	Surgical mask (n=20)	No mask (n=20)	p
Breathing discomfort (0-10)	3.3 ± 2.41	2.0 ± 1.95	0.015*
$Sp0_2$ peak	98.1 ± 0.60	97.6 ± 0.94	0.038*
HRpeak (bpm)	124 ± 16	123 ± 22	0.746
RPE (6-20)	11.8 ± 2.21	11.6 ± 2.12	0.394
Total work knee extension (ft-lbs)	6783.9 ± 2165	6748.6 ± 2206	0.860
Total work knee flexion (ft-lbs)	3461.4 ± 922	3320.4 ± 1046	0.202
Total work knee extension and flex (ft-lb)	10245.3 ± 2987	10069.1 ± 3141	0.554
Peak torque dominant knee ext set #1 (ft-lbs)	87.3 ± 25.7	87.9 ± 27.3	0.783
Peak torque dominant knee ext set #2 (ft-lbs)	85.5 ± 22.4	87.3 ± 26.2	0.349
Peak torque dominant knee ext set #3 (ft-lbs)	83.3 ± 22.2	83.4 ± 21.9	0.990
Peak torque dominant knee flex set #1 (ft-lbs)	46.7 ± 11.7	45.3 ± 13.8	0.264
Peak torque dominant knee flex set #2 (ft-lbs)	45.7 ± 10.2	43.6 ± 12.0	0.142
Peak torque dominant knee flex set #3 (ft-lbs)	42.2 ± 8.5	40.4 ± 11.5	0.270

Table 2: Surgical mask *vs.* no mask: mean ± standard deviation, *= statistical difference between conditions (p<0.05).

Discussion

The purpose of this study was to build upon existing recommendations made by the CDC that nose and mouth facial coverings are to be worn in public spaces, by providing evidence that while individuals might experience an increase in perceived breathing discomfort during cardiovascular and resistance exercise, exercise capacity and physiologic measures were largely unaffected. For the vast majority of individuals, protective mask use during exercise has consistently been found to be safe with minimal impact on exercise capacity [26]. In our current study examining surgical face mask use on exercise capacity during resistance training, we found that perceived breathing discomfort during resistance exercise is significantly elevated when performed while wearing a surgical mask. Additionally, we found that performing resistance exercise with a mask did not significantly alter HR peak, RPE, total work knee extension, total work knee flexion, total work combined knee extension and flexion, or peak torque generated during knee flexion and extension. While there was a statistically significant difference in SpO_2 between conditions, this was determined to not meet a clinical significance of mild exercise induced hypoxemia (arterial O_2 saturation of 93%–95% (or 3%–4% <rest) [37]. Furthermore, SpO_2 was actually greater while wearing a surgical mask compared with no mask during resistance exercise. We had similar concerns as those expressed by Shaw et al. that wearing a spirometry mask to evaluate gas exchange over the surgical mask may essentially seal the surgical mask to the face, changing the properties of the mask and reducing the external validity of measurements (Figure 2) [25]. In our previous study in which we evaluated the effect of mask use during cardiovascular exercise, we did not evaluate gas exchange to avoid altering the face seal of the masks during testing. In addition to our study, other groups that evaluated facemasks without utilizing spirometry masks did not identify significant reductions in exercise capacity or $\dot{V}O_2$ max [22,23,17]. Future research efforts should be directed towards evaluating the degree to which placing a spirometry mask over the protective mask being evaluated alters the mechanics of the protective mask, which could potentially decrease the external validity of previous studies that followed this study design (Figure 3A-3C) [38].

Figure 3: (A) Fitting of surgical mask.

Figure 3: (B) Fitting of spirometry mask over surgical mask.

Figure 3: (C) Fitting of spirometry mask over surgical mask and leak-age test.

Conclusion

In conclusion, to our knowledge this is the first study to assess the effects of wearing a protective nose and face covering on resistance exercise capacity, peak force generation and breathing perception in the larger muscle groups of knee extensors and flexors in a healthy population. Similar to previous work from our group and others examining the impact of masks on aerobic exercise we found that wearing mask during resistance exercise increases breathing discomfort but does not otherwise negatively impact peak force, exercise capacity, perceived effort, nor physiologic measures of exertion. Based on these findings it seems that in active and otherwise healthy population, that surgical mask may be used during resistance exercise without additional safety concerns or significant decrements in exercise capacity.

Practical Applications

The current study's investigation of surgical mask use during resistance training helps to bridge the existing gap in knowledge pertaining to the mask use during physical activity. Findings from our previous work, combined with our current findings suggest that neither cardiovascular nor resistance exercise participation in any public setting should at this time be excluded from current expert-guided universal recommendations strongly encouraging the public display of nose and mouth facial coverings to help curb the transmission of COVID-19. Incorporation of this research into the current CDC guidelines for mask use could potentially decrease the closure of fitness facilities by adopting universal mask recommendations, when appropriate during both cardiovascular and resistance exercise. With the emergence of COVID-19 variants, this is more urgent than ever.

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