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Effect of Deep Breathing on Functional Capacity among Healthcare Workers Wearing FFP2/N95 Filtering Facepiece Respirators

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Abstract

Background: The novel 2019 coronavirus disease (COVID-19) pandemic is putting the world at risk due to the spread of virus-infected respiration droplets. Healthcare workers (HCWs) wear N95 respirators to avoid this infection but Wearing it invokes several physiologic implications with prolonged use.

Aim of Study: The aim of this study was to measure the effect of deep breathing on functional capacity among healthcare workers wearing FFP2/N95 filtering facepiece respirators.

Subjects and Methods: Sixty HCWs (14 males and 46 females) wearing FFP2/N95 filtering facepiece respirators, their age ranged from (25-35) years old and body mass index (BMI) less than 30 kg /m2. participants were recruited from intensive care unit department and inpatient clinics, Cairo University Hospitals, Egypt. Participants were assigned into two groups equal in number; the group (A) (22 females & 8 men) performed deep breathing training by incentive spirometer (IS) daily for 6 weeks, while the group (B) (24 females & 6 men) was the control group. Both groups were wearing the respirator for 4-8h/day. Data obtained regarding six-minute walk test (6MWT) at the beginning of the study and after 6 weeks for both groups. Parameters were evaluated include heart rate (HR), oxygen saturation (SPO_2), modified borg dyspnea scale (MBS) and six-minute walking distance (6MWD) without wearing N95 mask, while wearing N95 mask from 2 hours Pre training and while wearing N95 mask from 2 hours Post training after 6 weeks also breath holding time (BHT) was measured at the beginning and the end of the study.

Results: After 6 weeks of training, there was no significant difference between groups in HR, O_2 saturation and 6MWD at Pre training without mask and at Pre training with mask ($p>0.05$). However, there was a significant decrease in resting HR, HR after 6MWT, resting MBS and MBS after 6MWT at Post training with mask of study group compared with that of control group ($p<0.001$). There was a significant increase in resting O_2 saturation, O_2 saturation after 6MWT and 6MWD at Post training with mask of study group compared with that of control group ($p<0.01$). There was a significant increase in the BHT of study group compared with that of control group Post training ($p<0.001$).

Conclusion: The results demonstrated that deep breathing training improve functional capacity among healthcare workers wearing FFP2/N95 filtering facepiece respirators.

Key Words: *Deep breathing – Functional capacity – FFP2/N95 filtering facepiece respirators.*

Introduction

ON March 11, 2020, the World Health Organization (WHO) declared COVID-19 to be a pandemic [1]. As COVID-19 pandemic spreads across the world, millions of people are remaining at home to slow the spread of the disease and help to flatten the curve associated with the exponential increase in the number of cases. HCWs on the other hand, will not be staying at home [2]. During the ongoing COVID-19 outbreak, it is recommended that HCWs in close contact with infected patients wear N95 filtering facepiece respirators (FFR) rather than surgical masks [3], due to medical masks, also known as surgical masks, are less effective than N95 FFR at minimizing aerosol exposure [4].

The use of a N95 FFR induces a rise in inhaled carbon dioxide (CO_2), a decrease in inspired oxygen (O_2), and an increase in work of breathing. Transient acidosis and compensatory increases in minute ventilation, work of breathing, and cardiac output result from the inhaled carbon dioxide of 2 to 3 percent (normal, 0.04 percent) [5]. In general, wearing a mask increases the resistance to breathe, resulting in an increase in CO_2 in the mask's dead space. As a result, the wearer would have to exert more effort to breathe, causing discomfort and fatigue [6]. In healthy young subjects, surgical masks decrease cardiopulmonary exercise capacity and ventilation, and wearing masks can affect aerobic exercise capacity [7]. Reduced forced vital ability (FVC), forced expiratory volume in one second (FEV1) and peak expiratory flow (PEF)

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with the surgical mask and even greater impairments with the FFP2/N95 FFR. Wearing the FFP2/N95 FFR resulted in a reduction of maximum oxygen uptake (VO2max) by 13 percent and of ventilation by 23 percent. These results correspond to a rise in airway resistance [8].

The cardiorespiratory functions improve with regular practice of the deep breathing technique. Previous studies have shown that it is well known to reduce the effects of stress, which, in turn, increases an individual's physical and mental health [9]. Incentive spirometer (IS) is intended to help you reach and maintain maximum inspiration. It is easy to use and gives visual feedback to the user. Its use leads to a longer period of successful inspiration, a more regulated flow, and an increased desire to practice [10], also IS helped to improve cardiopulmonary function and functional capacity [11].

Field walking tests are frequently used to assess functional capacity [12]. For a long time, timed walking tests have been used to assess functional exercise performance. 6MWT is among modalities available for objective assessment of functional exercise capacity [13]. The 6MWT is a simple test that objectively assesses a patient's functional capacity [14]. A substantial body of literature has been published on the validity and repeatability of the 6MWT in healthy children and adolescents [15]. It has been shown to correlate well with pulmonary function test (PFT) variables such as forced expiratory volume in one second (FEV1), forced vital ability (FVC), and carbon monoxide diffusion capacity (DLCO) [16].

Subjects and Methods

This study had approval of the Ethics Committee of Faculty of Physical Therapy, Cairo University, NO: P.T.REC/012/002978 Egypt. Participants fully understood the purpose and methods of the study, which complied with the ethical standards. Written informed consent was obtained from each participant.

Included and excluded of participants were according to the following criteria.

Inclusion criteria: Sixty participants, Age ranged from 25-35 years, both genders could participate, working at intensive care units and inpatient clinics. Subjects were assigned into two groups, thirty in each group; the group (A) (22 females & 8 men) the study group who performed deep breathing training using incentive spirometer, while the group (B) (24 females & 6 men) was the control group wearing FFP2/N95 FFR 4-8h/day as the study group, BMI less than 30kg/m^2, Wearing FFP2/N95 FFR 4-8h/day, Active but not involved in any competitive sport. They had been recruited from Intensive Care Unit Department and Inpatient Clinics, Cairo University Hospitals, Egypt. They were received their training program from November 2020 to February 2021.

Exclusion criteria: Smokers' participants, Chronic respiratory diseases history including chronic obstructive pulmonary disease (COPD) and asthma, showing respiratory tract infection symptoms within last two weeks, History of chronic disease that could influence their exercise capacity, Walking Disability due to neurological or musculoskeletal condition, History of cardiac diseases, Pregnant women, Obese (BMI greater than 30kg/m^2), Tachycardia, Hypertension, Sinusitis.

Randomization:

The participants were randomly assigned to group (A) (n=30) and group (B) (n=30) by an independent person who selected blindly from sealed envelopes containing numbers created by a random number generator. The randomization was restricted to permuted blocks to ensure that equal numbers were allocated to each group A and group B. The sequences assigned to the participants were placed in enveloped containing the allocation to each group. The aim and procedures of the study were informed to eligible participants.

Measures and Equipment:

A- Evaluating Equipment:

Six-minute walking distance equipment: Stopwatch, Mechanical lap counter, two small cones, A portable chair that can be moved along the walking path, Worksheets on a clipboard, 30-meter wind-up tape measure.

Body weight and height scale: Weight and height scale to calculate (BMI) for subjects' selection (UGM 200 health scale), Mercury sphygmomanometer & pulse oximeter: KBM blood Pressure Measuring Device Model Number: Sm300 and Yuwell stethoscope, Portable pulse oximeter (Choice Med Oxy Watch): Monitoring of arterial oxygen saturation (SpO2) and heart rate (HR).

B- Training Equipment:

Incentive spirometer [MEDITREAT (M-6026)] - 3 balls incentive spirometer.

Preliminary assessment: Before and after each 6MWT, HR, BP, SPO2, and Borg value were recorded [13]. BHT and BMI was also measured.

Functional capacity test (6MWT): In this study, three measurements result of 6-MWT was taken: 6-MWT Pre training without mask (both groups), 6-MWT Pre training with mask from 2h (both groups) and 6-MWT Post training with mask from 2h after 6 weeks of breathing exercise training using incentive spirometer for the (study group) and without training for the (control group). Incentive spirometry training program for group A: Subjects were instructed to take five sets of five sustained maximal inspirations and expirations twice a day, for a total of 50 maximal inspirations and expirations everyday using an incentive spirometer. Daily for 6 weeks [17].

Statistical analysis: After collecting data, Unpaired *t*-test was conducted for comparison of the age and BMI between groups. Chi squared test was conducted for comparison of sex distribution between groups. The normality of data was assessed using Shapiro-Wilk test and Levene's test was used to assess the equality of variances. Mixed MANOVA was conducted for within and between group effects on mean values of HR, O_2 saturation and 6MWD. Multiple post-hoc tests were conducted using the Bonferroni correction. Mann-Whitney U test was conducted for comparison of median values of MBS between groups and Friedman test and Wilcoxon signed ranks test were conducted for within group comparison of median values of MBS in each group. Unpaired *t*-test was conducted for comparison of BHT between groups. Paired *t*-test was conducted for comparison between pre and Post training BHT in each group. Statistical measures were performed through the statistical package for social studies (SPSS) version 22 for windows. The level of significance for all statistical tests was set at $p<0.05$.

Results

Subject characteristics:

Sixty healthcare workers wearing FFP2/N95 filtering facepiece respirators participated in this stud. Subjects' characteristics presented in Table (1). There was no significant difference in the age, BMI, and sex distribution between groups ($p>0.05$). (Table 1).

Between group comparison:

There was no significant difference between groups in HR, O_2 saturation and 6MWD at Pre training without mask and at Pre training with mask ($p>0.05$). However, there was a significant decrease in resting HR and HR after 6MWT at Post training with mask of study group compared with that of control group ($p<0.001$). There was a significant increase in resting O_2 saturation, O_2 saturation after 6MWT and 6MWD at Post training with mask of study group compared with that of control group ($p<0.01$). (Table 2).

There was a significant decrease in resting MBS and MBS after 6MWT at Post training with mask of study group compared with that of control group ($p<0.001$). (Table 3).

There was a significant increase in the BHT of study group compared with that of control group Post training ($p<0.001$). (Table 4).

Within group comparison:

Study group:

There was a significant increase in resting HR and HR after 6MWT Pre training with mask compared with that Pre training without mask and Post training with mask ($p<0.001$). There was no significant difference in resting HR between Pre training without mask and Post training with mask ($p>0.05$) while there was a significant decrease in HR after 6MWT Post training with mask compared with that Pre training without mask ($p<0.05$).

There was a significant decrease in resting O_2 saturation, O_2 saturation after 6MWT and 6MWD Pre training with mask compared with that Pre training without mask ($p<0.01$). There was a significant increase in resting O_2 saturation, O_2 saturation after 6MWT and 6MWD Post training with mask compared with Pre training without mask ($p<0.05$). There was a significant increase in resting O_2 saturation, O_2 saturation and 6MWD after 6MWT Post training with mask compared with that Pre training with mask ($p<0.001$).

There was a significant increase in resting MBS and MBS after 6MWT Pre training with mask compared with that Pre training without mask and Post training with mask ($p<0.001$). There was a significant increase in resting MBS Post training with mask compared with Pre training without mask ($p<0.01$). There was no significant difference in MBS after 6MWT between Pre training without mask and Post training with mask ($p>0.05$). There was a significant increase in the BHT of the study group Post training compared with that Pre training ($p<0.001$). (Tables 2,3,4).

Control group:

There was a significant increase in resting HR and HR after 6MWT Pre training with mask compared with that Pre training without mask ($p<0.001$). There was a significant increase in resting HR and HR after 6MWT at Post training with mask compared with Pre training without mask ($p < 0.001$). There was no significant difference in resting HR and HR after 6MWT between Pre training with mask and Post training with mask ($p > 0.05$).

There was a significant decrease in resting O_2 saturation and O_2 saturation after 6MWT Pre training with mask compared with that Pre training without mask ($p < 0.05$). There was no significant difference in resting O_2 saturation and O_2 saturation after 6MWT between Pre training without mask and Post training with mask ($p = 0.19$). There was no significant difference in resting O_2 saturation and O_2 saturation after 6MW between Pre training with mask and Post training with mask ($p > 0.05$).

There was a significant increase in resting MBS and MBS after 6MWT Pre training with mask compared with that Pre training without mask ($p = 0.0001$). There was a significant increase in resting MBS and MBS after 6MWT Post training with mask compared with Pre training without mask ($p < 0.001$). There was no significant difference in resting MBS and MBS after 6MWT between Pre training with mask and Post training with mask ($p > 0.05$). There was no significant difference in the BHT between pre and Post training ($p > 0.05$). (Tables 2,3,4).

Table (1): Basic characteristics of participants.

	Group A	Group B	*p*-value
Age, mean ± (SD), years	27.8±2.12	28.03±2.89	0.76
BMI, mean ± (SD), kg/m^2	24.77±2.95	24.74±3.57	0.96
Sex, n (%):			
Females	22 (73%)	24 (80%)	0.54
Males	8 (27%)	6 (20%)	

SD: Standard deviation; *p*-value, level of significance.

Table (2): Mean resting HR, resting O_2 saturation, 6MWD, HR after 6MWT and O_2 saturation after 6MWT Pre training without mask, Pre training with mask and Post training with mask of the study and control groups.

	Pre training without mask	Pre training with mask	Post training with mask	*p*-value		
	Mean ± SD	Mean ± SD	Mean ± SD	Pre training without mask vs Pre training with mask	Pre training without mask vs Post training with mask	Pre training with mask vs Post training with mask
Resting HR (beats/min):						
Study group	81.06 ±6.73	86.07±5.86	79.03±6	0.001	0.44	0.001
Control group	78.87±7.13	84.23±6.85	85.7±9.14	0.001	0.001	0.73
	p=0.22	*p*=0.27	*p*=0.001			
HR after 6MWT (beats/min):						
Study group	100.6±8.31	109.46±8.2	96.36±7.95	0.001	0.02	0.001
Control group	97.33±7.83	108.16±7.57	110.26±9.31	0.001	0.001	0.5
	p=0.12	*p*=0.52	*p*=0.001			
Resting O2 saturation (%):						
Study group	98.23±0.89	97.96±0.88	98.6±0.62	0.01	0.03	0.001
Control group	98.3±0.95	98.06±0.94	98.13±0.82	0.02	0.73	1
	p=0.78	*p*=0.67	*p*=0.01			
O2 saturation after 6MWT (%):						
Study group	97.9±0.99	97.43±0.89	98.46±0.68	0.01	0.03	0.001
Control group	98.16±1.11	97.63±0.96	97.76±0.77	0.006	0.19	1
	p=0.33	*p*=0.4	*p*=0.001			
6MWD (m):						
Study group	451.67±48.97	410.63±47.43	495.73±52.1	0.001	0.001	0.001
Control group	457.43±41.76	410.26±45.04	390.46±51.76	0.001	0.001	0.004
	p=0.62	*p*=0.97	*p*=0.001			

SD: Standard deviation; *p*-value, level of significance.

Table (3): Median values od resting MBS and MBS after 6MWT Pre training without mask, Pre training with mask and Post training with mask of the study and control groups.

	Pre training without mask	Pre training with mask	Post training with mask	*p*-value		
	Mean ± SD	Mean ± SD	Mean ± SD	Pre training without mask vs Pre training with mask	Pre training without mask vs Post training with mask	Pre training with mask vs Post training with mask
Resting MBS:						
Study group	0 (0.5-0)	1 (2-0.5)	0.5 (1-0)	0.001	0.003	0.001
Control group	0 (0.5-0)	1 (2-0.87)	1 (2-1)	0.001	0.001	0.41
	p=0.73	*p*=0.83	*p*=0.001			
MBS after 6MWT:						
Study group	1 (1-0.5)	3 (3-2)	1 (2-0.5)	0.001	0.34	0.001
Control group	0.75 (1-0.5)	3 (4-2)	3 (4-2)	0.0001	0.0001	0.48
	p=0.42	*p*=0.47	*p*=0.001			

SD: Standard deviation; *p*-value, level of significance.

Table (4): Mean BHT pre and Post training of the study and control groups.

	Pre training Mean ± SD	Post training Mean ± SD	*p*-value
BHT (sec):			
Study group	44.86±9.35	54.23±8.14	0.001
Control group	46.3±9.62	45.93±9.97	0.62
	p=0.65	*p*=0.001	

SD: Standard deviation; *p*-value, level of significance.

Discussion

From the results shown above, the current study reflected an improvement of functional capacity among healthcare workers wearing FFP2/N95 filtering facepiece respirators after they performed deep breathing training daily for 6 weeks.

The results of this study supported by Nariyani and Vyas [18], who reported that after deep breathing exercise for 5 minutes (6 breaths/min) in healthy young individuals, the respiratory rate and heart rate both decreased. Oxygen saturation and breath holding time both improved at the same time.

Results also came coincident with Sunitha and Ravi [19] who stated that, Possible explanations for the substantial increase in breath holding time (BHT) in young healthy study were attributed to the fact that in deep breathing, the phase of inhalation is continued with strong voluntary control, so that the lungs are significantly expanded, and the walls of the alveoli are stretched to the greatest extent possible. As a result, the chest continues to expand under cortical control. Stretch receptors are thus trained to withstand increasing amounts of stretching. This allows them to hold their breath for a longer period. The respiratory center becomes acclimatized to withstand higher CO_2 concentrations in the alveoli and blood as the duration of breath holding during deep breathing is gradually increased by practice.

The results of this study are supported by Russo et al., [20] who provided a thorough overview of normal respiratory physiology as well as the documented physiological effects of slow breathing techniques in healthy humans and discovered that Slow breathing at 6 breaths per minute was discovered to be optimal for improving alveolar ventilation and reducing dead space in both groups in terms of increased oxygen saturation and easiness and sustainability of respiratory effort.

Results also came in line with Pal et al., [21], who revealed that regular practice of slow breathing exercise improves autonomic functions. they discovered a significant decrease in basal heart rate in the slow breathing group. The heart rate in normal resting subjects is primarily determined by background vagal activity. As a result, the parasympathetic nervous system controls the basal heart rate. This suggests that practicing slow breathing exercises improves vagal activity.

The results of this study also supported by Yamaguti et al., [22] who stated that an incentive spirometer is a portable device whose primary function is to encourage deep, slow inhalation up to maximal inspiratory capacity by assessing users with a visual stimulus indicating that the desired flow or volume has been achieved and Abid et al.,

[23] found that deep breathing have a direct influence on the respiratory system because they make ventilation easier and allow an individual to inhale the maximum amount of oxygen after a normal expiration. Breathing exercises cause the diaphragm to fully expand and more air to be inhaled in the lungs, resulting in an increase in stamina and flexibility of the respiratory muscles. deep breathing exercises can improve the effectiveness of the intercostals muscle between the ribs cage, which helps to improve breathing, oxygen saturation, lung function, and, ultimately, quality of life. These exercises are simple to learn and can be done anywhere, at any time.

The results of this study came in agreement with results of Amola et al., [24] and Weiner et al., [25], who demonstrated that inspiratory muscle training was effective and beneficial in relieving dyspnea, fatigue, improving pulmonary functions, and increasing submaximal exercise performance.

Moreover, the result of our study came in agreement with Aweto et al., [26] study, which found that IS improved cardiopulmonary function and functional capacity significantly. The IS group had a statistically significant increase in functional capacity (6MWD) after eight weeks of IS, whereas the control group had no statistically significant increase.

The results of this study came in accordance with Illi et al., [27], who conducted a systematic review and meta-analysis to determine the factors that affect the change in endurance performance after respiratory muscle training (RMT) in healthy subjects, found that regardless of the type of RMT or sport, RMT improves endurance exercise performance in healthy individuals.

Although the result of this study disagreed with a study conducted with Sperlich et al., [28], who found no benefits to 6-week high-intensity respiratory muscle training (RMT) in healthy nonsmokers in terms of maximum or submaximal physical performance, cardiorespiratory data, pulmonary parameters, or perception of respiratory effort. Previous research has partially confirmed the findings. Incongruency with other existing literature is also most likely due to methodological diversity in the pre-post-test design, a lack of control groups, as well as dissimilar training protocols.

Conclusion: Based on the scope and findings of this study, it could be concluded that deep breathing training has significant improvement on functional capacity among healthcare workers wearing FFP2/N95 filtering facepiece respirators.

Authors' Contribution:

All authors contributed equally to the whole research processes as conceptualization, data curation, investigation, methodology, writing-review & editing, read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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Declaration of interest:

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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تأثير التنفس العميق على القدرة الوظيفية بين العاملين فى مجال الرعاية الصحية أثناء ارتداء الكمامة ن٩٥

تعرض جائحة فيروس كورونا المستجد العالم للخطر بسبب انتشار قطرات التنفس المصابة بالفيروس. يرتدى العاملون فى مجال الرعاية الصحية الكمامة ن٩٥ لتجنب هذه العدوى، لكن ارتدائها يستدعى عدداً من الآثار الفسيولوجية مع الاستخدام لفترات طويلة.

الهدف من الدراسة: قياس تأثير التنفس العميق على القدرة الوظيفية بين العاملين فى مجال الرعاية الصحية أثناء ارتداء الكمامة ن٩٥.

الأشخاص والطريقة: شارك ستون من العاملين فى مجال الرعاية الصحية (١٤ من الذكور و ٤٦ من الإناث) يرتدون الكمامة ن٩٥ الذين يتراوح أعمارهم من الخمسة وعشرون إلى الخمسة وثلاثون عاماً ويتراوح مؤشر كتلة الجسم لهم أقل من (٣٠ كجم متر / مربع). تم تجميع العينة من العاملين فى وحدات العناية المركزة وعيادات المرضى الداخليين، مستشفيات جامعة القاهرة، وتم تقسيمهم إلى مجموعتين متساويتين فى العدد، حيث أن المجموعة الأولى مكونة من ٢٢ من الإناث و ٨ من الذكور قاموا بتمارين التنفس العميق باستخدام جهاز الحافز التنفسى يومياً لمدة ٦ أسابيع بينما كانت المجموعة الثانية المكونة من ٢٤ من الإناث و٦ من الذكور هى المجموعة الضابطة. وكلا المجموعتين كانوا يرتدون الكمامة لمدة ٤ إلى ٨ ساعات يومياً. وتم الحصول على البيانات المتعلقة بالمشى لمدة ٦ دقائق فى بداية الدراسة وبعد ٦ أسابيع لكلا المجموعتين. والقياسات شملت (معدل ضربات القلب، وتشبع الأكسجين، ومقياس ضيق التنفس ومسافة ست دقائق سيراً على الأقدام) دون ارتداء الكمامة، أثناء ارتداء الكمامة قبل التدريب وأثناء ارتداء الكمامة بعد التدريب لمدة ٦ أسابيع، تم أيضاً قياس وقت حبس النفس قبل بدء ونهاية الدراسة.

وقد أظهرت النتائج ما يلى: أن هناك تحسن ذو دلالة إحصائية فى المجموعة الأولى (أ) والتى قامت بأداء تمارين التنفس العميق لمدة ٦ أسابيع مقارنة بالمجموعة الثانية (ب) حيث أظهرت النتائج أن هناك إنخفاض ذو دلالة إحصائية فى معدل ضربات القلب ومستوى الاجهاد وكذلك وجد زيادة ذو دلالة إحصائية فى نسبة تشبع الأكسجين وفى وقت حبس النفس ومسافة ست دقائق سيراً على الأقدام بعد أداء تمارين التنفس العميق فى مجموعة الدراسة (أ) مقارنة مع المجموعة الضابطة (ب).

وبعد مناقشة هذه النتائج وتحليلها قد تبين أن التدريب على التنفس العميق يحسن من القدرة الوظيفية للعاملين فى مجال الرعاية الصحية أثناء ارتدائهم الكمامة ن٩٥.