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Application of Chest physiotherapy program intervention on children post SARS-CoV2 to enhance vital lung capacity

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Abstract

Human Corona Viruses (HCoV) is of the Nidovirales order and are characterized by positive single-sense RNA. Seven strains have been discovered since 1965. At end of 2019, a new strain was detected, named Severe Acute Respiratory Syndrome coronavirus 2 (SARS-CoV2). The main structure of this virus comprises a genome covered by several layers of proteins. This structure allows the virus to target the human body through the Angiotensin-Converting Enzyme 2 (ACE2), disrupting alveoli cells reducing the O2 rate, leading to lung fibrosis negatively affecting respiratory Vital Capacity (VC). Thus, chest physiotherapy is aproposed therapeutic modality that offers a variety of techniques that greatly benefit the respiratory system. Similarly, nutrition plays an important role in improving the immune system's function, and so is also strongly related to severity and mortality rates in cases of SARS-CoV2.

Aim of the study: This study examines whether a chest physiotherapy program intervention on children post SARS-CoV2 will enhance vital lung capacity.

Methods: The study participants are (34) children post-SARS-CoV2, ranging in age range from 6 to 14 years. The control group comprises 17 children (who are not receiving any intervention), and the experimental group comprises 17 children (who receive aspecific chest physiotherapy program intervention).Randomization between both groups was performed using block randomization, and Spirometry and Chest Expansion Measurement (CEM) are both used as outcome measures. The specific chest physiotherapy program intervention includes (posture drainage, active cycle breath exercise, percussion, passive stretch, myofascial release, diaphragm breath exercise, and home nutrition instructions).

Results: Fifty-eight percent of patients were males (58.8%) with a mean age of 11.18 years (SD=2.42 years) and a mean height of (133.74 cm) and weight of (32.41 Kg), and a mean BMI of 18.04 Kg/m2. There were no significant differences between the control and experimental groups with regard to any of the children's characteristics. The mean baseline of FVC was not significant, as the mean FVC in the total control sample was 2.4 L, while FVC in the experimental group was 2.42 L, P=0.910. A measurement of FVC is a significant group by time interaction p<0.001. The group who received the chest physiotherapy program intervention performed better than the control group in spirometry p<0.001. A comparison between post-intervention and pre-intervention revealed the experimental group attained significant improvement in FVC measured by spirometry at p<0.001, with a mean difference = 0.865L. There was no significant change from baseline in the CEM at baseline p=0.232. The group-by-time interaction for CEM was statistically significant p=0.002. The experimental group performed no better than the control group in terms of CEM p=0.131. However, the group who received the intervention showed significant improvements in the expansion of the chest post-intervention compared to the pre-intervention p= 0.05, with a mean difference = 0.765CM. Meanwhile the control group showed no change in chest expansion at the upper level of CEM after the intervention (p=0.269).

*** Introduction**

The order Nidovirales is part of the International Committee on Taxonomy of Viruses' (ICTV) hierarchal system, distinguished by a positive charge sequence of mono Ribonucleic acid representing a positive strain-sense RNA (+ssRNA) length range between 13-32 (kilo bases). It contains the Cornidoviridae family, which is categorized into four subgenuses, depending on serological and gene properties (Alpha, Beta, Delta, Gamma)

(Russell, et al. 2020). The majority of Human Corona Viruses (HCoV) are Beta coronaviruses (Caponio, et al. 2022).

HCoVs have been known for more than 50 years. In 1965, the scientists Tyrrell and Bynoe identified the B814 strain. Prior to the most recent variant to emerge, there were six different strains known to affect humans: Human Corona Virus E229 (HCoV- E229) (Vaira LA et al, 2020). Human Corona Virus Organ Culture (HCoV-OC43) identified in 1967(Patel, et al. 2020). Corona Virus Hong Kong University 1 (HCoV-HKU1) identified in 2005, and Middle East Respiratory Syndrome Corona virus (MERS-CoV) identified in 2012 (Caponio, et al. 2022). At the end of 2019, the city of Wuhan in China witnessed the appearance of a new HCoV strain, following four cases of respiratory disorders associated with a seafood shop. In February 2020, this strain was officially labelled severe acute respiratory syndrome corona virus 2 (SARS-CoV2), due to its close structural similarity to SARS-CoV1(Almasi, et al. 2023). The exact reasons for this are currently under examination (Politi LS, et al. 2020). Commonly, children post SARS-CoV2 suffer from (symptoms of common cold, tiredness, breathlessness (dyspnea), decreased exercise tolerance, and effects of limited respiratory muscles). These symptoms negatively influence the respiratory function of half of patients, and can present for more than (20) days (Ahmed, et al. 2020). Lung vital capacity (LVC) is the maximum amount of air that can be expired out of the lung after a maximum amount of air has been inspired (Zhang, et al. 2020). A measurement of VC serves to clarify lung volume, and gives information about respiratory muscles strength. It can be determined by Spirometry in the form of Forced Vital Capacity (FVC) (Cheng, et al. 2020).

Relevant to this research, Chest Physiotherapy (CPT) is a therapeutic modality that promotes respiratory system function via an incentive of airway hygiene that allows greater gas reciprocity, raises air rate to lungs through the strength of the respiratory muscles, improves LVC, and helps lower dependency on artificial ventilation (Pumpens, et al. 2022).

A CPT mechanism involves applying an inconsistent pressure force on the thoracic or back region to assist in modulating airway size and changing airflow inside of the lung to support the movement of sputum (Lai C-C, et al. 2020). It can be performed using various techniques, some of which can be used during the hospitalization period, such as (Hyperinflation) (Alyami, et al. 2020). CPT is contraindicated in the acute stage of SARS- CoV2, as it can result in more respiratory droplets, that may rapidly spread the virus. During the first (7) days the virus pathology is characterized by non-productive secretions with a cough (Castells, et al. 2020).

Aim: The aim of the study is to examine whether CPT program intervention on children post SARS-CoV2 will result in enhanced LVC.

*** Null Hypothesis**

children post SARS-COV2 who a receive CPT intervention program will not have enhanced vital capacity.

*** Significance of the study**

1- Try to incentivize more studies about the role of physiotherapy on SARS-CoV2 pandemic.

2- Justify the impact of CPT interventions used with children.

3- Try to explore the effect of CPT on vital capacity specifically among children post SARS-CoV2.

4- Attempt to reduce SARS-CoV2 complications and the mortality rate.

5- Compare the outcomes for children post SARS-CoV2 with/without CPT intervention.

*** Literature Review**

*** Respiratory system**

The respiratory system is considered a foundational system of life. It energizes the human body through the chemical process that occurs when swapping gases. This process is called breathing, and is an exchange between the air in the atmosphere and our body via the respiratory tract. Respiration also occurs within the body among the cells (Roy, B., et al. 2020).

*** Upper respiratory tract**

The nose is considered an initial part of the respiratory system that includes an anterior project called an external nose and a nasal cavity, these are separated by a septum. The external nose is positioned in the center of the midline of the face, it starts at the root from the forehead and moves anterior to the end by the apex or nasal tip. The inferior face external nose includes right and left hollows called nares. The nasal cavity is a bridge between the nose and pharynx via the nasopharynx. The nose serves the respiratory system through a filter and moistens the air as it enters the lung. (Schrading, et al. 2021).

*** Lower respiratory track**

The trachea is located between the lower neck in the middle of the thoracic region (from C7 to T5). It is a half cycle in shape with a mixed structure between cartilage in the lateral and anterior with muscle in the posterior. The inside of the trachea contains a mucus membrane with cilia that are employed to filter air from the lung via a contract of trachea muscles, which create a compressive force that leads to unpredictable opening of the epiglottis with the expulsion of air (Jamaati H., et al. 2020). The two hyaline cartilage branches of the trachea are called the main bronchi, and work with the trachea to spread air into the two lungs. They extend from the sternal angle into the lung in hila. (Nagy, et al. 2021).

*** Physiology of respiratory system**

Mechanisms of breath depend on five phases, starting with ventilation (inhale, exhale) in which phase the air moves in or out of the lungs depending on changes in pressure between alveolar pressure and pleural pressure (transpulmonary pressure), the diameter of the air duct, muscle power lung, and elasticity. These two processes are called inspiration and expiration (Renaud, M., et al. 2021).

Inspiration muscles: The diaphragm contracts during inspiration moving downward before rising up again. The thoracic cage dimension is close to 2 cm in terms of travel. The bilateral thoracic cage dimension is increased via contracting the external intercostal muscles, leading to an elevation in the ribs. This movement is called the buckle handle, and another pump handle movement occurs when the ribs rotate with the sternum in the costovertebral joint, causing movement of the sternum forward. This movement assesses the rising of the anterior-posterior thoracic cage dimension. In the case of high physical exertion or chronic disease, the inspiration muscles are supported by a group of muscles called the accessory inspiratory muscles. (Alghamdi, et al. 2021).

Expiration: This process follows inspiration and involves the expulsion of air out of the lungs. It is a passive process, involving normal respiratory muscles and elastic rebound of the lung, pleural pressure is less negative, and the alveolar pressure is greater than atmospheric pressure (Alghamdi, et al. 2020).

Expiration muscles: The expiration muscles are mainly used during forced expiration. The major muscles are the internal intercostals muscle, which leans between the ribs in the opposite direction to the external intercostal muscle. It works to reduce thoracic cage size, pulling the ribs downward with a lower space between them. The abdominal muscles (rectus abdominal-transverse abdominal-external with internal oblique muscles) these muscles are considered accessory expiration muscles and function through pulling the ribs downward with rising intra-abdominal pressure (Alghamdi, et al. 2020).

The second phase is named gas exchange at the alveoli-pulmonary capillaries. In this case, the oxygen molecule moves from the alveoli to the capillaries and carbon dioxide molecules take the reverse pathway. This swap is affected by the thickness of the surface membrane, surface space, osmosis pressure, clearance of alveolar, lung surfactant, and partial pressure.

*** Lung volumes and capacities**

Lung volume refers to the amount of gas contained within the lung. The first person to measure lung volume was Giovanni Alfonso Borelli in 1681 (in De Motu Animalium) (Ikram, et al. 2021). Currently the lung is measured according to four standard volumes.

1- Tidal Volume (TV): the amount of air in or out of the lung during a quiet breath.

2- Inspiratory Reserve Volume (IRV): the amount of air inspired by maximum inspiration after normal.

3- Expiratory Reserve Volume (ERV): the amount of air that expires by maximum expiration after normal expiration.

4- Residual Volume (RV): the amount of air that remains in the lung after maximum expiration (Alghamdi, et al. 2021).

Inspiratory Capacity (IC) refers to the maximum amount of air that can be inspired to the lung after a normal expiration, it comprises the Tidal Volume added to Inspiratory Reserve Volume (TV+ IRV). Functional Residual Capacity (FRC) is the amount of air that stays in the lung after expiration concludes. It describes the Expiratory Reserve Volume (ERV) plus the Residual Volume (RV). Vital capacity (VC) relates to the amount of air that can be expired from the lung after maximum inspiration which means tidal volume (TV) added to inspiratory reserve volume (IRV) and the Expiratory Reserve Volume (ERV). Total Lung Capacity (TLC): is the maximum amount of air in the lungs after maximum inspiration. It means (TV+IRV+ERV+RV). Spirometry is an effective instrument for measuring lung volume and capacities (Alghamdi, et al. 2021).

*** Methodology**

*** Study Design**

This study is experimental research classified as a Randomized Controlled Trial (RCT) study. It evaluated the effect of a CPT intervention program on children post-SARS-CoV2 using CEM and spirometry results in pre- and post-intervention.

*** Setting and Participants**

(40) children post SARS-CoV2 registered in the Command-and-Control Center of SARS-CoV2 at the Saudi Ministry of Health (MOH) in Abha city, having undergone respiratory evaluation and intervention at the Obstetrics and Gynecology Hospital. The study duration was 12 weeks.

*** Sample Method**

The required sample size was estimated using a repeated measure within-between interaction Analysis of Variance (ANOVA) at an alpha level of 0.05, a power (1-β) of 80%. The number of groups is (2), the number of measurements is also (2) to estimate the differences between LVC in children post SARS-CoV2 undergoing a physiotherapy intervention program and LVC in a children post SARS-CoV2 without a physiotherapy intervention program at a medium effect size (f)= 0.25. The required sample size was (40) participants divided into two groups (**Experimental group** comprising (20) participants who will receive a specific CPT program and a **Control group** of (20) participants who will not receive any treatment intervention) with a mximum15% attrition rate. The study will be performed according to the G.power program 3,1, 9, 4.

The randomization method between the groups was devised using Systematic Sampling. Firstly, we searched the Obstetrics and Gynecology Hospital database in Abha city and chose (40) children post SARS-CoV2 who matched the inclusion criteria. Then, to assign the children to the control or experimental groups, we used the (Block Randomization method) that requires the creation of a block size, including (4) children. There are (6) shapes of blocks size ((E,E,C,C), (C,C,E,E), (E,C,E,C), (C,E,C,E), (C,E,E,C), (E,C,C,E)) C=control, E=experimental, and this study needed 10 block sizes. Finally, randomization was performed between block size shapes.

*** Procedures for evaluation respiratory function**

All children must attend the pulmonary clinic of the Obstetrics and Gynecology Hospital, and personal information will be gathered based on his/her ID (e.g., name, gender, age, height, and weight). LVC will be evaluated using two simple outcome instruments pre- and post-intervention for both groups.

*** Chest Expansion Measurements**

(CEM) is a measure of Chest Expansion (CE) using a tape measure, in the unit of a centimeter (CM). The tape is placed around the circumference of the chest at (2) different levels, upper CE and lower CE. The base principle of CEM is to measure the difference between the ultimate point of air inhaled into the lung and the ultimate point of air exhaled from lung (Jiang, et al. 2020).

*** Results**

This study was conducted with thirty-six children who were checked against the inclusion and exclusion criteria described in the previous chapter. Thirty-four children were found to match the study criteria. Of the 34 children, two were subsequently excluded because they did not complete the treatment plan. The figure below shows the registration and randomization scheme.

Table 1: General characteristics of the patients in control and experiment groups

		Total (N=34)	Control group (N=17)	Experiment group (N=17)	
		Count (N%)	Count (N%)	Count (N%)	P-value
Gender	Male	20 (58.8 %)	10 (58.8%)	10 (58.8 %)	1.000
	Female	14 (41.2 %)	7 (41.2 %)	7 (41.2 %	
Age (Years)	Mean (SD)	11.18 (2.42)	11.00 (2.26)	11.35 (2.62)	0.677
Height (cm)	Mean (SD)	133.74 (10.99)	132.24 (8.39)	135.24 (13.19)	0.435
Weight (Kg)	Mean (SD)	32.41 (10.81)	33.18 (8.68)	31.65 (12.83)	0.687
BMI (Kg/m2)	Mean (SD)	18.04 (4.08)	18.79 (3.5)	17.29 (4.58)	0.289

Seventeen children were assigned to the control group and the remaining seventeen to the experimental group. Fifty eight percent of the patients were males (58.8%) with a mean age of 11.18 years (SD=2.42 year). According to the collected data considering height and weight (133.74 cm and 32.41 Kg), we found the mean BMI for the total sample was 18.04 Kg/m2. According to the results shown in table 1, no significant differences were found between the control and experiment groups with regard to any of the children's characteristics.

Statistical Package for Social Sciences (SPSS 25) software was used for statistical analysis. Descriptive statistics were used for both groups; i.e., standard deviation and 95% confidence interval of (FVC, FEV1, PEF, FCV/FEV1, FEF25, FEF50, FEF75, FEF25-75).

Table 2: Descriptive statistics for respiratory function test for children in control and experiment groups pre-CPT program intervention

Parameter	Group without CPT program intervention (Control group)				Group within CPT program intervention (Experimental group)				
	Mean	Standard deviation	95% confidence interval		Mean	Standard deviation	95% Confidence interval		Comparison of mean
			Upper bound	Lower bound			Upper bound	Lower bound	P- value
FVC	2.40	0.65	2.73	2.06	2.42	0.58	2.72	2.12	0.910
FEV1	2.05	0.51	2.31	1.78	2.06	0.48	2.30	1.81	0.978
FVC/FEV1	86.05	4.98	88.6	83.5	85	3.63	86.9	83.1	0.506
PEF	3.20	0.65	3.53	2.86	3.08	0.75	3.47	2.70	0.641
FEF25	2.86	0.55	3.15	2.57	2.81	0.71	3.16	2.45	0.829
FEF50	2.09	0.45	2.32	1.87	2.07	0.50	2.33	1.82	0.899
FEF75	1.27	0.31	1.43	1.10	1.20	0.25	1.33	1.06	0.488
FEF25-75	2	0.36	2.18	1.81	1.96	0.43	2.18	1.73	0.785

-FVC; Forced Vital Capacity, FEV1: Forced Expiratory Volume in the first second, PEF: Peak expiratory flow, FEF: Forced Expiratory Flow.
- P-value: <0.05 statistically significant

The results shown in Table 2 depict the mean baseline parameters used in this study. The mean FVC in the total control samples were 2.4 L, while FVC in the experimental group was 2.42 L. The FEV for the first second was 2.05 in the control group and 2.06 in the experimental group. The FEV1/FVC was 86.05% in the control group and 85% in the experimental group. Moreover, the FEF was 25% of vital capacity in the control group was 2.86 and 2.81 for the experimental group. 50% of vital capacity was closer to the value of the mean range from 2.07 to 2.09 and 75% of vital capacity was 1.27 in the control group and 1.20 for the experimental group. The closure mean at FEF25-75 for both groups extended from 1.96 to 2. In general, we did not find any significant differences between the control and experimental groups in any of these parameters.

*** Discussion**

When comparing between the control and experimental groups, this study found asignificant difference in improvements to most parameters. The mean improvement in FVC was 0.865 L, P<0.001), in children using the specific CPT program intervention compared with no mean improvement in the control group p=0.987. Moreover, FEV at one second showed an improvement in patients in the experimental group of (0.79L, P<0.001), which is higher than reported in the control group. No significant difference was reported considering FEV1/FVC (P=0.865); however, there was little improvement in the experimental group, although more so than in the control group. Mean improvement in PEF was significantly higher in the experimental group (0.816L/S) compared with a slight improvement in the control group (0.03L/S, P=0.005). In the control group, it was found that FEF25-75 was worse after the study duration at baseline results as well as chest expansion (-0.18cm), which showed significant improvement in patients experiencing the CPT program intervention (0.76 cm, (P=0.05).

SARS-CoV2 entry to the human body occurs at the Receptor-Binding Domain in S1 that recognized the transmembrane protein called angiotensin-converting enzyme 2 (ACE2), where it extended to the plasma membrane of different bodily organs, mostly the lungs, kidney, and heart. It serves as a receptor for the virus, after interacting between (S1/ACE2). Furin starts to work by removing the inactive protein S1, then wakes up (S2) to the fusion of protein-membranes. In this situation ACE2 is blocked and leads to a disturbance in the renin-angiotensin-aldosterone system (RA) (Cohen, 2016).

Normal mechanisms of RAAS are like traffic control, where the regular blood volume balances blood vessel resistance, and sodium reabsorption using two arms (protective arm and classical arm). Thus, in case of a disturbance, it stimulates the liver to release angiotensinogen into the blood and activates the kidney to release rennin enzyme changing angiotensinogen from liver to angiotensin I. Angiotensin (I) enters the respiratory system, with angiotensin converted enzyme I (ACEI) changed ANGI to ANGII working on the AT1 receptor in different body parts to produce a classical arm.

Despite the consequences of SARS-CoV2 being heterogeneous, patients with SARS-CoV2 develop many different alterations in respiratory mechanics. Severe acute respiratory syndrome caused by SARS-CoV2 is reported in several studies as associated with lung damage (acute lung injuries) and damage to many other organs (Engle, 2020). Therefore, it is important to develop a general rehabilitation program which focused on the muscular, respiratory, and cardiovascular systems and is based on the clinical condition of each patient affected. This protocol should be developed based on the next points: being simple, safe and functional (Cooper, 2020). The CPT concept has been used in many different respiratory medical conditions, and has been found to have an impact on improved gas exchange, reverse pathological progression, and a reduction or avoidance of the need for artificial ventilation when provided in the early stages (Khan, 2017).

Recommendations are that rehabilitation should be performed on a case-by-case basis because patients have different clinical characteristics. According to many Cochrane and non - Cochrane reviews, pulmonary rehabilitation programs, including CPT programs have had a positive impact on increasing exercise capacity and PFT parameters in chronic lung conditions, including chronic obstructive pulmonary disease and interstitial ling disease (Sullivan, 1991).

In a previous systematic review conducted by Barman et al., among twenty-one studies designed to assess the efficacy and safety of CPT in patients recovering from SARS-CoV2, those who received CPT improved significantly faster than control groups in exercise capacity (6-MWD) with a mean difference of 45.79 and PFT parameters. This was especially true of forced vital capacity, with a mean difference of 4.38, and diffusion lung capacity for carbon monoxide with a mean difference of 11.78. Moreover, Barman et al. failed to demonstrate significant improvement among patients in an intervention group in quality of life and activities in daily live, with no significant adverse events associated with the intervention (Padmavati, 2016).

*** Conclusion**

This research examined whether a specific CPT program intervention designed for children post SARS-CoV2 would improve recipients LVC. The results of this study showed that application of the specific CPT program intervention in children post- SARS-CoV2 is associated with better outcomes considering functions of lung and chest expansion. This study is important as it contributes to preserving human health and improving quality of life, and sheds light on the role of physiotherapy during the pandemic. The findings reported reveal that physiotherapy contributes to reducing the consequences of SARS-CoV2. Moreover, it offers important information for health service providers who deal with people with SARS-CoV2 suffering from respiratory complications.

*** Recommendations for Future Research**

The results generated from the present study indicate a need for further studies, and opens the prospect of many opportunities for physical therapists and others interested in the medical field to control for the complications of the SARS-CoV2 pandemic, with the continued establishment of protocols and programs to improve patient outcomes. This study considered an important step in treating lung complications post-SARS-CoV2 in children; however, the results should be tested against future studies including a larger sample size to attain additional information and more accurate results. To provide evidence concerning using a specific CPT program intervention post-SARS-CoV2 the study should be applied to different age groups and other respiratory conditions.

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