University of Pécs
Faculty of Health Sciences
Doctoral School of Health Sciences
Head of the Doctoral School: Prof. Dr. József Bódis *MD, Ph.D., DSc.*

The Effect of Preoperative Chest Physiotherapy on Oxygenation and Lung Functions among Open Heart Surgery Patients

Ph.D. Dissertation

Hadel Shahood

PR-2. Cardiovascular Health Science Programme

Programme Leader:

Prof. Dr.Verzár Zsófia MD, Ph.D.

Supervisors:

Prof. Dr. Verzár Zsófia, MD, Ph.D., Doctoral School of Health Sciences
Faculty of Health Sciences, University of Pécs

Dr. habil. Annamária Pakai, Institute of Nursing Sciences, Basic Health Sciences and Health Visiting, Faculty of Health Sciences, University of Pécs

Pécs, 2022

1. Introduction

In spite of the recent developments in the field of preoperative care, postoperative pulmonary complications (PPCs) remain a principal reason for operation-related morbidity and mortality. PPCs are the respiratory system disorders that typically occur during the first postoperative week. These PPCs range from lung atelectasis to respiratory failure (Miskovic and Lumb, 2017).

Patients undergoing cardiac surgery are particularly vulnerable for developing PPCs. During cardiac surgery, several factors act integrally and are implicated in the occurrence of PPCs. These include general anesthesia, mechanical ventilation duration, cardiopulmonary bypass, and the sternotomy incision (Naveed et al., 2017).

The use of cardiopulmonary bypass (CPB) and general anesthesia is a main factor influencing the patient outcome in cardiac surgeries. Post-operative pulmonary complications (PPCs) have been attributed to several factors related to CPB. In part, substance-related factors; blood being exposed to artificial materials, or other factors including variability in body temperature, ischemia-reperfusion of organs, surgical trauma, and endotoxins release, all of these elicit acute inflammatory response (De Backer et al., 2009). As regards anesthesia, they possibly predispose to PPCs through reducing the functional residual capacity and vital capacity and widening the alveolar-arterial oxygen gradient, with subsequent hypoxemia and atelectasis. In fact, the anesthetic drugs are predisposing to PPCs via immunity dysfunction, which subsequently yields to lung injury (Justus et al., 2019).

Preoperative physiotherapy in patients undergoing CABG includes different interventions such as inspiratory muscle training (IMT), respiratory exercises, aerobic exercise, education and counselling. The IMT interventions are addressed to improve oxygen saturation, gas exchange and to reduce postoperative complications while psycho-emotional strategies based on education and counselling seem to contribute to a reduction in preoperative anxiety and depression (Perelló-Díez and Paz-Lourido, 2018).

2. Aims

The overall aim of this study was to assess the importance of applying preoperative chest physiotherapy on patients undergoing open heart surgery.

Specific aims

2.1. Does Preoperative Chest Physiotherapy Affect the Postoperative Pulmonary Complications and Lung Functions in Patients undergoing Elective Cardiac Surgery? A Systematic Review and Meta-Analysis

- We aimed to assess the value of preoperative chest physiotherapy in patients undergoing elective cardiac surgeries through reviewing and meta-analyzing the articles investigating this issue.

2.2. The Effect of Preoperative Chest Physiotherapy on Oxygenation and Lung Functions among Open Heart Surgery Patients: A Randomized Controlled Trial.

- We aimed to investigate the role of preoperative chest physiotherapy on pulmonary functions and the length of staying at the hospital among patients undergoing open heart surgeries.

2.3. The preoperative chest physiotherapy and the amount of oxygen needed after CABG surgery: A randomized controlled trial

- We aimed to assess the relationship between the preoperative chest physiotherapy and participants' characteristics with the average O2 supplementation needed for CABG patients.

2.4. The effect of cold application on pain due to chest tube removal

- We aimed to examine the effect of cold application on pain intensity during chest tube removal

3. Materials and methods

3.1. Main study: Effectiveness of Preoperative Chest Physiotherapy in Patients Undergoing Elective Cardiac Surgery, a Systematic Review and Meta-Analysis

Study design: This is a systematic review and meta-analysis that was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The review was registered in the Research Registry (reviewregistry1278).

Literature Search Strategy: The included studies were those evaluating the preoperative chest physiotherapy value in adult patients who undergo elective cardiac surgery. The search was performed using the electronic resources; the Cochrane Central Register of Controlled Trials, the PubMed central database, and Embase.

Selection Strategy and Criteria: The search was conducted with the restriction limiting results to original articles published from January 2000 to December 2021. The search was performed using the following keywords: “preoperative care” OR “preoperative” OR “preoperational” OR “pre-habilitation” OR “pre-habilitation” OR “before operation” OR “ before surgery” AND “coronary artery disease” OR “CAD” AND “chest” OR “respiratory” OR “lung” OR “pulmonary” AND “physiotherapy” OR “physical therapy” OR “muscular training” OR “muscle training” OR “muscle exercise” OR “muscular exercise” OR “muscle strength” AND “cardiac surgery” OR “open cardiac surgery” OR “open heart surgery” OR “heart surgery” OR “coronary artery bypass graft” OR “coronary artery bypass grafting” OR “CABG” AND “postoperative” OR “following operation” OR “after” OR “after cardiac operation” AND “pulmonary complications” OR “lung complications” OR “lung impairment” OR “respiratory failure” OR “respiratory impairment” OR “impaired respiratory functions” OR “impaired lung functions.” The search was performed by two independent reviewers (the first and second authors). Then articles were matched and screened to ensure eligibility.

Inclusion Criteria: Original articles available in English were included. According to PICO, we included the studies meeting the following criteria: study design—all original articles that included randomized controlled trials or observational studies from 2000 until conducting the analysis (mid-2021), participants—patients undergoing elective cardiac surgery, intervention—preoperative chest physiotherapy, control—patients undergoing elective cardiac surgery without preoperative chest physiotherapy, outcome measures—the effect of

intervention on PPCs and any other effect.

Exclusion Criteria: Animal studies, studies completed prior to the year 2000, commentaries, or general discussion papers whose authors did not present original data were excluded. Studies assessing physiotherapy regimens other than chest physiotherapy and those applying postoperative physiotherapy programs other than the routine therapies were also excluded.

Data Extraction, Data Collection, and Analysis: Each article was read carefully and any relevant data were extracted (including the study setting, design, research questions, sample size, patients' demographic data, medical history, baseline preoperative data, type and details regarding the intervention, description of the intervention; type, time, duration, rate, and the used device, lung function tests, muscle strength, operative events, length of hospital stay, the occurrence of postoperative pulmonary complications, and the study conclusions). The extracted data were registered, tabulated, and analyzed.

Bias: Methodological quality check lists were used as tools for bias risk assessment. The included studies were assessed for potential bias using the Cochrane Collaboration's tool for assessing the risk of bias.

Summary Measures: The primary outcomes were the incidence of postoperative complications and the changes in the lung function parameters, and the secondary outcomes were the surgery duration, the length of stay in the ICU and hospital, and the time of mechanical ventilation.

The assessed lung function parameters were: $FEV1\%_{predicted}$: forced expiratory volume (FEV1%) of the patient divided by the average FEV1%. $FVC\%_{predicted:}$ forced vital capacity (FVC%) of the patient divided by average FVC%. Pi-max: maximum inspiratory pressure. Data about the ongoing RCTs related to the study topic was evaluated and described in the Discussion section.

Statistical Analysis: The retrieved data were presented as mean and standard deviation (SD) for numerical data, and frequency and percentage for categorical data. The meta-analysis and bias assessment were accomplished using the Review Manager software (RevMan version 5.4, the Cochrane Collaboration, London, UK). Dichotomous data were expressed as a risk ratio, with 95% confidence intervals (CIs) to compare intervention and control groups at the study level. For continuous outcomes, the mean differences in effects between the intervention and control groups were computed at the study level and pooled into weighted

mean differences (WMDs).

3.2. Main study: The effect of preoperative chest physiotherapy on oxygenation and lung function in cardiac surgery patients: a randomized controlled study

Study design: This randomized controlled study was carried out in the cardiothoracic surgical department, intensive care unit and preoperative outpatient clinic of Pécs Clinical Centre, Heart Institute, Pécs, Hungary between April 2019 and October 2019. The study was approved by the Regional Ethical Committee of Clinical Research (4114. 316-474/KK15/2011). The study is reported according to CONSORT guidelines19 and the protocol was registered on ClinicalTrials.gov (NCT04665024).

Study population and sample size: Adult patients scheduled for open heart surgery were eligible for the study. Patients with a history of strokes, musculoskeletal disorders, or psychological disorders were excluded. The minimum required sample size, calculated based on an O2 saturation estimated a mean difference of 2% (standard deviation of 1.9), was 20 participants in each group. Informed written consent was obtained from each patient.

Blinding and randomization: Eligible patients were randomly allocated to the intervention or control during their outpatient visit after being scheduled for cardiac surgery. The study was blinded by an independent hospital employee who prepared opaque sealed envelopes containing either number 1 (intervention group) or number 2 (control group). The patient then chose one of the opaque envelopes and was assigned to that group by the same employee.

Interventions: The intervention group underwent breathing exercises preoperatively after weaning from the ventilator, while the other group underwent the postoperative exercise only. Both were monitored for seven days after surgery. In the outpatient clinic, all patients received guidance on surgery and possible postoperative conditions. Patients in the intervention group received a standard educational paper about breathing exercise, written in an easily understandable language with pictures and shapes that describe the preoperative program elements. In the outpatient clinic, experienced registered physical therapy specialists explained how to perform chest physiotherapy exercises, and trained patients on the breathing exercise. The breathing exercises were as follows: patients practiced 10 deep breaths with an incentive spirometer (Respiflo FS, https://www.oxygen-ium.gr/en/proionta/respiflo-fs-kendall-2/), with breath holding during inspiration for 2 to 3 seconds, exhaling slowly in 5 deep breaths by incentive spirometer and coughing while exhaling in another 5 breaths. Patients were instructed to repeat this cycle of breathing exercises for 30 minutes daily with

0.5 to 1 minute breaks. Each patient practiced the exercises for one week before surgery. The physiotherapists trained each patient three times: once on the first day, on the third day and one day prior to surgery. In both groups, patients underwent routine postoperative daily chest physiotherapy until discharge.

Outcome measures: The primary outcome measures were differences between the groups in respiratory function and oxygen saturation. Forced vital capacity (FVC), forced expiratory volume in the first second (FEV1%) and oxygen saturation (SpO2) were measured in the outpatient clinic (first measurement), one day before surgery (second measurement) and for 7 consecutive days after surgery. Spirometry was performed using an Otthon 2.0 - Mobile Handheld Spirometer (https://www.healthcarehk.com/product/thor-2-0-mobile-handheld-spirometer/). The measurement was performed with the patient in a sitting position according to the American Thoracic Society recommendations. The value recorded was the best of three consecutive attempts. Oxygen saturation was measured by pulse oximeter (FaceLake FL400 Pulse Oximeter, https://facelake.com/products/fl400-pulse-oximeter). The secondary outcome measure was the difference in the length of postoperative hospital stay between groups.

Statistical Analysis: Numerical data are presented as mean and standard deviation, while categorical data are presented as number and percentage. The chi-square test was used to compare the categorical data. The t test (unpaired) was used to compare differences in FVC, FEV1 and SPO2. ANOVA was used to compare differences in repeated measures across the pre- and postoperative days using IBM SPSS version 22.0 program. $P \leq .05$ was chosen as the level of statistical significance.

3.3. Sub Study: The preoperative chest physiotherapy and the amount of oxygen needed after CABG surgery: A randomized controlled trial

This is a randomized controlled prospective study that was conducted after the approval of the Regional Ethical Committee of Clinical Research (4114. 316-474/KK15/2011), in the period from April 2019 to October 2019. The study setting was the preoperative outpatient clinic, cardiothoracic surgery department, and the intensive care unit of the University hospital. This study was reported according to CONSORT guidelines (Figure 17) (Schulzet al., 2010) and the protocol was registered on ClinicalTrials.gov (NCT04665024).

Study population and sample size: Eighty adult patients planned for CABG surgery were enrolled in this study. An informed written consent was requested form each patient. Patients

with musculoskeletal diseases, central nervous system, or psychological diseases were excluded. Twelve patients were excluded based on eligibility criteria, then finally, 68 patients were the study population; they were allocated equally into two groups; group 1 (intervention group): received preoperative chest physiotherapy program and group 2 (control group): did not receive the preoperative chest physiotherapy. Both groups underwent the routine care and the postoperative chest physiotherapy. Four patients from the interventional group did not complete the study. Therefore, the interventional group included 30 patients and the control group included 34 patients.

Blinding and randomization: The patients were allocated to their groups blindly and randomly after choosing on of opaque sealed envelopes those were prepared by an independent person who further conducted the patient recruiting to their suitable group.

Interventions: In the outpatient clinic, all patients were informed about surgery and the possible postoperative complications. Patients received a standard educational paper, describing the program elements, written in an easily understandable language with pictures and shapes. Physiotherapists educated the patient's how to perform chest physiotherapy exercises and informed them to practice the exercises daily for one week preoperative. The patients in group one achieved physiotherapists' supervision for the training program three times a week, once at the first day, second in the third day and the last at one day prior to the operation. For both groups, a post-operative daily chest physiotherapy program was introduced in accordance with the hospital's policy until the patient's discharge. The pre and postoperative chest physiotherapy program were the same. Both were carried out according to the previously described protocol and the hospital guidelines.

Outcome measures: The primary outcome measure in this study was the difference between both groups in the average O_2 supplementation needed postoperatively.

Statistical Analysis: All statistical methods were applied using version 22.0 of SPSS software (Beaver, 2014) and $p< 0.05$ was chosen as a level of significance. The descriptive statistics were used in describing the study participants' characteristics. To discover group differences in the baseline data, chi-square test was used for the categorical variables (gender, smoking, previous diseases, and type of surgery) and t-tests was used for the continuous variables (age and BMI). The bivariate correlation was used to investigate the significant associations in the studied variables. Then, regression test was used to find out the predictors of the dependent variable (amount of the oxygen needed). The independent-samples T-test test was used to

compare the average amount of O2 needed for CABG patients between patients who had preoperative chest physiotherapy and those who haven't receive a preoperative chest physiotherapy.

3.4. Sub Study: The effect of cold application on pain due to chest tube removal

Design: A semi experimental design (study - control) was used

Setting: The current study was conducted at the Cardiothoracic Surgical Department and Intensive Care Unit at Pécsi Tudományegyetem Klinikai Központ Szívgyógyászati Klinika, Pecs, Hungary. Between November 2017 July 2018.

Sample: A convenient sample of 100 patients hospitalized in the Cardiothoracic Surgical Department and Intensive Care Unit (ICU) and who had chest tubes for duration at least 24 hours after cardiac-thoracic surgery. Patients were assigned to two groups Study group Applied cold application with soft ice pack gel which comprised 50 patients, Control group without application with ice bag which comprised 50 patients.

Inclusive criteria: 18 years old or older, patients with normal vital signs, able to report pain, 6 hours after the last painkiller administration, for experimental group, have one or two mediastinal, pericardial or pleural tubes. ***Exclusive criteria:*** Mechanical ventilation support, communication problems, psychiatric disorder / Mental disabilities or with communication problems.

Tools of Data Collection: **First Part:** Demographic information was collected from the patients' medical records regarding: gender, age, surgical procedure, and length of surgery, type of chest tube, number of days chest tube was inserted, indication of chest tube insertion, skin temperature, heart rate, systolic, and diastolic blood pressure. **Second Part:** The Visual Analogue Scale is an instrument used to measure the intensity of pain.

Methods: **The study group:** The researcher measured the patients' vital signs and asked the patients to mark the pain they feel with the chest tube in place on the VAS and measured the skin temperature of the area where the ice was applied (**1st measurement**). The researcher placed a single layer of sterile gauze pad around the area of insertion to skin of the chest tubes and placed an ice pack on top of them. The researcher kept the patient in the same position throughout the ice application and stayed with the patient to prevent the slippage of ice pack from its place**.** The researcher terminated the ice application when the skin

temperature reached 13 ^{0}C and give the patient the VAS one more time asking him/her to mark the pain. It took average nine minutes for the skin to reach 13 ^{0}C (**2nd measurement).** Immediately after the CTR by the physicians, the researcher measured the skin temperature of the areas and asked the patient to mark the pain he/she felt during the removal of the chest tube on the VAS (**3rd measurement).** Five to Ten minutes after the CTR, researcher measured the skin temperature of the patient for the last time and recorded both the pain measurements as well as the skin temperatures which terminate the application (**4th measurement**). **The Control Group:** The control group received Analgesics before two hours of chest tube removal. The researcher measured the patients' vital signs and asked the patients to mark the pain they feel with the chest tube in place on the VAS and measured the skin temperature of the area around the chest tube (**1st measurement**). Immediately after the CTR by the physicians, the researcher measured the skin temperature of the areas and asked the patient to mark the pain he/she felt during the removal of the chest tube on the VAS (**2nd measurement**). Five to Ten minutes after the CTR, researcher measured the skin temperature of the patient for the last time and recorded both the pain measurements as well as the skin temperatures (**3rd measurement**)**.**

Data Analysis: In the statistical analysis, for the descriptive analysis, the categorical data were arranged in tables of absolute and relative frequencies. Data with normal distributions were presented as the mean and standard deviation. The Unpaired "t" was used to compare the means of continuous independent variables relative to the groups. In all of the analyses, standard 0.05 p-values and 95% confidence intervals were applied.

4. Results

4.1. Main study: Effectiveness of Preoperative Chest Physiotherapy in Patients Undergoing Elective Cardiac Surgery, a Systematic Review and Meta-Analysis

The search of the electronic resources first yielded a total of 24,106 records. After duplication adjustment, the search provided 1123 results. Ten studies were finally eligible for this systematic review. The included articles were published from 2006 to 2019. The included studies had a total population number of 1458. They were classified into two groups: the interventional (I) group, involving 651 patients, and the control (C) group involving, 807 patients.

Concerning the type of preoperative intervention in the included studies, some used respiratory training protocols, with an incentive spirometer (Shakuri et al., 2015; Fayyaz et al., 2016; Tung

et al., 2012), one study combined incentive spirometer with a threshold loading device (Valkenet et al., 2017), and others used threshold loading devices for chest physiotherapy (Hulzebos 2006a; Hulzebos et al., 2006b; Savci et al., 2011; Vakenet et al., 2013, Sobrinho et al., 2014, Chen et al., 2019). The time frame for preoperative intervention application differed considerably among the included studies, ranging from 5 days to 10weeks. The frequency of performing the interventional program ranged from twice a day (Chen et al., 2019), to three times every two weeks (Tung et al., 2012). The duration of training sessions ranged from 20 (Hulzebos et al., 2006 a; Hulzebos et al., 2006 b; Vakenet et al., 2013; Chen et al., 2019) to 60 min (Tung et al., 2012).

Preoperatively, the control groups underwent the usual management (Hulzebos et al., 2006a; Hulzebos et al., 2006b; Tung et al., 2012; Sobrinho et al., 2014; Valkenet et al., 2013), or usual management in addition to 1 day of chest physiotherapy (Valkenet et al., 2017), limbs and trunk mobilization (Savci et al., 2011), or abdominal breathing training (Chen et al., 2019). Postoperatively, both groups received chest physiotherapy and mobilization schemes Hulzebos et al., 2006 a; Hulzebos et al., 2006b; Tung et al., 2012; Vakenet et al., 2013; Shakuri et al., 2015; Vakenet et al., 2017), or physiotherapy, as required (Sobrinho et al., 2014).

Regarding studies outcomes, the primary outcome was occurrence of postoperative pulmonary complications (PPCs) in the study of Hulzebos et al., 2006 a, Tung et al., 2012, Vakenet et al., 2013, and Chen et al., 2019, the occurrence of adverse events, and patient satisfaction and motivation in the study of Hulzebos et al., 2006 b, the inspiratory muscle strength in the studies of Savci et al., 2011 and Sobrinho et al., 2014, spirometry parameters in the study of Shakuri et al., 2015, postoperative oxygenation in the study of Fayyaz et al., 2016 and quality of life assessment in the study of Vakenet et al., 2017. The postoperative stay length was the secondary outcome in 5 studies (Hulzebos et al., 2006 a; Hulzebos et al., 2006 b; Vakenet et al., 2013; Sobrinho et al., 2014; Chen et al., 2019).

The pooled analysis revealed no significant differences between the interventional and control groups in the surgery time and the ICU duration ($p = 0.84$ and 0.92, respectively), with no heterogeneity in the results ($p = 0.06$ and 0.62, respectively). The meta-analyses revealed significant differences between the interventional and control groups in the FEV1%predicted, FVC% predicted, and Pi-max ($p < 0.05$), favoring the interventional group. The pooled mean differences were 3.7%, 10.17%, and 17.25 cm H2O, respectively.

The PPCs meta-analysis demonstrated that the intervention had a protective effect on the occurrence of PPCs. The pooled risk ratio was shown to be 47%, with a 95%CI of 36–62%. The overlap between a part of the CI that was shown in the pooled estimates reflected the absence of statistical heterogeneity (I2 = 0%, p = 0.73). When examining the conclusions reached by the included studies, there was unanimous agreement on the importance and significance of preoperative chest physiotherapy in patients undergoing elective cardiac surgery.

4.2. Main study: The effect of preoperative chest physiotherapy on oxygenation and lung function in cardiac surgery patients: a randomized controlled study

Of 122 patients enrolled, 12 patients were excluded based on eligibility criteria, leaving 110 patients in the study population; 55 in each group. Nine patients from the intervention group and 1 patient in the control group did not complete the study, leaving 100 patients, 46 in the intervention group and 54 in the control group.

Ages ranged from 40 and 83 years, and males comprised 61% with no statistically significant differences between groups in clinical and demographic characteristics. The most common operation was coronary artery bypass graft (64%). There were no significant differences between groups in respiratory function or O2 saturation in the preoperative outpatient clinic or day 0, while differences in these measures were found for the postoperative 7 day measurements were evident. The postoperative hospital stay length ranged from 7 to 20 days, with statistically significant longer stay in the control group.

4.3. Sub Study: The preoperative chest physiotherapy and the amount of oxygen needed after CABG surgery: A randomized controlled trial

The mean age of participants was 67.7, the average BMI was 28.1. The average amount of O_2 needed over the seven postoperative days was 3.3 Litre/minute. Around 65.6% of the study participants were male patients, 37.5% were smokers. The CABG surgery for 14.1% of the participants was accompanied by either an aortic valve replacement (AVR) or mitral valve replacement (MVR), while majority of the participants (85.9%) had just a CABG surgery. No significant differences were found in the participants' characteristics between both groups.

The results of bivariate correlation showed a significant association between the average amount of O_2 needed and the type of open-heart surgery performed. The CABG patients, whose surgeries were accompanied by either AVR or MVR, needed higher mean postoperative O_2 needed than other patients with just a CABG. Most importantly, a negative

significant correlation was found between the average amount of O_2 needed and chest physiotherapy before the open-heart surgery. Patients who had chest physiotherapy needed lower average amounts of O_2 than patients who hadn't chest physiotherapy.

Linear regression analysis was run to find out the significant model to predict participants' average amount of O_2 needed. The predictors in the model were two: the type of open-heart surgery and chest physiotherapy. These predicting variables all together significantly predicted the average amount of O_2 needed (F (2, 61) = 4.51, p = 0.015, $R^2_{Adjusted}$ = 0.1). Within the model predicting the average amount of O_2 needed, it was found that the significant predictor was the chest physiotherapy (β = -0.28, p <0.05). The results of the independent-samples T-test showed significantly higher average amounts of O_2 needed post CABG surgery in patients who didn't any chest physiotherapy than those who had preoperative chest physiotherapy.

4.4. Sub Study: The effect of cold application on pain due to chest tube removal

One hundred chest tubes were inserted to patients in study group and control group (Study Group: 50 patients using ice pack during chest tube removal, while Control Group: 50 patients without using ice-pack during chest tube removal). This table shows that (30.0%) of patients were female and (70.0%) were male in study group. In control group (84.0%) were male and (16.0%) were female. The mean age was 65.4±7.1 years old in study group and 60.4±7.3 years old in control group. It can be seen that the mean duration of chest tube was 25.6±5.8 hours in study group and 27.8±9.9 hours in control group.

The means of pain intensity scores before chest tube removal were 2.4 ±2.8 for study group, while 2.6 ±2.1 for control group, pain intensity was insignificantly different between the two groups before intervention (P > 0.05). The means of pain intensity scores immediately after removal were 2.3±2.2 for study group, while 7.4±2.0 for control group, pain intensity was significantly different between the two groups immediately after removal (P < 0.01). The means of pain intensity scores after 5-10 min removal were 0.1±0.4 for study group, while 1.1±1.3.0 for control group, pain intensity was significantly different between the two groups 5-10 min after removal (P < 0.01).

5. Discussion

5.1. Main study: Effectiveness of Preoperative Chest Physiotherapy in Patients Undergoing Elective Cardiac Surgery, a Systematic Review and Meta-Analysis

The current study pooled analysis demonstrated that there was no effect of the intervention on the surgery time or the ICU stay duration, while it favorably affected the mechanical ventilation and the length of hospital stay. The association of preoperative chest physiotherapy with shorter hospital stay was also documented in previous studies (Kundra et al., 2010; Melnyk et al., 2011). Nardi et al. (2019) observed that the length of the postoperative hospital stay in the group that had preoperative training was reduced compared to the control group, but without a statistically significant difference. The short hospital stay affords the patients the chance to continue the recovery in their familiar home environment, saving the hospital resources for new patients to receive health care services (Santa-Mina et al., 2014; Gomes-Neto et al., 2016). In contrast with the findings of our study, the previous meta-analyses did not reveal a significant difference between the interventional and control groups in the mechanical ventilation time (Marmelo et al., 2018; Katsura et al., 2015; Hulzebos et al., 2012). However, we can state that the significant difference found in our study could be a quasi-significance, due to the heterogeneity found in the results.

The meta-analysis of this study showed that there was a significant difference between the interventional and control groups in the pulmonary functions, including FEV1% predicted, FVC% predicted, and Pi-max, favoring the interventional group. However, only the FEV1%predicted showed homogenous results. The Pi-max was the most commonly tested lung function parameter in the included studies. Pi-max reflects the inspiratory muscles' functional capacity and has been adopted as a reliable indicator for the weaning from mechanical ventilation in many hospitals (Passarelli et al., 2011). In our meta-analysis, the evidence of the intervention's improving effect was weak. Within the same context, in the meta-analysis conducted by Marmelo et al. (2018), the authors found significant improvement of the Pi-max related to the intervention. On the other hand, Katsura et al. (2015) reported no statistically significant effect in a three-articles meta-analysis, in spite of the fact that a tendency toward a favoring effect was found in all three articles.

The current meta-analysis revealed that intervention proved to be protective against the existence of PPCs. Consistent with our findings, the recent meta-analysis conducted by Odor et al. (2020) disclosed evidence of the prophylactic effect of preoperative physiotherapy against the occurrence of PPCs. Our findings were also congruent with the most recent meta-analysis conducted by Rodrigues et al. (2021), which demonstrated that preoperative chest physiotherapy (breathing interventions) helped to improve postoperative respiratory performance in patients undergoing cardiac surgery. Moreover, the authors concluded that

such interventions reduced PPCs and the length of hospital stay. Other previous studies affirmed the effect of preoperative intervention on PPCs. This was investigated in patients who underwent oncologic thoracic surgeries (Garcia et al., 2016), cardiac Westerdahl et al., 2005; Marmelo et al., 2018), intra-abdominal (Moron et al., 2016), and cardiac and abdominal surgery (Katsura et al., 2015). In these meta-analyses, a total of 31 studies reported decreased PPCs in the interventional group, while only 8 did not find this relationship. The study of Kamarajah et al. (2019) highlighted that pre-habilitation improved rates of morbidity, including for PPCs, and overall complications after both major abdominal and cardiothoracic surgery.

An earlier RCT conducted by Sweity et al. (2021) to assess the effect of preoperative incentive spirometry was compatible with our findings, as the study showed a significant difference between the interventional and control groups in the incidence of postoperative atelectasis, mechanical ventilation duration, and hospital LOS. The median of the amount of arterial blood oxygen and oxygen saturation was significantly improved in the intervention group.

5.2. Main study: The effect of preoperative chest physiotherapy on oxygenation and lung function in cardiac surgery patients: a randomized controlled study

In our study, respiratory physiotherapy was effective in improving lung function and oxygenation of the blood. There were statistically significant differences in measures of respiratory function in the postoperative days, suggesting that preoperative chest physiotherapy expanded the lungs, promoted circulation of air to all pulmonary regions, increased the expiratory volume, improved the movement of the rib cage, and increased vital capacity. An increase in inspiratory muscle strength that occurred in the preoperative period could be responsible for higher functional capacity compared to individuals with weak muscles before surgery (Melly et al., 1967; Valkenet et al., 2011). The findings of our study are consistent with previous studies (Shakuri et al., 2015; Nardi et al., 2017; Snowdon et al., 2014; Westerdahl et al., 2001; Felcar et al., 2008). Nardi et al reported improved physical and respiratory conditions in patients who underwent pre-operative respiratory exercises. These findings have also been confirmed (Melly et al., 1967). A systematic review of these studies showed improvements in functional capacity and decreased PPC in postoperative outcome in cardiac surgery patients (Hulzebos et al., 2012). Moreover, the breathing exercise alone demonstrated efficiency in decreasing PPCs after cardiac surgery (Thybo et al., 2018).

The postoperative hospital stay length in our study ranged from 7 to 20 days, but most did not exceed 12 days of hospital stay (84%). There was a statistically significant difference between groups in the length of hospital stay. Nardi et al also reported shorter lengths of hospital stay in the group treated preoperatively, but without statistical significance.4 The association of breathing exercise with less hospital stay length has also been documented in other studies (Felcar et al., 2008; Kundra et al., 2010; Melnyk et al., 2011; Arthur et al., 2000).

A recent meta-analysis analyzed a total of 12 randomized controlled trials (RCTs) involving the application of respiratory physiotherapy in patients undergoing abdominal and thoracic surgery (Odor et al., 2020). Physiotherapy protocols included both preoperative and postoperative interventions. They concluded that physiotherapy protocols reduced the incidence of PPCs. The largest and best quality RCT that included both preoperative and postoperative physiotherapy exercises revealed a statistically significant difference in developing PPCs postoperatively.

5.3. Sub Study: The preoperative chest physiotherapy and the amount of oxygen needed after CABG surgery: A randomized controlled trial

The results showed some significant associations between the preoperative chest physiotherapy and participants' characteristics with the average O2 supplementation needed for CABG patients. For instance, the average amount of O_2 needed and the type of open-heart surgery performed were associated. In other words, the average amount of O_2 needed postoperatively was higher in patients who had CABG surgeries with either AVR or MVR than other patients with just a CABG. This finding can be explained that those patients with more complicated surgeries will experience more postoperative complications. Moreover, they will need more O2 to recover from these complications. This study finding is incongruent with the findings reported by Chan et al. (2012) who reported that the O2 consumption significantly improved in the patients with CABG plus MVR, while the CABG only group did not show a significant change in the amount of oxygen supplementation. However, in their study, they did not apply preoperative chest physiotherapy, which could be a contributing factor in such controversy (Chan et al., 2012).

In addition, a negative significant relationship was found between the average amount of O_2 needed postoperatively and chest physiotherapy before the CABG. Furthermore, the results

of regression analysis showed that the preoperative chest physiotherapy is a significant predictor for the average amount of O_2 needed post CABG. So, patients who had chest physiotherapy prior to their CABG surgeries needed lower average amounts of O_2than patients who hadn't chest physiotherapy. This result is explainable by the fact the chest physiotherapy is effective in improving the respiratory function and oxygenation.

To the best of our knowledge, no previous studies investigated the effect of preoperative chest physiotherapy on post CABG O2 supplementation. However, within the same context, the most recent meta-analysis conducted by Odor et al. (2020), in which a total of 12 RCTs including 1345 patients, concluded an overall benefit of prophylactic physiotherapy in reducing the development of PPCs (Odor et al., 2020).

Our study found a significant difference in the average amounts of O2 needed post CABG surgery; higher average amounts of O2 needed in patients who didn't any chest physiotherapy than those who had preoperative chest physiotherapy. This result showed that the preoperative chest physiotherapy is essential in enhancing the postoperative oxygenation and recovery of the patient undergoing CABG. Furthermore, poor oxygenation and more O2 supply are expected to be needed for CABG patients who didn't receive a preoperative chest physiotherapy. In consistency with our finding, it was observed that a low rate of postoperative pulmonary complications in the treated groups of patients in comparison with the control group, and this was associated with better SaO2 values (Nardi et al., 2019). These findings were also confirmed by other former studies (Valkenet et al., 2013).

5.4. Sub Study: The effect of cold application on pain due to chest tube removal

In the present investigation, it was observed that the visual analogue score obtained immediately before chest tube removal were mild in study group and was higher than other score gotten for other time points in control group. The VAS scores got immediately after chest tube removal were moderate in control group, while it was mild in study group. The VAS scores got 5-10 minutes after CTR in cold application group produced the most enhancement in pain and was the most effective in relieving the pain association with CTR. The findings of the current study were in agreement with Ertug and Ulker (2012) who conducted a controlled clinical trial, to survey impact of cold application on pain because of chest tube removal. Cold was applied to the study group and the skin temperature and pain intensity was measured 4 times; prior to the application of cold, before removing chest tube, not long after the removal of chest tube, five minutes after the removal of the chest tube. The

visual analogue scale score was measured immediately after the removal of the tube in the experimental group was 3.8, compared with 5.6 in the control group. There was significant difference in pain between the two groups. Similar study conducted by Abdoullah et al. (2013) who agreed with our examination who speaks to correlation between control and study groups as regards to pain intensity measurement observed that the visual analogue score obtained immediately after chest tube removal were mild in study group and was higher than other score obtained for other time points in control group. The VAS scores got 15 minutes after CTR in cold application group produced the most enhancement in pain and was effective in relieving the pain association with CTR. Also, perceived pain was the most intense during CTR (VAS 2) in control group. Also, the study of Demir and Khorshid (2010) who found that cold application reduced patients' intensity of pain due to CTR. On contrast of the study done by Miller et al. (2008) who expressed that the finding of his investigation don't support that pain intensity scores & pain distress scores were not significantly different between the patients who received ice and the one who received tap water. A 10 minutes use of ice brought about subcutaneous tissue cooling and absence of pain in a few investigations. The results of the current study incongruity with study conducted by Sauls (2002) indicate that ice compression was ineffective in relieving the CTR pain. The inconsistency of our results with those of study may be due to some differences in the methodologies of the studies.

The findings of the present examination uncovered that there is a statistically significant decrease in pain intensity at the two measurement points after chest tube removal in the studied group compared to the control group. The findings of the current study are similar to what was reported by Mohamed et al. (2017) who found that, there is a statistically significant decrease in pain intensity at the three measurement points in the studied groups (cold application group, breathing exercise group and cold application and breathing exercise combined group) compared to the control group. The findings of the current investigation are like what was reported by Gorgi et al. (2017) and Mazloum et al (2012) whom examined the effect of cold application combined with a breathing exercises technique on pain intensity during chest tube removal and found that utilizing cold application joined with breathing exercises technique was effective in decreasing pain intensity. However, the study findings are different from what was reported by Mohamed et al. (2017) who found that cold therapy was not very efficient in diminishing pain. The patients in the cold application group reported that pain intensity at 15 and 30 minutes after chest tube removal was like to the control group. The study findings are different from what was reported by Rafii (2010) who examined

utilizing the cold bag and breathing technique to diminish anxiety level at 30 minutes after chest tube removal.

6. Conclusions

6.1. Main study: Effectiveness of Preoperative Chest Physiotherapy in Patients Undergoing Elective Cardiac Surgery, a Systematic Review and Meta-Analysis

The current work concluded that preoperative chest physiotherapy can yield better outcomes in patients undergoing elective cardiac surgery. The meta-analysis demonstrated no significant differences between the interventional and control groups in the surgery time and the ICU duration, but a significant difference in the time of mechanical ventilation and the hospital stay length, favoring the interventional group. A significant difference was shown in the FEV1% predicted, FVC% predicted, and Pi-max, favoring of the interventional group. The most notable significance was shown in the analysis of hospital stay length and the FEV1% predicted. The intervention was proved to be protective against the occurrence of PPCs.

6.2. Main study: The effect of preoperative chest physiotherapy on oxygenation and lung function in cardiac surgery patients: a randomized controlled study

This study concluded that preoperative chest physiotherapy is effective in improving respiratory functions following the open heart surgery.

6.3. Sub Study: The preoperative chest physiotherapy and the amount of oxygen needed after CABG surgery: A randomized controlled trial

Significant associations between the preoperative chest physiotherapy and participants' need for O2 supplementation were concluded. This emphasizes the chest physiotherapy improving effect on the respiratory function and oxygenation.

6.4. Sub Study: The effect of cold application on pain due to chest tube removal

Based on the study findings, it could be concluded that the application of ice pack during CTR appears to have a remarkable effect on pain intensity. Thus it can be used as a non-pharmacological intervention as it provides a safe and effective reduction in pain without side effects.

7: Summary of novel findings and clinical implications

Summary of novel findings

 The preoperative chest physiotherapy intervention favoably affected the time of the mechanical ventillation and the length of the hospital stay.

 Preoperative physiotherapy proved to be protective against the existence of PPCs.

 Preoperative physiotherapy caused significant improvement of the postoperative pulmonary functions.

 Preoperative physiotherapy caused improvement in the postoperative oxygenation of the blood and decreased the need for oxygen supplementation.

 The application of ice pack during chest tube removal appears to have a remarkable effect on pain intensity. Thus it can be used as a non-pharmacological intervention as it provides a safe and effective reduction in pain without side effects.

Clinical implications

 Working to prevent or reduce the incidence of pulmonary complications that are occurring in patients after heart surgery is a major goal among health workers. To achieve this goal, it is recommended to educate patients about how important is to learn the physical therapy techniques. These techniques could help improving the respiratory functions, and promoting the expansion of the lungs, and identifying the high - risk patients for the development of pulmonary complications after surgery. In this vein, physical therapy is highly regarded among the basic treatments and should be offered to the patients in intensive care units.

 This study is confirming the potential performance of the rehabilitation program before cardiac surgery, and recommending its achievement to all patients if possible, in order to make the post-operative period less traumatic, and to facilitate a faster functional recovery.

 Preoperative physical therapy techniques could to reduce the need for oxygen supplementation, which reflects improving the respiratory functions. This further emphasizes the importance for implication preoperative physiotherapy as a routine preoperative preparation for patients undergoing cardiac surgeries.

 This study findings suggest considering the use of cold application as a standardized

technique during chest tube removal to reduce the patient pain and help to diminish procedure associated distress that may affect patient outcome.

Acknowledgements

I am greatly honored to express my thanks and deepest gratitude to my supervisors; Dr. Verzar Zsofia, and Dr. Annamaria Pakai for giving me the honor of working under their supervision, for their continuous encouragement with kind guidance throughout the whole work.

I would like to express my profound gratitude and cordial appreciation to Prof. Dr. József Bódis, Head of the Doctoral School, Faculty of Health Sciences, to Prof. Dr. Endre Sulyok, Secretary of the Doctoral School of Health Sciences, University of Pécs for their creative comprehensive advice and support to overcome the obstacles until this work came to existence.

I deeply thank the colleagues of the doctoral school, primarily To Dr.Viktoria Premusz and Piroska Bakonyi and Petra Szabó for always helping me with my work.

At last I want to tell thanks my family for real appreciated support.

Funding

This research was supported by [Stipendium Hungaricum Scholarship, Doctoral School of Health science, University of Pecs].

List of publications

Related to the dissertation

1. Shahood H, Pakai A, Kiss R, Bory E, Szilagyi N, Sandor A, Verzar Z. Effectiveness of Preoperative Chest Physiotherapy in Patients Undergoing Elective Cardiac Surgery, a Systematic Review and Meta-Analysis. *Medicina*. 2022; 58(7):911.

2. Shahood H, Pakai A, Kiss R, Bory E, Szilagyi N, Sandor A, Verzar Z. The effect of preoperative chest physiotherapy on oxygenation and lung function in cardiac surgery patients: a randomized controlled study. *Ann Saudi Med.* 2022 Jan-Feb;42(1):8-16.

3. Shahood H, Khatatbeh H, Pakai A, Verzar Z. The preoperative chest physiotherapy and the amount of oxygen needed after CABG surgery: A randomized controlled trial (under publication).

4. Shahood H. The Effect of Cold Application On Pain Due To Chest Tube Removal. Paripex - Indian Journal of Research. 2019;8(1).

In other topics

1. Pethőné TI, Ahmann M, Shahood H, Bálint C, Pakai A. Trends in ventilator associated pneumonia in context using closed suction system. Nővér (A Hungarian Journal of Nursing Theory and Practice). 2021;34(1):22-29.

2. Pakai A, Verzar Z, Shahood H, Bálint C, Pethőné TI. Factors for Ventilator Associated Pneumonia - Literature Review (under publication).

3. Pakai A, Khatatbeh H, Shahood H. Attitudes toward COVID-19 pandemic and vaccination: A comparison of health and non-health workers in Hungary (under publication).