Research Article

A Randomized Clinical Trial: Immediate Respiratory Warm-Up Effect on Dynamic Inspiratory Muscle Strength in Cardiac Surgery Candidates

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Abstract
Background: The strength of inspiratory muscles is one of the important factors in preventing postoperative pulmonary complications (POPC). One of the new tools to safely measure the strength of the inspiratory muscles in heart patients, in a dynamic manner and without breath holding, is the use of strength-index (s-index).
Objective: This study aims to evaluate the immediate effects of a respiratory warm-up (RWU) session on the S-index and other lung parameters in cardiac surgery candidates, a subject with limited existing research.

Material & Methods: This study was conducted as a randomized controlled trial. Forty participants scheduled for heart surgeries were randomly assigned to either the study (RWU between two tests) or control (without RWU) groups. RWU consists of threshold loading inspiratory muscle training (TL-IMT) exercises, at 30% of S-index with 30 breathing cycles. Respiratory tests, including S-index, peak inspiratory flow (PIF), and vital capacity (VC), were assessed two times with using an electronic respiratory device (Power Breath K5).
Results: Covariance analysis showed no significant difference in the average and best values of the S-index, PIF, or VC indices, at the second tests, between two groups (P>.05), or in the independent T-test and Mann-Whitney U test for the “rate of changes”, between two tests (P>.05). Finally, intra-group changes, assessed with paired sample T-test between two tests, were mostly non-significant for these indices (P>.05), except for the Best Vital Capacity in the study group (P=.03).
Conclusions: The study results suggest that a respiratory warm-up session does not significantly impact the S-index or other respiratory parameters in cardiac surgery candidates. Thus, incorporating RWU before S-index testing may not be necessary.
Keywords: Dynamic respiratory pressure, Warm-up, Cardiac disease

Introduction

Post-operative pulmonary complications (POPC) are common after heart surgeries such as coronary artery bypass graft surgery (CABG) or valve replacement surgery due to decreased inspiratory muscle strength.(1, 2) One of the most important POPCs after these surgeries are atelectasis and pneumonia, which are caused by the reduction of lung volume and its expansion.(3) In recent years, the role of pulmonary rehabilitation with different methods in improving pulmonary function tests and general parameters such as quality of life and functional capacity in various respiratory diseases has been considered. (4) It has also been seen that performing threshold loading inspiratory muscle training (TL-IMT), in the pre-operative phase can reduce these complications. (5) Like the effect of peripheral limbs in the form of aerobic loading exercises on improving cardiac parameters such as blood pressure (6), TL-IMT can also have favorable effects on improving cardiovascular function and metabolism.(7) In these exercises, after measuring the maximum strength of the inspiratory muscles, the training load is considered based on a percentage of this strength and the amount of load gradually increases, during consecutive days.(5, 8) Measuring breathing pressures through the mouth is one of the common ways to discover this maximum strength of respiratory muscles.(9) which can be done in static manner through the maximal inspiratory pressure (MIP) test or dynamically through the strength index (S-index) test. (10, 11) at measurement the inspiratory muscle strength with S-index, which is performed by an open-valve system, the maximum pressure produced during a deep breath is measured against an applied linear resistance.(12) And since it is done without holding the breath, it can be used with less risks in heart patients.(13) On the other hand, it has been shown that the measurement of inspiratory muscle strength in heart failure patients with both methods (MIP & S-index) has a low difference and a high agreement.(14) However, the voluntary nature of such tests and the role of the patient in performing the maximum possible effort can affect the reproducibility of the test and present challenges in reporting the results.(9) A recent study suggests that respiratory warm up (RWU), particularly with TL-IMT, can improve S-index results and test reliability in healthy people.(15) Also, it seen that RWU can lead to a reduction in the need to repeat the test to achieve a reliable result.(16)

This study aims to investigate the immediate effects of a single TL-IMT warm-up session on S-index results in cardiac surgery candidates, a topic that, to our knowledge, has not been thoroughly explored in the literature.

Material and methods:

Participants:

This study was conducted in the Cardiac Surgery Center of Shahid Modares Hospital in Tehran, between April 2023 to January 2024, and it was approved by the ethics committee of Shahid Beheshti University of Medical Sciences with the IR.SBMU.RETECH.REC.1401.058 code, and the clinical trial code of IRCT20220801055596N1 have been gotten for it.

Forty patients who were admitted to the hospital, for pre-operative preparations were selected according to the study entry criteria and were randomly placed in one of the two control (n=20) or study (n=20) groups. This study was a single-blind clinical trial (participants), and the basic and follow-up evaluations as well as the main intervention, were performed by the main physiotherapist. Also, intervention and assessments were done separately in the examination room, for each patient. An informed consent form was obtained from all the participants and they were given information about how to do the tests.

Inclusion criteria:

1. candidates for coronary graft or valve replacement surgery based on the heart surgeon's diagnosis
2. age between 30 to 80, of both sexes
3. Cardiac functional class 1 and 2, Based on NYHA (New York heart association classification)

Exclusion criteria:

1. prior heart surgeries
2. chronic obstructive pulmonary disease (COPD)
3. Use of medications that affect neuromuscular function before performing tests and exercises
4. if the patients showed any signs of hemodynamic instability during the test or TL-IMT
5. if they did not understand the technique used.

Consort's flow diagram of the participant's follow-up in this study can be seen in Figure 1.

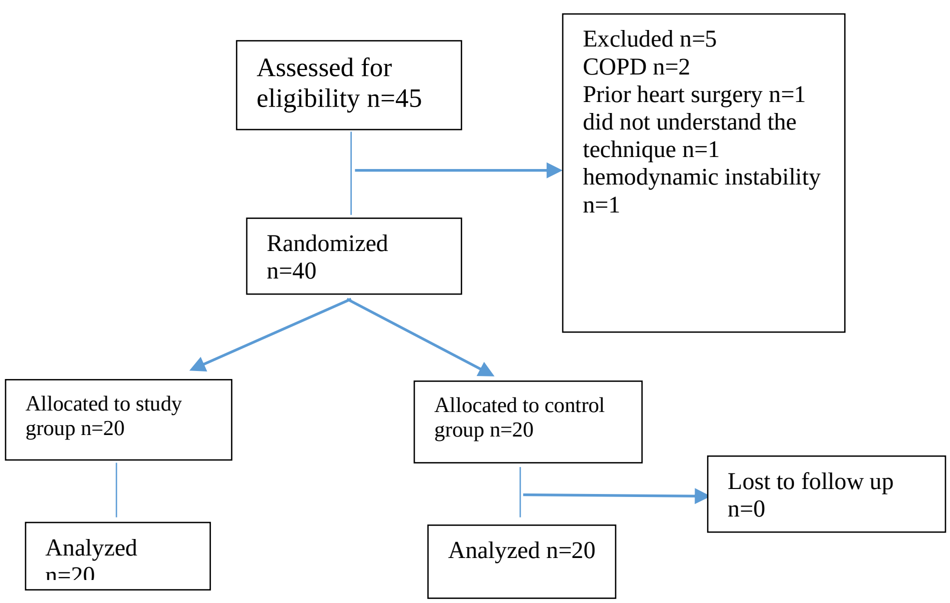

Figure 1: Consort flow diagram

Respiratory tests:
For this test, after the patient was in a comfortable sitting position and had put on the nose clip, he held the mouth piece firmly in front of his mouth and after a deep exhalation, he was asked with a strong verbal message to take a deep breath through the mouth and after 30 seconds repeat the process, until 3 consecutive attempts were recorded and the results were displayed in the Breath link software that was connected to the device (Power-Breath K5, 2010 HaB International Ltd, UK). After the test, the average values of 3 attempts (average), and the best values of 3 attempts (Best) obtained for each of the S-index, peak inspiratory flow (PIF), and vital capacity (VC) indicators were recorded in tables, include of: average S-index (SA), best S-index (SB), Average PIF (PA), best PIF (PB), average VC (VA), and best VC (VB). This tests were repeated two times with 10 to 15 minutes' interval, at the same session.

Respiratory warm-up exercise:
For this purpose, we used TL-IMT exercises with an electronic device (Power Breath K5). Exercises were performed in the form of 30 breathing cycles, in 3 sets of 10, with a minute of rest between each set and 8 seconds of rest between each breathing cycle, for a total of 10 to 15 minutes and at the load of 30% of the S-index. It should be noted that these exercises were performed only in the study group as the warm-up exercises and Before repeating the test at the same session. In the control group, two tests were repeated from each other after the time interval of RWU in the study group (approximately 10 to 15 minutes between two tests), and without any type of exercises or physical activity between two tests.

Statistical Analysis

Descriptive statistics were used to express demographic characteristics. The ANCOVA, independent and paired samples T-tests were used to compare the data of dependent variables, including S-index, PIF and VC (in both forms of average and best values), In two tests. in such a way that, the ANCOVA was used to compare these variables, between two groups at the second test while adjusting them at the first test. Independent sample T-test was used to compare these variables at the first test and also for compare the "rate of changes" of theme, between two groups. Paired sample T-test was used to examine "intra-group changes" of dependent variables, between two tests. The data normality was assessed using the Shapiro-Wilk test, and the statistical analysis was conducted using SPSS 25 software with a significance level of $P<0.05$.

Results:

Table 1 shows the results of the Independent Samples T-test between two groups at baseline time, for demographic characteristics.

Table 1: Comparison of demographic characteristics at baseline time between 2 groups:

Independent variable	**group**	**N**	**Mean**	**Std. Deviation**	**Sig. (2-tailed)**
age	**control**	**20**	**56**	**13**	**0.32**
	experiment	20	19	11	
height	**control**	20	163	10	0.14
	experiment	20	168	10	
weight	**control**	20	70	11	0.47
	experiment	20	75	28	

BMI*	**control**	20	27.22	4.53	0.33
	experiment	20	25.18	8.06	

*BMI (Body Mass Index)

based on the independent T-test results, the two groups are homogeneous, and there is no difference between theme in terms of demographic characteristics.

with the use of independent sample T-test, there was no significant difference between 2 groups at baseline time for dependent variables (P-values with stars in Table 2), but since the differences in the averages were clinically significant, especially in some variables such as the first S-index indices, to compare two groups at the second test, the analysis of covariance (ONCOVA), was used (while adjusted variables at the first test), and finally, no significant level were obtained in any of them (P-values with a cross sign in Table 2).

Table 2: Comparison of mean values for dependent variables at first and second tests between two groups

Dependent variable	Group	N	Mean	Std. Deviation	Sig. (2-tailed)
S-index$_1$(A)	**control**	20	32.37	16.38	0.17*
	experiment	20	39.74	17.04	
S-index$_1$(B)	**control**	20	38.90	21.22	0.19*
	experiment	20	47.96	22.04	
PIF$_1$(A)	**control**	20	1.74	1.02	0.18*
	experiment	20	2.17	1.03	
PIF$_1$(B)	**control**	20	2.11	1.28	0.19*
	experiment	20	2.66	1.31	
VC$_1$(A)	**control**	20	1.69	.80	0.14*
	experiment	20	2.04	.68	
VC$_1$(B)	**control**	20	2.01	.81	0.08*
	experiment	20	2.43	.69	
S-index$_2$(A)	**control**	20	34.64	17.09	0.2 Ɨ
	experiment	20	46.61	21.89	
S-index$_2$(B)	**control**	20	39.67	20.53	0.29 Ɨ
	experiment	20	51.63	23.18	
PIF$_2$(A)	**control**	20	1.87	1.05	0.18 Ɨ
	experiment	20	2.59	1.27	
PIF$_2$(B)	**control**	20	2.18	1.26	0.28 Ɨ
	experiment	20	2.90	1.34	
VC$_2$(A)	**control**	20	1.80	.82	0.91 Ɨ
	experiment	20	2.10	.67	
VC$_2$(B)	**control**	20	2.01	.80	0.25 Ɨ
	experiment	20	2.29	.62	

*Based on independent samples T-test, Ɨ Based on ONCOVA, (A): average values, (B): best values, 1: first test, 2: second test

Also, we used the paired sample T-test to compare within- group changes in each of the control and study groups and between the two tests (table 3).

Table 3: within group changes for dependent variables, from first test to second test:

group	pair	Sig. (2-tailed)
control	**(A)S-index$_{1-2}$**	0.25
	(B)S-index$_{1-2}$	0.7
	(A)PIF$_{1-2}$	0.28
	(B)PIF$_{1-2}$	0.6
	(A)VC$_{1-2}$	0.16
	(B)VC$_{1-2}$	0.97
study	**(A)S-index$_{1-2}$**	0.13
	(B)S-index$_{1-2}$	0.44
	(A)PIF$_{1-2}$	0.11
	(B)PIF$_{1-2}$	0.4
	(A)VC$_{1-2}$	0.65
	(B)VC$_{1-2}$	0.03

(A): average values, (B): best values, 1-2: first test to second test

Based on the results reported above, in none of the mentioned paired variables, except for the best-VC, in the study group, a significant level was not obtained.
Finally, we checked the "rate of changes" between the two groups by independent t-test for normal distributions and Mann-Whitney U test for non-normal distributions, in the Shapiro-Wilk test results. (table 4)

Table 4: “rate of changes” comparison between 2 groups from the first test to the second test:

Dependent variable	group	Mean	Std. Deviation	Shapiro-Wilk test (sig.)	Independent sample T-test / Mann-Whitney U test* (sig)
(A)S-index$_{1-2}$	**control**	2.26	8.72	0.002	0.52*
	experiment	6.87	19.42	0.23	
(B)S-index$_{1-2}$	**control**	.77	9.11	0.17	0.57
	experiment	3.66	21.08	0.33	
(A)PIF$_{1-2}$	**control**	.13	.54	0.002	0.59*
	experiment	.41	1.13	0.47	
(B)PIF$_{1-2}$	**control**	.06	.56	0.31	0.58
	experiment	.23	1.2	0.22	
(A)VC$_{1-2}$	**control**	.10	.33	0.33	0.74
	experiment	.05	.57	0.86	
(B)VC$_{1-2}$	**control**	-.00	.24	0.97	0.09

	experiment	-.14	.2793	0.27	

(A): average values, (B): best values, 1-2: first test to second test, *is the result of Mann- Whitney U test

According to the results mentioned above, a significant level was not obtained for “rate of changes” between two groups.

Discussion:

The main purpose of this study was to investigate the immediate effect of RWU, in the form of TL-IMT, on the S-index test and other respiratory parameters, but the obtained results did not reveal any significant level.

In recent years, some of the few methods have been described to obtain maximum and repeatable results from S-index test. At the present study, we used 3 consecutive attempts, method, to obtain the S-index, and other respiratory parameters. With using the same method in Lee's study, high reproducibility of the results, including S-index, was reported.(17) Also the results of our study are align with the study of Minahan, that RWU in the form of repeated cycling could not change the S-index and MIP indices after using 3 consecutive breathing maneuvers, Although it increased the reproducibility of results in that study.(18) It is possible that higher values can be achieved with more repetitions in the S-index test. Silva observed that the maximum values of the S-index were obtained after the 8th maneuver in healthy participants, (15) The same method has also been used to check the reliability of S-index in heart failure (HF) patients. (14)

Previous contractions in the form of warm-up cause an increase in the amount of muscle oxygen through oxidative phosphorylation mechanisms and its faster increase during the main contraction.(19) Regarding the respiratory muscles, an increase in respiratory strength after respiratory warm-up exercises has been reported due to an increase in the neuromuscular activity of the primary respiratory muscles such as the diaphragm and external intercostal muscles, as well as secondary respiratory muscles such as the sternocleidomastoid and internal intercostal muscles (20, 21).

it has been seen that the higher loads for RWU, that obtained as a product of repetitions in the amount of load can cause a greater increase in MIP values after warm-up in healthy people.(22) So it seems that an important factor in obtaining maximum results from respiratory strength tests is the protocol of warm-up exercises which has been used. For example, in a study due to the use of high (80%) and moderate (40%) intensities of the MIP in the RWU exercises, compared to the placebo type (15 % of MIP), a greater increase in the electromyography activity of the secondary respiratory muscles and the maximal respiratory strength was obtained.(21) Similar to the same results were obtained in another study with using 15% loads as a placebo and 40% loads as a RWU, which the pulmonary function and maximal inspiratory strength tests, were improved with greater loads .(23)

This is while, we face limitations in applying load in cardiac patients. In various studies that have investigated the effect of TL-IMT exercises in the hospitalization phase before or immediately after heart surgeries, the amount of loads used was in the range of 15 to 40% of MIP, based on the conditions of the patients. (24-26) According to the available studies, that the use of respiratory loads in the range of 40% of MIP is considered as a moderate load, (21, 27) it can be hypothesized that the use of a load of 30% of S-index in the present study, has been in the low range of the minimum load necessary to create the warm up effect in the respiratory muscles.

Also it has been seen that people with lower initial strength, have more physiological potential to increase the strength of inspiratory muscles. (28) as can be seen in the present study (Table 2), the maximum and average dynamic power of the inspiratory muscles in the study group and in the baseline time was more than the control group, although this difference was not statistically

significant between the two groups, but it can be another hypothesis for the non-significance of the results in the RWU group.
Finally the S-index test, is performed on the total lung volume and without isometric resistance (without breath holding), (12) so another hypothesis is that this test is more similar to the person's natural breathing and can reduce the learning effect (LE) through the RWU exercises on it, and increase the stability of results. For example it was seen that the LE on a test such as MIP is greater than the SNIP(sniff nasal inspiratory pressure) test, which the recent test is like normal breathing and is used daily. (29)

Limitations:
One of the limitations of this study was that, due to the fact that so far, the exact amount of the maximum load and the number of repetitions of the respiratory cycle to create a warm-up and at the same time prevent fatigue in the respiratory muscles, using the TL-IMT exercises in a study not reported, we used a percentage of the dynamic strength of inspiratory muscles (30% of S-index) to determine the load in TL-IMT exercises, as well as 30 breathing cycles to create warm-up in these muscles, which this method according to previous studies in These exercises were performed during the hospitalization period of cardiac surgery patients. Therefore, it is suggested to conduct studies in the future with the aim of determining the threshold of the appropriate protocol of TL-IMT exercises to create a warm-up in the respiratory muscles without causing fatigue.

Conclusion:
According to the results of the present study, it seems that there is no need to perform a RWU to obtain the best values for the S-index, and other respiratory parameters mentioned in this study.

Conflicts of Interest:
The authors declare no conflicts of interest.

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Authors contributions:
Conceptualization: Sedigheh Sadat Naimi, Bahareh Mehregan Far, seyed Ahmad Raeissadat; Methodology: Bahareh Mehregan Far, Mohsen Abedi, Mahmod Beheshti Monfared; Investigation: Bahareh Mehregan Far, Sedigheh Sadat Naimi; Data Analysis: Alireza Akbarzadeh Baghban; Writing-original draft: Bahareh Mehregan Far, Sedigheh Sadat Naimi, Mohsen Abedi, Writing-review, and editing: Bahareh Mehregan Far, Sedigheh Sadat Naimi, Mohsen Abedi

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