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Immediate Respiratory Warm-Up Effect on Dynamic Inspiratory Muscle Strength in Cardiac Surgery Candidates

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ABSTRACT

Introduction: The strength of inspiratory muscles is one of the essential factors in preventing postoperative pulmonary complications (POPC). One of the new tools to safely measure the strength of the inspiratory muscles in heart patients dynamically and without breath holding is the strength-index (S-index). 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.

Materials and 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 the S-index with 30 breathing cycles. Respiratory tests, including S-index, peak inspiratory flow (PIF) and vital capacity (VC), were assessed twice using an electronic respiratory device.

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>0.05), or in the independent t test and Mann-Whitney U test for the "rate of changes," between two tests (P>0.05). Finally, intra-group changes, assessed with paired sample t test between two tests, were mostly non-significant for these indices (P>0.05), except for the best VC in the study group (P=0.03).

Conclusion: The study results suggest that a RWU session does not significantly impact cardiac surgery candidates' S-index or other respiratory parameters. Thus, incorporating RWU before S-index testing may not be necessary.

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Introduction

Postoperative pulmonary complications (POPC) are common after heart surgeries such as coronary artery bypass graft surgery (CABG) or valve replacement surgery due to diminished inspiratory muscle strength [1, 2]. After these surgeries, one of the most important POPCs is 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 preoperative 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 mouth is one of the common ways to estimate the maximum strength of respiratory muscles [9], which can be done statically through the maximal inspiratory pressure (MIP) test or dynamically through the strength index (S-index) test [10, 11].

Regarding measuring 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]. Since it is done without holding the breath, it can be used with fewer 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 respiratory warm-up (RWU), particularly with TL-IMT, can improve S-index results and test reliability in healthy people [15]. Also, RWU can reduce 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.

Materials and Methods

Study participants

This study was conducted in the Cardiac Surgery Center of Shahid Modares Hospital in Tehran City, Iran, between April 2023 and January 2024. Forty patients admitted to the hospital for preoperative 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 baseline and follow-up evaluations, as well as the main intervention, were performed by the main physiotherapist. Intervention and assessments were also 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.

The inclusion criteria were as follows: Candidates for coronary graft or valve replacement surgery based on the heart surgeon's diagnosis, 30 to 80 years old and of both sexes and cardiac functional class 1 and 2, based on New York heart association classification (NYHA).

The exclusion criteria were as follows: Having prior heart surgeries, suffering chronic obstructive pulmonary disease (COPD), using medications that affect neuromuscular function before performing tests and exercises, showing any signs of hemodynamic instability during the test or TL-IMT, and not understanding the technique.

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

Respiratory tests

For this test, after the patient was in a comfortable sitting position and had put on the nose clip, he held the mouthpiece firmly in front of his mouth. 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

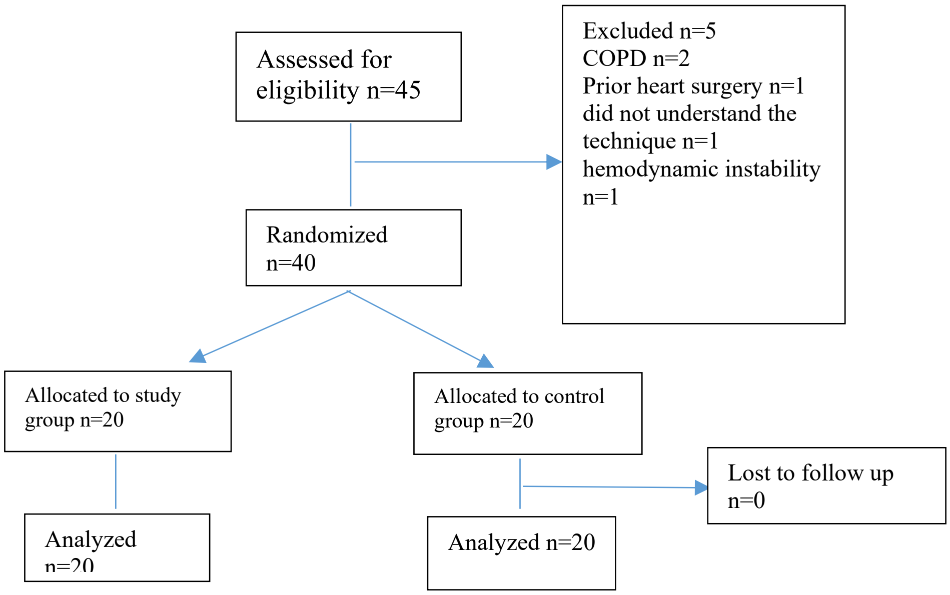

Figure 1. CONSORT flow diagram

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for each of the S-index, peak inspiratory flow (PIF) and vital capacity (VC) indicators were recorded in tables as average S-index (SA), best S-index (SB), Average PIF (PA), best PIF (PB), average VC (VA) and best VC (VB). These tests were repeated twice in the same session at 10 to 15 minute interval.

RWU 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 in the same session. In the control group, two tests were repeated after the time interval of RWU in the study group (approximately 10 to 15 minutes between the two tests) and without any exercises or physical activity between the two tests.

Statistical analysis

Descriptive statistics were used to express demographic characteristics. The analysis of covariance (ANCOVA), the 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. The ANCOVA was used to compare these variables between two groups at the second test while adjusting them at the first. The independent sample t test was used to compare these variables at the first test and the "rate of changes" of theme between the 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 software, version 25 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. Based on the independent t-test results, the two groups are homogeneous and there is no difference between themes in terms of demographic characteristics.

The independent sample t-test showed no significant difference between the two groups at baseline time for dependent variables (P with [*] in Table 2). However, since the differences in the averages were clinically significant, especially in some variables, such as the first S-index indices, ANCOVA was used to compare two groups on the second test (while adjusted variables on the first test). Finally, no significant level was obtained (P with [†] in Table 2).

Also, we used the paired samples t-test to compare within-group changes in the control and study groups and between the two tests (Table 3).

Table 1. Comparing demographic characteristics at baseline between 2 groups (n=20)

Variables	Group	Mean±SD	Sig. (2-tailed)
Age (y)	Control	56±13	0.32
	Experiment	19±11	
Height (cm)	Control	163±10	0.14
	Experiment	168±10	
Weight (kg)	Control	70±11	0.47
	Experiment	75±28	
Body mass index (kg/m²)	Control	27.22±4.53	0.33
	Experiment	25.18±8.06	

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Based on the results reported above, a significant change was obtained in none of the mentioned paired variables, except for the best-VC, in the study group.

Finally, in the Shapiro-Wilk test results, we checked the "rate of changes" between the two groups by an independent t-test for normal distributions and a Mann-Whitney U test for non-normal distributions (Table 4).

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 the S-index test. In the present study, we used 3 consecutive attempts to obtain the S-index and other respiratory parameters. 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 align with the study of Minahan, which showed that RWU in the form of repeated cycling could not change the S-index and MIP indices after using 3 consecutive breathing maneuvers. However, it increased the reproducibility of results in that study [18]. However, 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 eighth maneuver in healthy participants [15]. The same method has also been used to check the reliability of the S-index in heart failure (HF) patients [14].

Previous contractions in the form of warm-up increase muscle oxygen through oxidative phosphorylation mechanisms, and it increases faster during the main contraction [19]. Regarding the respiratory muscles, an increase in respiratory strength after RWU 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, 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 results were obtained in another study with 15% loads as a placebo and 40% loads as an RWU, which improved the pulmonary function and maximal inspiratory strength tests with greater loads [23].

This is why we face limitations when applying load in cardiac patients. In various studies investigating the effect of TL-IMT exercises in the hospitalization phase before or immediately after heart surgeries, the loads used were 15% to 40% of MIP, based on the patients' conditions [24-26]. According to the available studies, the use of respiratory loads in the range of 40% of MIP

Table 2. Comparing mean values for dependent variables between two groups at the first and second tests (n=20)

Variable	Group	Mean±SD	Sig. (2-tailed)
S-index$_1$ (A)	Control	32.37±16.38	0.17*
	Experiment	39.74±17.04	
S-index$_1$ (B)	Control	38.90±21.22	0.19*
	Experiment	47.96±22.04	
PIF$_1$ (A)	Control	1.74±1.02	0.18*
	Experiment	2.17±1.03	
PIF$_1$ (B)	Control	2.11±1.28	0.19*
	Experiment	2.66±1.31	
VC$_1$ (A)	Control	1.69±0.80	0.14*
	Experiment	2.04±0.68	
VC$_1$ (B)	Control	2.01±0.81	0.08*
	Experiment	2.43±0.69	
S-index$_2$ (A)	Control	34.64±17.09	0.2ᵻ
	Experiment	46.61±21.89	
S-index$_2$ (B)	Control	39.67±20.53	0.29ᵻ
	Experiment	51.63±23.18	
PIF$_2$ (A)	Control	1.87±1.05	0.18ᵻ
	Experiment	2.59±1.27	
PIF$_2$ (B)	Control	2.18±1.26	0.28ᵻ
	Experiment	2.90±1.34	
VC$_2$ (A)	Control	1.80±0.82	0.91ᵻ
	Experiment	2.10±0.67	
VC$_2$ (B)	Control	2.01±0.80	0.25ᵻ
	Experiment	2.29±0.62	

*Based on independent samples t-test, ᵻBased on ANCOVA.

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Note: A): Average values, B): Best values, 1: First test, 2: Second test.

is considered a moderate load [21, 27]; it can be hypothesized that the use of a load of 30% of the 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 seen in the present study (Table 2), the maximum and average dynamic power of the inspiratory muscles in the study group at the baseline time was more than that of the control group. However, 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.

Table 3. Within-group changes for dependent variables from the first test to the 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

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

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Table 4. Rate of changes comparison between two groups from the first test to the second test

Variables		Group	Mean±SD	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	0.77±9.11	0.17	0.57
		Experiment	3.66±21.08	0.33	
A	PIF$_{1-2}$	Control	0.13±0.54	0.002	0.59*
		Experiment	0.41±1.13	0.47	
B	PIF$_{1-2}$	Control	0.06±0.56	0.31	0.58
		Experiment	0.23±1.2	0.22	
A	VC$_{1-2}$	Control	0.10±0.33	0.33	0.74
		Experiment	0.05±0.57	0.86	
B	VC$_{1-2}$	Control	-0.00±0.24	0.97	0.09
		Experiment	-0.14±0.27	0.27	

Note: A): Average values, B): Best values, 1-2: First test to second test.

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*The result of the Mann-Whitney U test, according to the above results, a significant level was not obtained for the "rate of changes" between the two groups.

Finally, the S-index test was performed on the total lung volume 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 through the RWU exercises and increase the stability of the results. For example, it was seen that the learning effect on a test such as MIP is greater than the SNIP (sniff nasal inspiratory pressure) test, a recent test that is like normal breathing and is used daily [29].

Conclusion

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

Study limitations

Because 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 was not reported in any study using the TL-IMT exercises, we used a percentage of the dynamic strength of inspiratory muscles (30% of S-index) to determine the load in TL-IMT exercises. Also, we used 30 breathing cycles to create warm-up in these muscles, which this method according to previous studies. These exercises were performed during the hospitalization period of cardiac surgery patients. Therefore, it is suggested that further studies be conducted to determine the threshold of the appropriate protocol of TL-IMT exercises to create a warm-up in the respiratory muscles without causing fatigue.

Ethical Considerations

Compliance with ethical guidelines

The study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (Code: IR.SBMU.RETECH.REC.1401.058 code)and by the Clinical Trial (Code: IRCT20220801055596N1).

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Authors' contributions

Conceptualization: Sedigheh Sadat Naimi, Bahareh Mehregan Far and Seyed Ahmad Raeissadat; Methodology: Bahareh Mehregan Far, Mohsen Abedi and Mahmoud Beheshti Monfared; Investigation: Bahareh Mehregan Far and Sedigheh Sadat Naimi; Data analysis: Alireza Akbarzadeh Baghban; Writing the original draft, review and editing: Bahareh Mehregan Far, Sedigheh Sadat Naimi and Mohsen Abedi.

Conflict of interest

The authors declared no conflict of interest.

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