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# Effect of inspiratory muscle training with threshold valve on the functional capacity of physically active women who are older than 60 years of age

Efecto del entrenamiento de la musculatura inspiratoria con válvula umbral sobre la capacidad funcional en mujeres físicamente activas mayores de 60 años

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## Resumen

**Introducción:** Los cambios fisiológicos asociados al envejecimiento generan una serie de modificaciones funcionales, destacando una disminución en la capacidad respiratoria. En este sentido, una estrategia alternativa para mejorar tal condición podría ser el entrenamiento de la musculatura inspiratoria (EMI). **Objetivo:** Analizar el efecto del EMI con válvula umbral, sobre la capacidad funcional en mujeres físicamente activas mayores de 60 años. **Materiales y métodos:** Se realizó un EMI con válvula umbral durante 4 semanas, sobre un grupo experimental (GE; n:10), contrastado con un grupo control (GC; n:5). Se valoraron las siguientes variables hemodinámicas y antropométricas: peso, talla, índice de masa corporal (IMC), lactato, doble producto y capacidad funcional, analizando los cambios pre y post entrenamiento. **Resultados:** En el grupo GE disminuye post intervención la concentración de lactato y la escala de percepción del esfuerzo; 3,16±0,51 a 2,5±0,39 y 5,56 ± 1,81 a 4±2, respectivamente. En el mismo grupo se incrementan los valores de presión inspiratoria máxima (Pimáx) post intervención; 42,11±14,57 a 60,44±14,47. El GC no presentó cambios en sus valores. **Conclusiones:** No se evidencian cambios favorables en los metros recorridos post intervención, sin embargo, el EMI mostró una disminución sobre la concentración de lactato post ejercicio, lo que podría identificar un retraso en la aparición de la fatiga.

**Palabras clave:** Presión inspiratoria máxima; entrenamiento del músculo respiratorio; lactato; tests función respiratoria; adulto mayor (Fuente: DeCS, Bireme).

## Abstract

**Introduction:** Physiological changes associated with aging generate a series of functional modifications, mainly a decrease in respiratory capacity. In this regard, an alternative strategy to improve such a condition could be inspiratory muscle training (IMT). **Objective:** To analyze the effect of IMT with threshold valve on the functional capacity of physically active women who are older than 60 years of age. **Materials and methods:** IMT with threshold valve was carried out over a period of 4 weeks, comparing data from the experimental group (GE; n:10) to the control group (GC; n:5). The following hemodynamic and anthropometric variables were assessed: weight, height, body mass index (BMI), lactate, double product (DP) and functional capacity. Pre and post training changes were evaluated. **Results:** The GE group showed a decrease in both post-intervention lactate concentration (from 3.16±0.51 to 2.5±0.39) and effort perception scale (from 5.56 ± 1.81 to 4±2). On the other hand, this group experienced a post-intervention increase in maximal inspiratory pressure (MIP) from 42.11±14.57 to 60.44±14.47. The GC group did not present changes in its values. **Conclusions:** Although no evidence was found regarding favorable changes in the walked distance post-intervention, IMT induced a reduction in post-exercise lactate concentration, which could indicate a delay of onset of fatigue.

**Key words:** Maximal inspiratory pressure; respiratory muscle training; lactate; respiratory function tests; elderly (Source: DeCS, Bireme).

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## Introduction

The aging of populations is a worldwide reality in which nearly 7% of the world population is older than 65 years, a proportion that is even higher in developed countries (15%)[1]. In Chile, the number of seniors surpassed 15% of the total population in 2012. It is expected that this community will continue to grow until reaching 20% in 2020, which will exceed the number of citizens aged 15 years or below[2]. Within this context, the physiological changes associated with aging deteriorate the functional capacity (FC) of older adults (OA), which in turn leads to a sedentary lifestyle. The progressive weakening of their FC is exacerbated by the fact that only 7% of OA carry out physical activity of low intensity[3].

The regular practice of physical activity has an impact on the appropriate control of cardiometabolic and musculoskeletal diseases[4]. The type of physical exercises practiced by older adults should be oriented to encourage their active social participation, incorporating aerobic exercises of low or medium intensity and muscular strengthening[5]. Consequently, an alternative training method has started to be applied to seniors, which has been previously used by athletes and people suffering from cardiorespiratory diseases. This method, known as *inspiratory muscle training (IMT)*, is based on the use of a multipurpose inhalator that induces resistance to the inspiratory air flow[6].

The objective of this study is to analyze the effect of inspiratory muscle training with a threshold valve on the functional capacity of physically active women who are older than 60 years of age and belong to the Young Men's Christian Association of Chile.

## Materials and methods

We studied 15 OA healthy women, with no morbid history diagnosed or reported, who did not present any injury or disease that prevented them from walking. The experimental group was composed of 10 women (EG, age = 74.22 ± 7.07 years old), whereas the control group had 5 women (CG, age = 74.8 ± 7.98 years old) (Table 1). Sampling was carried out for convenience, generating an unequal distribution associated with the number of participants that met the entry criteria. The individuals participated in an exercise and health program at the Adapted Exercise Center (AEC). This program consisted in performing continuous aerobic, flexibility, coordination, strength, and lumbo-pelvic stabilization exercises supervised by physical educators, kinesiologists and medical specialists. All participants were physically active (≥150 minutes of moderate to vigorous physical activity per week). The exclusion criteria were: uncontrolled blood pressure above 130/85 mmHg and/or any musculoskeletal pathology (either metabolic or systemic, acute or chronic) that prevented them from carrying out the exercise protocol.

**Table 1.** Anthropometric characteristics of the participants

| Variable | Control group | Experimental group |
|---|---|---|
| Age (years) | 74.8 ± 7.98 | 74.22 ± 7.07 |
| Weight (kg) | 69.8 ± 6.91 | 70.44 ± 9.99 |
| Height (m) | 160.2 ± 5.07 | 157.4 ± 7.04 |
| BMI (kg/m$^2$) | 27.24 ± 2.90 | 28.3 ± 2.52 |

### Procedure

This study was developed at the Exercise Physiology Laboratory of Santo Tomás University, Santiago campus, in collaboration with YMCA. The subjects were distributed into two groups by simple randomization. 100% of the subjects stayed in the AEC exercise program for 4 weeks (5 times per week). While the CG group carried out its usual exercise program, the EG group incorporated the inspiratory muscular training to the same routine (Figure 1). For safety and control purposes, we assessed heart rate, blood pressure and effort perception through the Borg scale. In addition, we monitored proper hydration. Participants were not allowed to eat for two hours prior to assessment.

### Maximal Inspiratory Pressure (MIP)

Maximal inspiratory pressure (MIP) was measured in the morning, two days before and two days after the four-week intervention. After a resting period of 10 minutes, MIP was measured using a *CareFusion* equipment (*Micro RMP* model, USA) that registers maximal inspiratory pressures and evaluates the strength of respiratory muscles in order to adjust the *Threshold* valve to the desired percentage. This test was performed with: (i) the patient seated, (ii) a noseband to cause nasal airway obstruction, (iii) the thorax and neck in an upright position, and (iv) both feet resting on the floor. Subsequently, a filter nozzle was placed so that patients could externally seal it with their lips. Then, they were asked to make a gentle and complete exhalation followed by a fast and strong inhalation for two seconds. Three reproducible attempts were recorded (showing less than 10% difference between the two highest values). In order to avoid not reaching the expected values, eight attempts were recorded with pauses of 1 minute between each one[7].

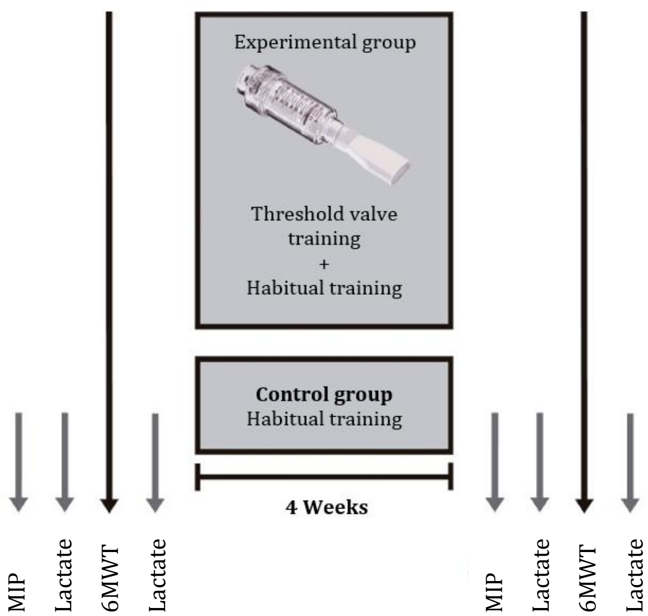


**Figure 1.** Experimental Design.

### Lactacidemia

Blood lactate concentration was measured before and after the 6-minute walk test (6MWT), both at the beginning and the end of the 4-week intervention period with the *Threshold* valve. The values at resting condition were recorded with the subject first at a supine decubitus position during 10 minutes. Then, patients were seated in order to puncture their right ring fingers and obtain a capillary blood sample to be analyzed with *Accutrend Plus*® (Roche, Switzerland). This procedure was repeated immediately after the 6MWT.

### 6-minute walk test (6MWT)

The aerobic functional capacity was assessed through 6MWT, a submaximal test used to record the distance covered during a 6-minute walk on a delimited flat surface every 30 meters. Blood pressure, heart rate, oxygen saturation, Borg scale and double product were measured before and after the test. Prior to this activity, it was verified that participants had not engaged in any exhausting physical exercise. All subjects had to remain at rest for at least 15 minutes before performing the 6MWT. Finally, they were not allowed to consume any heart rate stimulator during the days that the test was performed[8].

### Inspiratory Muscle Training (IMT)

Inspiratory muscle training was achieved using a threshold valve. The EG group performed 30 respiratory efforts at 60% of MIP within approximately 10 – 15 minutes and with the following frequencies: once a day, five times a week (participants chose the days they wanted to perform the exercises), for 4 weeks. An inspiratory movement was carried out from the residual volume until the maximum inspiratory capacity, holding the air for three seconds and followed by an exhalation. The intensity was regulated once a week according to their progression in MIP. To keep track of the training, a check list was designed with all the available sessions, where each participant marked the days she trained[9,10].

### Statistical analysis

The Shapiro Wilk test was applied to establish the normal distribution of the examined variables: lactate, MIP and 6MWT. For those variables with a non-normal distribution, we used the nonparametric Mann-Whitney U test in order to determine whether the differences in values obtained before and after IMT were significant ($p<0.005$). *GraphPad* software, version 6.0 was used.

### Ethical considerations

All the participants signed the informed consent form and the procedures were approved by the Ethics Committee of Santo Tomás University. This study was conducted under the ethical guidelines of the Declaration of Helsinki.

## Results

### Hemodynamic and anthropometric variables

Data obtained from the 15 OA is shown in Table 2. We did not observe differences in body weight, resting heart rate, double product and blood pressure between control and experimental groups before they both were subjected to the AEC exercise program.

**Inspiratory muscle training (IMT)**

We evaluated the effect of IMT on lactate concentration, MIP, perception scale and 6MWT of the EG group. As observed in Figure 2A and 2D, IMT induced significant reductions in lactate concentration (from 3.16±0.51 to 2.5±0.39; p<0.049) and effort perception (from 5.56 ± 1.81 to 4 ± 2; p<0.043), respectively. Although the control group (CG) also showed a reduction in effort perception, this difference was not statically significant. Figure 2B shows that IMT had the opposite effect on MIP, with a significant increase from 42.1 ± 14.57 to 60.44 ± 14.47 (p<0.017). Finally, the absolute values of the 6MWTdid not significantly change in both EG and CG groups (Figure 2C). Nonetheless, there was a significant increase in percentage (p<0.031) in the 6MWT values of women practicing IMT (Figure 3). The CG group did not show changes in any of its variables (Table 2).

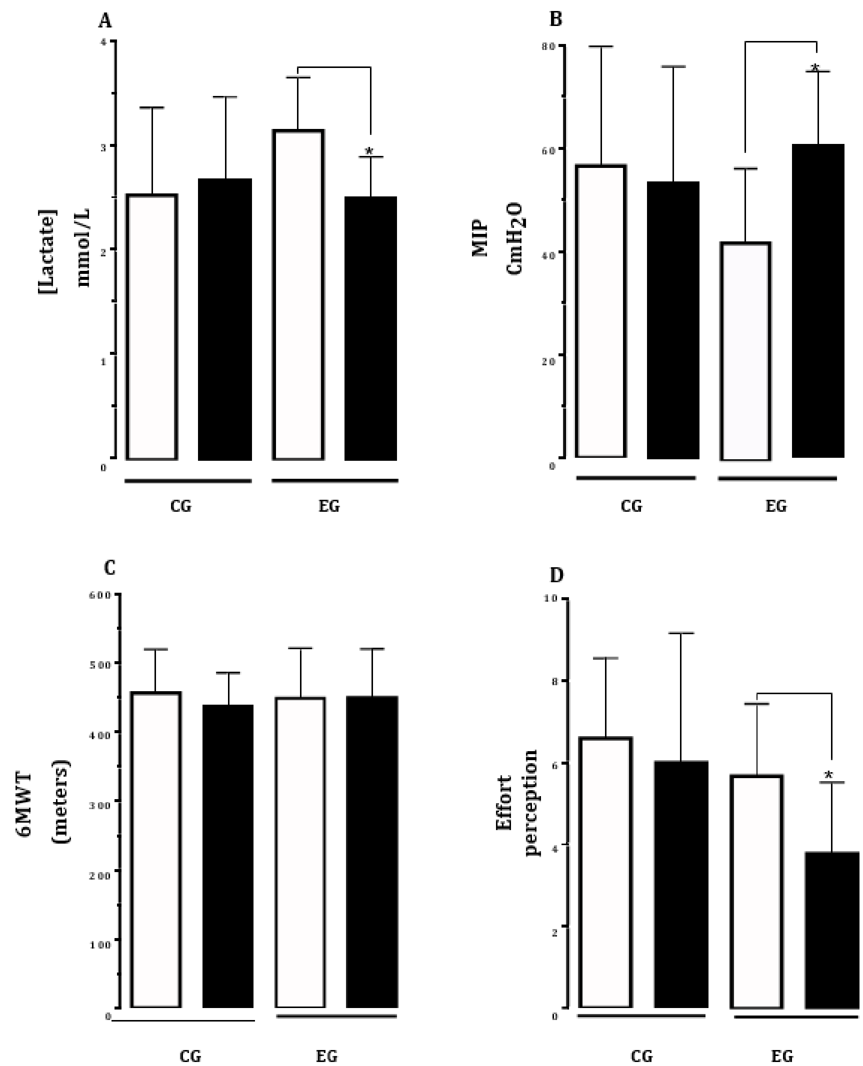


**Figure 2.** Effect of threshold valve training on experimental group vs. control group

The absolute values before (white bars) and after (black bars) the 4-week training. CG (control group), EG (experimental group). A and B show changes in lactate concentration and MIP for both groups, respectively. C and D display changes in covered distance and effort perception, respectively. Averages and standard deviation are presented; *p<0.05, based on the Mann-Whitney U test.

**Table 2.** Effects of the training program with threshold valve on experimental group vs. control group

| Variable | Control group | | | | Experimental group | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre-AEC training | Post-AEC training | % Change | p value | Pre-AEC training | Post-AEC training | Change % | p value |
| HR, bpm | 79.80 ± 8.23 | 78.60 ± 7.30 | - 1.2 ± 1.37 | 0.0058 | 67.67 ± 8.03 | 69.78 ± 6.38 | - 5.5 ± 2.61 | <0.0001 |
| Blood pressure, mmHg | | | | | | | | |
| Systolic | 118.6 ± 8.9 | 111 ± 9.61 | - 2.1 ± 2.66 | 0.0400 | 119.33 ± 8.32 | 119.44 ± 6.42 | - 3.5 ± 2.75 | 0.0030 |
| Diastolic | 63.8 ± 4.14 | 60.6 ± 3.78 | - 1.0 ± 4.69 | 0.6465 | 71.3 ± 4.58 | 66.11 ± 7.81 | - 3.6 ± 6.55 | 0.0739 |
| MBP | 80.87± 2.18 | 78 ± 2.74 | - 1.5 ± 3.17 | 0.1535 | 87.23 ± 4.23 | 83.89 ± 6.59 | - 3.7 ± 3.50 | 0.0040 |
| Double pressure, AU | 1 ± 1 | 1 ± 1 | - 4.4 ± 5.07 | 0.0320 | 1 ± 1 | 1± 1 | - 9.3 ± 5.3 | <0.0001 |
| Lactate, mmol/L | 2.54 ± 0.83 | 2.88 ± 1.13 | - 2.1 ± 2.66 | 0.0400 | 3.16 ± 0.51 | 2.51 ± 0.39 | - 3.5 ± 2.75 | 0.0030 |
| MIP, $cmH_2O$ | 56.6 ± 23.24 | 53.80 ± 22.48 | - 1.0 ± 4.69 | 0.6465 | 42.11 ± 14.5 | 60.44 ± 14.4 | - 3.6 ± 6.55 | 0.0739 |
| 6MWT, meters | 458.4 ± 66.63 | 435.8 ± 50.32 | - 1.5 ± 3.17 | 0.1535 | 448.8 ± 72.3 | 449.6 ± 70.9 | - 3.7 ± 3.50 | 0.0040 |
| Effort perception | 6.2 ± 2.68 | 5.8 ± 3.56 | - 4.4 ± 5.07 | 0.0320 | 5.56 ± 1.81 | 4 ± 2 | - 9.3 ± 5.3 | <0.0001 |

Data is presented as average ± SD. MBP (Medium blood pressure); bpm (beats per minute); HR (Heart rate); 6MWT (6-minute walk test); AU (Arbitrary units)
* Statistically significant difference between before and after training (p>0.005)

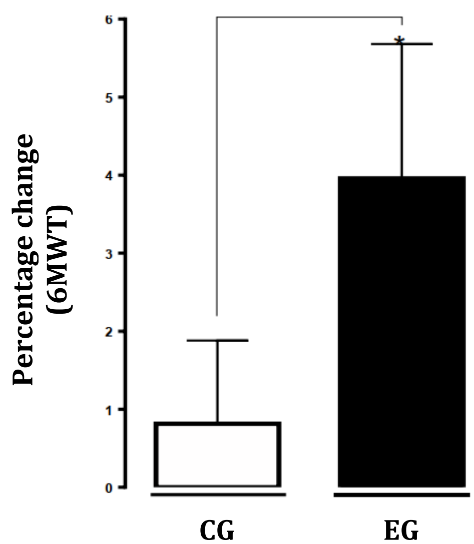


**Figure 3.** Percentage change in covered meters after training with threshold valve

6-minute walking test (6MWT). The figure shows the percentage change in covered meters by the control group (white bar) and experimental group (black bar). Averages and standard deviation are displayed, *p<0.05, based on the Mann-Whitney U Test.

## Discussion

Inspiratory muscle training is a specific method that increases respiratory muscle strength and resistance. Since this group of muscles has similar characteristics to skeletal muscle fibers, respiratory muscles should equally respond to training under an appropriate physiological load. Nevertheless, there is controversy regarding the exercise dosage (volume and intensity) that is necessary to generate muscle and functional adaptations[11].

Likewise, an increase in metabolic demands of untrained respiratory muscles affects their functional capacity. In this context, Moreno, *et al.*[12] have established a relationship between inspiratory muscle strength and $VO_{2max}$ , which shows that a correct IMT affects muscle energetic metabolism generating a lower oxygen demand. They also reported that such reduced requirement is associated with a lower lactate accumulation after physical effort that translates into better functional capacity. This observation is in agreement with the results of this current study since it showed a statistically significant difference in blood lactate between EG and CG (p<0.049). Similarly, Tong, *et al.*[13] studied the function of inspiratory muscles in 30 university athletes after IMT, and suggested that lactate reduction is related to adaptations of diaphragm strength and resistance. This event could also be explained by the role of the acid-base equilibrium that optimizes the metabolic acidosis control by means of an efficient activity of the chemoreceptors. They normally modulate the frequency and amplitude of the respiratory pattern, establishing a control of the acid-base equilibrium in exercise conditions[14].

Two possible mechanisms can explain a minor increase in lactate concentration from a post-exercise basal state[15]:

1) There is a reduction in energetic demand after inspiratory muscle training due to a lower respiratory work.
2) Trained muscles use more lactate as fuel for their own activity.

The first mechanism links lactate to fatigue. Archiza *et al.*[16] reported that IMT improves the supply of oxygen and blood to locomotor musculature, delaying the onset of fatigue. This result coincides with observations made by Rodriguez *et al.*, who demonstrated better aerobic capacity and delayed onset of fatigue in 20 OA women[17]. Both groups concluded that by postponing glycogen depletion, the initiation of fatigue is delayed too, which is in line with its definition: "fatigue is the inability to maintain an appropriate muscle strength during effort, decreasing subject performance"[18]. Thus, respiratory muscle fatigue is connected to the activation of mechanoreceptors and metaboreflex by the contractile force associated with exercise. It is suggested that this dynamic process intensifies the mechanical deformation of the diaphragm and increases the level of metabolites linked to exercise progression such as adenosine, lactic acid, phosphate and cations that are commonly present in type III and IV afferent fibers, respectively[19]. Ultimately, all this can lead to a sympathetic response associated with a vasoconstriction in locomotor muscles, intensifying fatigue of active muscles and increasing the effort perception, as suggested by Romer[20].

The second mechanism is explained by: the adaptation of respiratory muscles; increase in the capacity to metabolize lactate; and removal of lactate from blood. This view agrees with studies carried out with animals, where it was demonstrated that as they can consume more lactate during extreme exercise, it is more efficiently metabolized and its blood concentration is reduced. Similar results were obtained by Mehani[18], who suggested a drop in metaboreflex, in this way, attenuating vasoconstriction in lower limbs muscles.

Since half of the energy required for diaphragm activity is derived from metabolism of carbohydrates, in the form of lactate, this muscle will utilize more lactate as its energy source if it is properly trained, which can be ultimately reflected in the MIP. Indeed, MIP increased due to training under a high-intensity exercise program which led to: the strengthening of respiratory accessory muscles (and the diaphragm itself); helping the ventilation process; and delaying both fatigue onset and redistribution of blood[21]. Similarly, we reported better MIP values in our experimental group compared to the control one ($p<0.017$), which are also similar to the results presented by Kilding and Karadalli[22]. We decided to choose a simple exercise routine of 30 repetitions, once a day, five times a week, for a total of 4 weeks as this program matched the schedule of our participants, and it is a routine that has been previously used[23].

Interestingly, we did not observe significant differences in the 6MWT values obtained from EG and CG groups. This could be explained by the subjective nature of the test, mainly reflected from the motivation and general physical status of people as well as the evaluator's disposition. Nevertheless, when we normalized and analyzed the differences between both groups, we could observe that participants walked longer distances after intervention. This could be a consequence of a delay in the appearance of peripheric fatigue, as explained before.

Lastly, the EG group displayed a significant reduction in effort perception as compared to the control group ($p<0.043$), which coincides with what Figuereido, *et al.* has previously reported[5]. We showed that the threshold valve training to which the EG group was subjected delayed the onset of fatigue and, we believe, this is the reason why this group showed reduced effort perception. However, it is important that the person in charge of assessing this variable has enough experience as psychological and emotional factors can affect the fatigue scores reported by each individual[23].

## Conclusions

Our data shows that threshold valve training did not affect the covered distance in the 6-minute walk test, which is reflected on an unaltered functional capacity. Nonetheless, the decrease in lactate concentration observed in the experimental group after the exercise program could trigger a delay in the beginning of fatigue and limit a potential energy competition between respiratory and locomotor muscles. Based on our data, we suggest that incorporating IMT in health-oriented exercise plans provide simple and applicable strategies to improve the functional capacity of older adults.

We recommend to extend training intervals in order to analyze if the observed responses are maintained for longer periods of time. Also, it would be relevant to include a larger sample size with patients with different conditions.

**Conflict of interests:** the authors declare no conflict of interests

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