Original Research

Elastic Taping's Effect on Exercise Capacity in Recreational Runner with Inspiratory Muscle Training

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Abstract

Background: Running is a new trend of recreational sports in Indonesia. About 70% of recreational runners have difficulty in improving exercise capacity due to exercise-related transient abdominal pain (ETAP), caused by fatigue of the diaphragmatic muscles. Previous studies have shown that various training methods may increase diaphragmatic muscle strength and endurance, for example, inspiratory muscle training (IMT). Unfortunately, improvement of inspiratory muscle strength and endurance after exercise and IMT are still varies. Therefore, other methods are needed to optimize the effect of IMT. Application of the elastic taping on thoracic wall during exercise allows the inspiratory muscles to contract optimally which might improve functional capacity.
Aim: To assess the effect of elastic taping on inspiratory muscle training using the pressure threshold IMT, in increasing the functional exercise capacity of recreational runners. Functional capacity was measured based on VO_{2max} value, rating of perceived breathlessness (RPB) and rating of perceived exertion (RPE).
Methods: an experimental study involved 14 nonsmoker recreational runners, ages 20-40 years, at Outpatient Clinic of Physical Medicine and Rehabilitation Department of Dr. Soetomo Hospital Surabaya. Subjects were divided into two groups (pressure threshold IMT with and without elastic taping groups), which were observed for four weeks. IMT was done five times a week, twice a day, with 30 repetitions, and 60% resistance 30 RM using Respironics®. Elastic taping Leukotape® was applied on the first until fifth day in each IMT sessions. The running exercises were done three times a week with EnMill® Treadmill ETB-03195 with a speed of 4.5 mph and 0% inclination. RBP, RPE and VO_{2max} were measured using Borg Dyspneu scale, Borg Scale, and Bruce Treadmill Protocol test, respectively, before the first exercise and after 4 weeks of exercise.
Results: There were an improvement of functional exercise capacity in both groups which were marked with a decline of RPB and RPE and increase of VO_{2max} (p values < 0.05). However, there were no significant differences in the decrease of RPB and RPE and an increase of VO_{2max} between groups (p values of were 0.31, 0.83, and 0.13, respectively). The effect of the elastic taping (r2 = 0.99) was not reflected in the differences of RPB, RPE and increasing VO_{2max}.
Conclusion: Inspiratory muscle training using pressure threshold IMT with or without the elastic taping for four weeks can improve exercise capacity of recreational runners.

Keywords: *pressure threshold IMT, elastic taping, recreational runners, functional capacity, RPB, RPE,* VO_{2max}.

Introduction

Running has become a new trend of recreational sports in Indonesia since 2013. About 70% of recreational runners had difficulty in improving their exercise capacity due to exercise-related transient abdominal pain (ETAP) that was caused by fatigue of diaphragmatic muscles.[1] Various training methods have been carried out to increase the strength and endurance of diaphragmatic muscles, such as inspiratory muscle training. Unfortunately, the increase in strength and endurance of respiratory muscles obtained after exercise with inspiratory muscle training still varies in previous studies.[2] Other methods are needed to obtain an optimal effect of inspiratory muscle training. The improvement of inspiratory muscle strength and endurance has the possibility to improve exercise capacity.

Inspiratory muscle training (IMT) is a specific exercise to improve inspiratory muscle strength and endurance.[3,4] Upper extremities proprioception stimulation with the Proprioceptive Neuromuscular Fascilitation (PNF) method has been reported to improve respiratory muscles strength and endurance.[5] But usage of PNF alongside with IMT is rather difficult, thus the choice of elastic taping. Elastic taping facilitates muscle contraction through stimulation of proprioception receptors of muscles and joints proprioception receptors.[6,7] We hypothesized that the addition of elastic taping application on the chest wall (diaphragm projection) during inspiratory muscles training will provide neuromuscular feedback which will optimizes diaphragm contraction.

The effect of inspiratory muscle training and elastic taping in increasing inspiratory muscle strength and endurance has been reported. Minsoo *et al.* (2014) found that elastic taping along with inspiratory muscle training showed significant improvement in inspiratory muscle strength in the treatment group compared to the control group.[8] Complete information about the effect of elastic taping and inspiratory muscle training on exercise capacity has not been obtained. This study aimed to assess the effect of elastic taping and inspiratory muscle training on the exercise capacity of recreational runners. Exercise capacity was measured with VO2max, rating of perceived breathlessness (RPB), and rating of perceived exertion (RPE).

Material and Methods

Study design

The research was an experimental study with a pre – posttest control design. Subjects were divided into two groups: pressure threshold IMT with elastic taping and pressure threshold IMT without elastic taping. Our study lasted for 4 weeks.

Participants and inclusion criteria

Fourteen nonsmoker recreational male runners with ages 20-40 years were involved in the study. Inclusion criterias were regular running with frequency of three-four times a week (with total distance 5-10 km per week) of running in the past 1 year, willing to run on the treadmill during study, understand verbal instructions well (*Mini-Mental State Examination* score 24-30), normal body mass index (18.5-24.9 kg/ m^2), no history of pulmonary nor heart disease, have an intact eardrum, and did not follow formal breathing and proprioceptive exercises of upper extremity in last 2 months. Ethical clearance was given by Ethics Committee of Dr. Soetomo Hospital and all subjects signed an informed consent form before participating in the study.

Protocols

Subjects were divided into two groups, randomly. However, subjects who had any allergic reaction with the elastic taping would be placed in the control group (group without elastic taping). Each group underwent a pressure threshold IMT and running exercises. The inspiratory muscle training was done five times a week, twice-a day, with 30 repetitions and 60% resistance of 30 RM using Respironics®. Dosage of RM 30 was adjusted every week. IMT was done in diaphragmatic breathing at sitting position with nose covered by nose clamp and a

mouthpiece in horizontal position. The elastic taping Leukotape® was applied in the projection of diaphragm anteroposterior of the chest wall from first day until fifth day of IMT. Re-application was done in each IMT session per week. The elastic taping was applied in 30% of stretch, with anchor on the center of taping and tail on the lateral side of taping. Running exercises were done three times a week with EnMill® Treadmill ETB-03195 at 4.5 mph of speed, 0% inclination, and three kilometers of distance at the Physical Medicine and Rehabilitation Department Outpatient Clinic of Dr. Soetomo General Hospital Surabaya. Borg Dyspneu Scale, Borg Scale, and Bruce Treadmill Protocol were used to measure RPB, RPE and VO_{2max}, respectively, before the treatment and after four weeks of exercise.

Data analysis

Data analysis was performed using SPSS software (Version 22.0, Chicago,IL). Descriptive statistics including mean and standard deviation (SD) were calculated for all variables at baseline. Data of the RPB and RPE were statistically analyzed by non-parametric statistical procedures using Wilcoxon and Mann-Whitney tests, while VO_{2max} data was analyzed by parametric statistical procedures using independent T tests. The level of significance for all statistic tests was set at $p<0.05$. The effect of adding elastic taping on inspiratory muscle training was measured by using regression analysis with determinant coefficients.

Results

The subjects' characteristic data showed normal distribution and homogeneous result ($p>0.05$, CI95%) as shown on Table 1. There were adverse events met during the study, one subject got contact dermatitis allergy, one subject got blisters during first training using treadmill, and two subjects experienced ETAP during first training using treadmill. Subject who got contact dermatitis allergy followed a wash out period for three days, then the subjects were put into the control group. All adverse events diminished after healing treatment.

Table 1.Demographic characteristic

Characteristic	*Pressure threshold IMT* with *elastic taping* (n=7)		*Pressure threshold IMT* without *elastic taping (*n=7*)*		p [b]
	Mean ± SD	p[a]	*Mean* ± SD	p[a]	
Age (years)	29.86 ± 5.38	0.97	30.29 ± 5.94	0.44	0.71
Body weight (kg)	68.85 ± 4.52	0.99	63.85 ± 9.31	0.87	0.36
Body height (m)	170.00 ± 4.83	0.66	165.70 ± 5.25	0.96	0.75
BMI (kg/m^2)	23.81 ± 1.04	0.74	23.57 ± 1.78	0.60	0.16
MPV(fL)	10.17 ± 0.51	0.87	10.02 ± 0.86	0.83	0.10
Other sports activity	5 (35.7%)	-	4 (28.5%)	-	-

Note :IMT (Inspiratory Muscle Training), BMI (*Body Mass Index*); *MPV (Mean Platelet Volume)*; Numbers is *mean* ± standard deviation (SD) ; *p* value significant if $p< 0,05$ CI 95%. a. Normality test with *Kolmogorof Smirnov's Test,* b. Homogeneity test with Levene's Test

Table 2. Comparison of RPB, RPE, and *VO2max* pre-post exercise 4 weeks

Outcome Measurement		N	Mean (fL) ± SD	*p*	Effect size
Pressure threshold with elastic taping group	RPB pre-exercise[a]	7	3.14 ±0.38	0,02*	Z=-2.39, r= 0.90**
	RPB post-exercise[a]	7	1.21 ± 0.75		
	RPE pre-exercise[a]	7	4.57 ± 1.27	0.01*	Z=-2.39, r= 0.90**
	RPE post-exercise[a]	7	2.57 ± 0.78		
	VO2max pre-exercise[b]	7	37.57 ± 7.45	0.01*	Cohen's d = 1.65**
	VO2max post-exercise[b]	7	45.50 ± 4.51		
Pressure threshold without *elastic taping*	RPB pre-exercise[a]	7	3.14 ±0.38	0,02*	Z=-2.43, r= 0.91**
	RPB post-exercise[a]	7	1.57 ± 0.79		
	RPE pre-exercise[a]	7	4.14 ± 0.38	0.02*	Z=-2.46, r= 0.93**
	RPE post-exercise[a]	7	2.43 ± 0.54		
	VO2max pre-exercise[b]	7	33.0 ± 8.05	0.01*	Cohen's d = 1.73**
	VO2max post-exercise[b]	7	41.50 ± 4.70		

Note :RPB (Rating of perceived breathlessness), RPE (Rating of perceived exertion), [a] Wilcoxon Sign Rank test Test[b] Paired T test Numbers is *mean* ± standard deviation (SD) ; **p* value significant $p < 0,05$ CI 95%, **large effect size

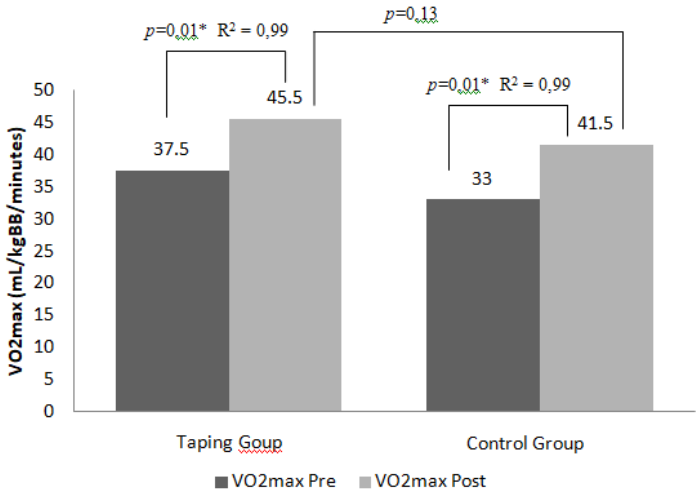

Figure 1. Comparison of *VO2max* pre-post exercise using pressure threshold inspiratory muscle training four weeks. Increased *VO2max* indicates the improvement of exercise capacity. Statistical significant value showed with $p<0.05$, 95% CI.

The results of our study showed a reduction of RPB and RPE and increase of VO_{2max} in both groups. In control group, alteration of RPB, RPE and VO_{2max} pre- and post-exercise was statistically significant (*p* values of 0.02, 0.02, and 0.01, respectively), with large size effect (Cohen's d 0.9, 0.9, 1.65, respectively). In group with elastic taping, alteration of RBP, RPE and VO_{2max} pre- and post-exercise was also statistically significant with *p* values of 0.02, 0.01, and 0.01, respectively (Table 2).There were no significant differences in the decrease of RPB and RPE and an increase of VO_{2max} between groups with *p* values of 0.31, 0.83, and 0.13, respectively, and large size effect on VO_{2max} parameter (Cohen's d 0.38, 0.08, 4.00,respectively) as shown in Figure 1. The effect of the elastic taping (r2 = 0.75, 0.92, 0.99, respectively) was not reflected in the difference of RPB, RPE and increasing VO_{2max}.

Discussion

Exercise capacity and inspiratory muscle strength are influenced by gender, age, body mass index (BMI), and smoking habits.[9] Study subjects in this study were males who did not smoke. There were no significant differences of the age, weight, height, and BMI between groups (Table 1), indicates a homogeneity of the subjects' characteristics at the baseline. Erythema occurred in one subject after four days of elastic taping application on the chest wall. There were subjects who experienced erythema which were estimated due to irritation of the elastic taping adhesive component because they had no atopic history. The erythema healed after detaching the elastic taping and consuming anti-pruritic medication. Three days washout period considered adequate to eliminate ambiguouing factors due to previous taping. Wash out period in a previous study was only done for one day.[10] Adverse events due to treadmill activity occurred in three subjects. One subject experienced blisters on the feet due to not wearing socks. The blisters healed without leaving a sequelon on the following days, therefore the subject could continue the research protocol. Two subjects experienced exercise related transient abdominal pain (ETAP) at the beginning of treadmill exercise. Pain was felt on the lateral part of the abdomen along the costal margo. ETAP occurs due to the inability of respiration muscles to meet oxygen demand which increases up to five times during running activity.[11] ETAP disappeared after a week of breathing exercises. This pattern showed that there has been an adaptation of the subject's respiratory muscles to an increase in oxygen demand during running.

This study showed increased VO_{2max} and decreased RPB and RPE pre and post exercise in each group with significant difference statistically ($p<0.05$). Nevertheless, there was no significant difference statistically between groups ($p>0.05$). Rating of perceived breathlessness (RPB) is a reliable indicator to monitor symptomatic shortness of breath during exercise. Rating of perceived exertion (RPE) is a reliable indicator to monitor exercise tolerance during practice. The RPE scale shows individuals' level of fatigue during exercise. Increased RPE showed an enhancement of muscle fatigue threshold (muscle fatigue), while a reduction of RPE showed a lowering of individual tiredness threshold. Escalation of work of breathing (WOB) occurred due to elevation of ventilation per minute which affected the performance of the extremity muscles. In addition, it will cause higher oxygen demand in respiratory muscles (about 10% of VO_{2max}), as the result, blood flow to the extremities is reduced by vasoconstriction of the extremity blood vessels. Reduction of blood flow to the extremity causes muscle fatigue of the extremities. This phenomenon is known as metaboreflex.[12,13] The metaboreflex phenomenon is triggered by the accumulation of lactic acid in the respiratory muscles.

WOB is an attempt to meet tissue oxygen requirements by the lungs. The lungs' effort to meet oxygen needs depends on the elastic and non-elastic lung components. The elastic components are related with recoil ability of lung and chest wall, also the amount of alveolar surface tension. Meanwhile, the non-elastic lungs component is related to airway resistance. Lung elastic recoil ability is affected by the respiratory muscle strength.[14] The aim of inspiratory muscle training and application of elastic taping is to improve inspiratory muscle strength Reduction of RPB during exercise in this study showed an improvement in the lungs ability to meet oxygen requirements during exercise, in other words, lighter effort was exerted by the lungs to obtain enough oxygen during exercise. Tong *et al.* (2008) showed a decreased RPB and RPE in healthy men who received inspiratory muscle training for six weeks.[15] The study of Volianitis *et al.* (2001), regarding the provision of IMT to rowers for 11 weeks at a dose of 50% Pimax twice a day and 30 repetitions, also showed a significant reduction in RPB.[16] Downey *et al.* (2007) reported a decrease of RPB and RPE in 12

healthy subjects who received IMT with 15-50% Pimax for four weeks.[17]

Inspiratory muscle training (IMT) improves neuromuscular coordination, and consequently inspiratory muscles do not require more effort to get the same level of ventilation. Alteration of histological and biochemical characteristic of the muscles after exercise are shown as an increased capillarization, number and size of mitochondria, and oxidative enzyme activity. These changes improved muscle capacity in extracting oxygen from the blood for metabolism.[18,19] The capillarization that occurs in respiratory muscles facilitates local oxygen transport and removal of local metabolites in respiratory muscles.[20]

Improvement on the fatigue threshold and shortness of breath scale showed a postponing of metaboreflex, consequently the extremities blood supply was adequate and the accumulation of metabolites was delayed.[14] Muscle limb fatigue delay played an important role in increasing individual exercise performance.[21] Kwok *et al*. (2009) reported there were no significant changes of VO_{2max} in recreational runners treated with IMT for six weeks at a dose of 50% Pimax, twice a day, with 30 repetitions.[11] Edwards (2013) also reported no significant changes in VO_{2max}, but showed a significant increase in the duration of the plateau phase in 36 healthy men with inspiratory muscle training for four weeks at a dose of 55% Pimax, twice a day, with 30 repetitions.[22]

The different results in the improvement of VO_{2max} after exercise in this study compared with previous studies might occur due to difference in VO_{2max} measurement technique performed. This research used the Bruce Protocol while previous research used a Modified Bruce Protocol. The fundamental difference between these measurement techniques was the inclination; in the Bruce Protocol the inclination was given from the beginning of the measurement while the Modified Bruce Protocol started without inclination. The Modified Bruce Protocol is more often used in older subjects who have limited exercise capacity due to heart disease. Trabulo *et al* (1994) reported higher VO_2 peak using the Bruce Protocol compared to the Modified Bruce Protocol in 80 healthy people.[23]

The improvement of the VO_{2max} in this study showed an improvement of the aerobic capacity of recreational runners after the study. This result was in line with the metaboreflex theory discussed in the previous section. Maximum aerobic capacity (VO_{2max}) is affected by physiological factors, including pulmonary diffusion capacity, maximal cardiac output, oxygen transport capacity by hemoglobin, and the musculoskeletal system. The subjects of this study were homogeneous in the absence of heart, lung, and musculoskeletal diseases, therefore, elevation of VO_{2max} which occurred due to inspiratory muscle adaptation to the breathing exercises was comparable with elevation of VO_{2max} due to running activity.

The increased VO_{2max}, decreased RPB and RPE occurred in both groups showed that alteration of the values were not affected by the addition of elastic taping. This result is different from previous study by Malehorn *et al.* (2013) which showed significant differences in the results of mechanical efficiency (ME) and tidal volume of healthy subjects who used elastic taping. Increased ME caused the work of respiratory muscles become more efficient without requirement for increased metabolic energy.[24] Elastic taping provides neural feedback to areas of inspiration in the medulla oblongata which enhance the work of respiration.[9]

The advantage of elastic taping can be accessed from the duration of the plateau phase before the appearance of the lactate threshold. Enhancement of the duration of the plateu phase which illustrated in Edwards and colleagues (2013) study was not performed in this study.[22] Plateau phase duration measurement can describe physiological changes after inspiratory muscle training and elastic taping. Plateau phase can be seen by measuring VO_{2max} directly using Quark CPET.

Regression analysis showed a large effect of adding elastic taping on inspiratory muscle training on increasing VO_{2max} and decreasing RPB and RPE (R^2 = 0.99, 0.75,

0.92 respectively). Verges *et al.* (2006) reported reduction of RPE and RPB without endurance escalation in 21 healthy men with 30 repetitions inspiratory muscle training daily for 4-5 weeks.[25] Mischenko *et al.* (2017) reported there was an increase of strength and endurance of inspiratory muscles and aerobic capacity in 22 healthy women using elastic taping of thoracic cage and static cycle for 30 minutes daily, 3 times per week, for 8 weeks.[26] The difference between our study and Mischenko *et al.*, was in the types of tape used. Mischenko *et al.* used 220 mm elastic belt with polyurethane material and the trademark was Spandex®, while our study used Leukotape® with cotton as basic material. This difference could affect the stimulating effects of proprioception.

There were some limitations of this study. First, subjects were limited only to men, therefore,the result may not be generalized to women. Second, measurement of vascular blood flow and arterial distensibility were not perfomed after exercise. These parameters can also be performed to describe vascular endothelial fitness. Third, number and duration of subject's sleep were not controlled, which can lead to interpretation bias. However, it concluded that inspiratory muscle training with or without addition of elastic taping showed improvement of the recreational runners' exercise capacity.

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Conflicts of Interest

The authors have no conflict of interest.

References

1. Morton D, Callister R. Exercise-related transient abdominal pain (ETAP). *Sport Med* 2014; 45: 23–35.
2. Hajghanbari B, Yamabayashi C, Buna TR, *et al*. Effects of respiratory muscle training on performance in athletes: A systematic review with meta-analyses. *J Strength Cond Res* 2013; 27: 1643–1663.
3. Enright S, Unnithan V, Heward C, *et al*. Effect of high-intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. *Phys Ther*. Epub ahead of print 2006. DOI: 10.1093/ptj/86.3.345.
4. Agnihotri DS, Bhise AR, Patel SM. Effect of inspiratory muscle trainer on running performance and respiratory muscle strength in athletes. *Int Arch Integr Med* 2016; 3: 159.
5. Arêas GPT, Borghi-Silva A, Lobato AN, *et al*. Effect of upper extremity proprioceptive neuromuscular facilitation combined with elastic resistance bands on respiratory muscle strength: A randomized controlled trial. *Brazilian J Phys Ther* 2013; 17: 541–546.
6. Halseth T, McChesney JW, DeBeliso M, *et al*. The effects of Kinesio™ taping on proprioception at the ankle. *J Sport Sci Med* 2004; 3: 1–7.
7. Konishi Y. Tactile stimulation with Kinesiology tape alleviates muscle weakness attributable to attenuation of Ia afferents. *J Sci Med Sport* 2013; 16: 45–48.
8. Lee M, Kim M, Ahn C. Impact of concurrent inspiratory muscle training and tape on inspiratory muscle strength, endurance and pulmonary function. *J Korean Soc Integr Med* 2014; 2: 65–73.
9. Tortora GJ, Derickson B. *Principles of Anatomy and Physiology*. 12th ed. John Wiley & Sons, 2009.
10. Hui HK, Karne NJ, Sonawane N. Acti-tape™ (elastic therapeutic tape) as compared with a knee guard in providing support to the knee joint: An open-label, randomized, crossover study. *Open Access J Clin Trials* 2013; 6: 29–36.
11. Kwok TMK, Jones AYM. Target-flow inspiratory muscle training improves running performance in recreational runners: A randomized controlled trial. *Hong Kong Physiother J* 2009; 27: 48–54.
12. Crisafulli E, Clini EM. Measures of dyspnea in pulmonary rehabilitation. *Multidiscip Respir Med* 2010; 5: 202–210.
13. Wüthrich TU, Notter DA, Spengler CM. Effect of inspiratory muscle fatigue on exercise performance taking into account the fatigue-induced excess respiratory drive. *Exp Physiol* 2013; 98: 1705–1717.
14. Guenette JA, Sheel AW. Physiological consequences of a high work of breathing during heavy exercise in humans. *J Sci Med Sport* 2007; 10: 341–350.
15. Tong TK, Fu FH, Chung PK, *et al*. The effect of inspiratory muscle training on high-intensity, intermittent running performance to exhaustion. *Appl Physiol Nutr Metab* 2008; 33: 671–681.
16. Volianitis S, McConnell AK, Koutedakis Y, *et al*. Inspiratory muscle training improves rowing performance. *Med Sci Sports Exerc* 2001; 33: 803–809.

17. Downey AE, Chenoweth LM, Townsend DK, *et al*. Effects of inspiratory muscle training on exercise responses in normoxia and hypoxia. *Respir Physiol Neurobiol* 2007; 156: 137–146.
18. Romer LM, McConnell AK. Specificity and reversibility of inspiratory muscle training. *Med Sci Sports Exerc* 2003; 35: 237–244.
19. McConnell A. *Respiratory Muscle Training. Theory and Practice*. Elsevier Ltd, 2013.
20. C.M. S. Respiratory control, respiratory sensations and the effects on exercise performance. *Schweizerische Zeitschrift fur Sport und Sport* 2002; 50: 101–108.
21. Romer LM, Polkey MI. Exercise-induced respiratory muscle fatigue: implications for performance. *J Appl Physiol* 2008; 104: 879–888.
22. Edwards AM. Respiratory muscle training extends exercise tolerance without concomitant change to peak oxygen uptake: Physiological, performance and perceptual responses derived from the same incremental exercise test. *Respirology* 2013; 18: 1022–1027.
23. Trabulo M. Does modified Bruce protocol induce physiological stress equal to that of the Bruce protocol? *Rev Port Cardiol*.
24. Malehorn K, Hiniker J, Mackey T, *et al*. Kinesio Tape® applied to the thorax augments ventilatory efficiency during heavy exercise. *Int J Exerc Sci* 2012; 5: 157–163.
25. Verges S, Lenherr O, Haner AC, *et al*. Increased fatigue resistance of respiratory muscles during exercise after respiratory muscle endurance training. *AJP Regul Integr Comp Physiol* 2006; 292: R1246–R1253.
26. Mishchenko V, Sawczyn S, Cybulska A, *et al*. Special training of inspiratory muscles in fitness activities and exercise capacity in young women. *Hum Mov* 2017; 18: 46–54.