Medical Rehabilitation / Rehabilitacja Medyczna (Med Rehabil) 2018, 22 (4): 49-57 DOI: 10.5604/01.3001.0013.1474 eISSN 1896–3250 © AWF Krakow

Methodologies of inspiratory muscle training techniques in obstructive lung diseases

Metodologie treningu mięśni wdechowych w chorobach obturacyjnych układu oddechowego

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Key words
inspiratory muscle training; respiratory muscle training; pulmonary rehabilitation; pulmonary disease, chronic obstructive; asthma

Abstract
Background: Inspiratory muscle training (IMT) is a non-pharmacological, non-invasive therapeutic method that can improve the quality of life in patients with obstructive lung diseases. The effectiveness of IMT may depends on the type of the device used in the training and the parameters of the training programme.
Objectives: The aim of the review was to present different techniques and protocols of IMT used in patients with obstructive lung diseases.
Methods: The MEDLINE and EMBASE were searched to identify the potentially eligible publications from the previous 5 years. The various protocols of IMT used in different studies were analyzed and described in detail.
Results: A database search identified 333 records, of which 22 were included into the final analysis. All of the finally analyzed studies were conducted in patients with chronic obstructive pulmonary disease (COPD). The protocols of IMT used in the studies differed in the type of the device used, the duration of the training program, the number and the duration of training sessions, the initial load, and the rate at which the load was changed during the training.
Conclusions: IMT is used mainly in studies on patients with COPD and not with asthma. There is no one approved training programme for IMT. The most predominant type of IMT is a training with threshold loading. The most frequently used devices for IMT are POWERbreath and Threshold IMT. The protocols of IMT used in the studies are very diverse.

Słowa kluczowe
trening mięśni wdechowych; trening mięśni oddechowych; rehabilitacja pulmonologiczna; przewlekła obturacyjna choroba płuc; astma

Streszczenie
Wstęp: Trening mięśni oddechowych (IMT) należy do niefarmakologicznych, nieinwazyjnych metod terapeutycznych, które mogą prowadzić do poprawy jakości życia pacjentów z chorobami układu oddechowego. Skuteczność IMT może zależeć od rodzaju urządzenia użytego do treningu oraz sposobu prowadzenia programu treningowego.
Cele: Celem przeglądu było przedstawienie różnych technik i protokołów IMT stosowanych u pacjentów z obturacyjnymi chorobami płuc.
Metody: W celu zidentyfikowania publikacji z ostatnich 5 lat potencjalnie kwalifikujących się do analizy przeszukano elektroniczne bazy MEDLINE i EMBASE. Szczegółowo przeanalizowano i opisano protokoły IMT stosowane w różnych pracach badawczych.

The individual division of this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

Article received: 15.10.2018; Accepted: 20.03.2019

Please cite as: Kaszuba M., Śliwka A., Piliński R., Nowobilski R., Wloch T. Methodologies of inspiratory muscle training techniques in obstructive lung diseases. Med Rehabil 2018; 22(4): 49-57. DOI: 10.5604/01.3001.0013.1474

Internet version (original): www.rehmed.pl

Wyniki: W efekcie wyszukiwania w bazie danych zidentyfikowano 333 rekordy, z których 22 zostały włączone do ostatecznej analizy. Wszystkie finalnie włączone do przeglądu badania zrealizowano u pacjentów z przewlekłą obturacyjną chorobą płuc (POChP). Protokoły IMT stosowane w badaniach różniły się rodzajem stosowanego urządzenia, czasem trwania programu treningowego, liczbą i czasem trwania sesji treningowych, początkowym obciążeniem oraz szybkością zmiany obciążenia podczas treningu.

Wnioski: IMT jest stosowany głównie w badaniach nad pacjentami z POChP, a nie z astmą. Nie istnieje jeden zatwierdzony program treningowy dla IMT. Najczęściej stosowanym rodzajem IMT jest trening z obciążeniem progowym. Najbardziej rozpowszechnionymi urządzeniami do IMT są POWERbreath i Threshold IMT. Protokoły IMT wykorzystywane w badaniach naukowych są bardzo zróżnicowane.

INTRODUCTION

Respiratory muscle training includes exercises aimed at increasing the strength and endurance of inspiratory and expiratory muscles. In the case of respiratory system diseases, causing periodic or constantly increased respiratory effort, the ability to provide adequate gas exchange in the lungs depends on the efficiency of the respiratory muscles. This efficiency is also directly related to the intensity of experienced dyspnoea and the limitation of exercise tolerance.

In literature on the subject, we can find the two most commonly used types of inspiratory muscle training (IMT). During training with inspiratory resistance (resistive loading), the patient inhales through a device that has holes with adjustable diameters (providing inspiratory resistance) - a hole with a smaller diameter generates greater resistance of air flow, increasing the training load[1-3]. In turn, during training consisting in exceeding threshold loading, the resistance is not dependent on air flow. The patient inhales through the spring valve and when such pressure (threshold) is generated, causing the valve to open, air flow begins[3-5].

Loads during IMT, through increased work of the inspiratory muscles, lead to improvement of their functional parameters, including strength and endurance, improving muscle performance during exercise[6,7]. The mechanisms due to which respiratory muscle training increases exercise tolerance are unclear. Alleged mechanisms include delaying respiratory muscle fatigue, redistributing blood flow from the airways to the locomotor muscles and reducing the sensation of respiratory and limb discomfort[8].

Inspiratory muscle training is a non--pharmacological, non-invasive therapeutic method that can lead to increased strength and endurance of the respiratory muscles, and thus, improving the quality of life of patients with respiratory diseases associated with reducing dyspnoea and increasing effort tolerance (increase in strength during marching). Scientific data does not justify the routine use of inspiratory muscle training as an essential component of pulmonary rehabilitation[9], but many studies have demonstrated its beneficial effects[9-15]. According to ATS/ERS recommendations from 2006 and those of the ACCP/AACVPR from 2011, respiratory muscle training should be considered in patients with respiratory disorders and documented respiratory muscle weakness (e.g. due to cachexia or chronic corticosteroid use) as well as in patients with persistent dyspnoea and limitation of exercise tolerance despite training aimed at increasing the endurance and strength of the peripheral muscles[10,11,16]. In combination with other methods of respiratory disease treatment, IMT may improve exercise capacity in patients[17]. Respiratory muscle training of (mainly inspiratory) in patients with low baseline maximal inspiratory pressure (MIP) enhances the effects of classic respiratory training[18-23].

It seems that in the majority of well-controlled and rigorously designed tests, respiratory muscle training has a chance to positively influence exercise performance[8] Presumably, the type of applied IMT methodology may have direct impact on the effectiveness of IMT in improving the efficiency of respiratory muscles and the quality of life of patients with respiratory diseases. However, the development of optimal methodology requires thorough analysis of the existing methods of inspiratory muscle training.

AIM

The aim of this review is to systematise and present the IMT methodology including threshold and resistive loading used in research work including this type of rehabilitation among patients with obstructive respiratory diseases.

METHODS

In order to identify current publications on the discussed subject, the MEDLINE and EMBASE databases were independently searched. Keywords were taken from the MeSH (key words: *pulmonary disease, chronic obstructive; asthma; inspiratory muscle training; respiratory muscle training*) and Emtree dictionaries (keywords: *chronic obstructive lung disease; asthma; inspiratory muscle training; respiratory muscle training*), respectively.

The search was limited to the publications available in full version, which were published in English or Polish between the years 2014-2018 and containing the selected keywords (Tab. 1). For further analysis, interventional studies containing the description of the IMT methodology and systematic reviews of IMT-related studies were selected. First, the titles and abstracts were analysed, and then the full versions of the identified publications were reviewed (Fig. 1).

The intervention in the studies that were ultimately analysed was the method of IMT (with resisted or threshold loading), which was a separate therapy type or one of the components of the complex procedure of pulmonary rehabilitation.

In order to analyse the additional interventional studies including IMT,

Table 1

Search strategies	
PubMed	*((('pulmonary disease', 'chronic obstructive') OR 'asthma')) AND (('inspiratory muscle training') OR 'respiratory muscle training')* Filters: Full text; Publication date from 2014/01/01 to 2018/12/31; Humans; English; Polish
Embase	*('chronic obstructive lung disease'* OR *'asthma')* AND *('inspiratory muscle training'* OR *'respiratory muscle training')* AND *'human'/de* AND (2014:py OR 2015:py OR 2016:py OR 2017:py OR 2018:py)

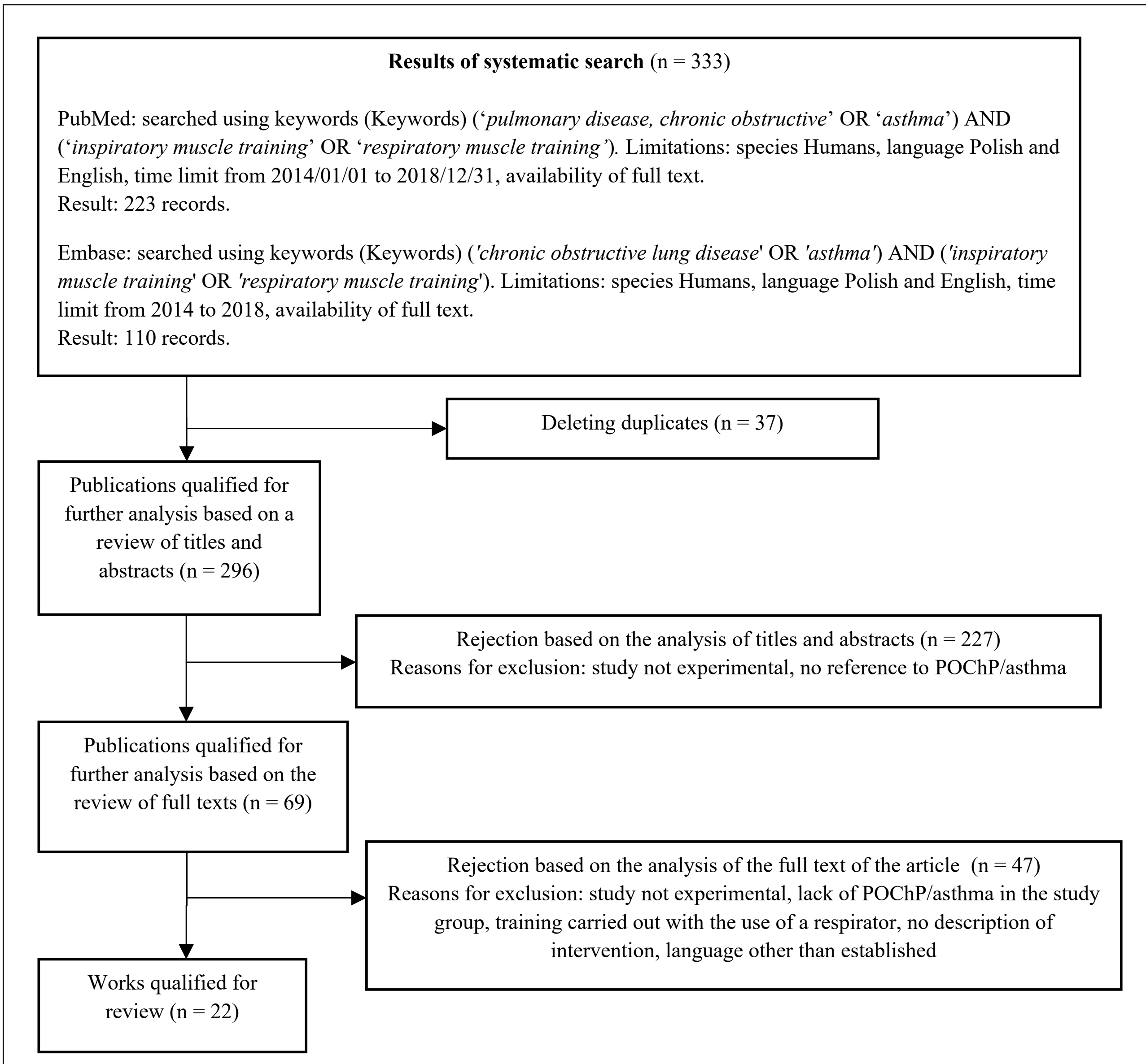

Figure 1
Systematic review PRISMA flow diagram

the lists of references included in the systematic reviews identified during this review were checked.

RESULTS

22 publications describing the IMT methodology were qualified for final analysis. All of these studies concerned patients with chronic obstructive pulmonary disease (COPD). Despite the inclusion of asthma in the search criteria, none of the studies qualified for the analysis concerned this disease entity. The literature published in three systematic reviews meeting the assumed search criteria and related to the discussed issue was also analysed.

The process of searching and selecting publications included in the analysis

Based on the analysis of 22 publications in full text that were ultimately qualified for the review, it was found that IMT protocols used in the analysed research presented significant differences in their assumptions (Tab. 2).

The duration of the entire training programme in the analysed studies ranged from 1 week to 4 months. Most often, the training programme lasted 8 weeks. The number of days per week during which IMT was conducted and the number of training sessions per day as part of individual training programmes also varied, ranging from 1 session per day for 3 days a week to 3 sessions a day, 7 days a week. Most often, patients exercised once a day, 7 days a week. The duration of one training session as part of the analysed tests was very different and ranged from 4 to 60 minutes, although information about possible intervals (between cycles) was not always given, hence, it was difficult to deduce how long the training part actually lasted. In the case of some publications, the number and duration of cycles as well as the duration of intervals were given, e.g. 6 cycles of 5 min of training and 3 minutes of rest, or 7 cycles of 2 min of training and 1 min of rest. In part of the work, the number of breaths per cycle was given (e.g. 1 cycle of 30 breaths and 1 min of rest). The duration of the training sessions was being increased only in one trial – from 5 min in the 1st week to 30 min in the 7th and 8th week of training. Resistive loading was usually determined on the basis of the measured MIP. The assumed resistive loading at the beginning of the training programmes ranged from 15% to 60% (for endurance training, most often 50%), and 80% (for strength training) of the current MIP. If the initial resistive loading was set without the MIP measurement, it was between 10 and 15 cmH_2O. In the majority of the trials, resistive during the training programme was systematically increased, which was carried out during training programmes at totally different paces. The value of MIP was measured in such cases before each training session or - most often – regularly, every 1-2 weeks. The resistance was increased gradually (e.g. every week by 5-10% or by 10 cmH_2O) until reaching 60% of the initial/baseline or until 50-60% MIP of the current/previous MIP (measurement every 1-2 weeks). In some works, the intensity of training was based on the degree of exercise tolerance (threshold symptoms). In such cases, resistance was gradually increased every week to the highest tolerated MIP value (e.g. to grade 4-6 on the Borg CR-10 scale or 12-14 on the Borg RPE scale). One work included the use of two types of training: strength and endurance training, for which different threshold pressures and durations of training sessions were assumed[24].

In the analysed tests, training was carried out using 7 different devices, including 1 prototype containing a one-way spring valve. This suggests the use of a training method with threshold loading, however, the most frequently used trainers were: the POWERbreathe instruments (in 9 trials); in 6 of them, a spring valve (mechanical) was used, while 4 devices included an electronic valve. The Threshold IMT (in 8 trials) as well as the Respifit S Trainer with an electronic valve generating threshold resistance (in 1 trial) were also implemented. In the case of 3 works, devices using resistance training (PFLEX, Portex and TFLR trainers) were used. Thus, the training model with threshold loading dominated. In 2 trials, neither the brand nor the type of the trainer were specified, although (in 1 case), the name suggesting training with inspiratory resistance (tapered flow resistive loading - TFLR) was given (Tab. 2).

SUMMARY AND CONCLUSIONS

The efficacy of the respiratory muscle training method in the treatment of obstructive lung diseases has not been supported by evidence from high-quality scientific research[9]. At the same time, IMT is often used in many research works and in clinical practice. Among clinicians and researchers, the question regards not only whether to use this type of training, but also, how it is to be used in the care of patients so that it is optimal for a given disease, resulting in beneficial therapeutic effects.

The analysed literature shows numerous training protocols differing from one another when considering many variables (intensity, duration and load size). Despite the sugges-

Table 2

Types of trainers and parameters of inspiratory muscle training programmes applied in patients with chronic obstructive pulmonary disease

Types of trainers	Duration of training programme	Number of training sessions per week	Number of training sessions per day	Total number of days/training sessions	Duration of training programme	Baseline resistance	Maximal resistance
Threshold loading training • POWERbreath • Threshold IMT • Respifit S Trainer • Prototype device with one-way spring valve Resistive loading training • Portex • PFLEX • TFLR trainer	from 1 week to 4 months	from 3 to 7 sessions a week	from 1 to 3 sessions a day	- from 5 to 84 training days in the whole training programme - from 10 to 252 training sessions in the whole training programme	from 4 min to 60 min or from 30 to 180 inhalations (not always information whether there were intervals between cycles)	- from 15% MIP to 80% MIP - from 10 to 15 cm H_2O	from 45% to 60 % of baseline or current MIP, measured during a given training week or in the week prior to it

Table 3

Characteristics of inspiratory muscle training programmes in patients with chronic obstructive pulmonary disease

Leading author/Year	Device	Duration of training programme	Number of training days per week	Number of training sessions per day	Total number of days/training sessions	Number of cycles per day and duration of cycle/interval	Duration of training during the day	Changes in duration of training session (change in intensity)	Baseline resistance	Changes in resistance
Basso-Vanelli R, 2016[30]	POWERbreath (POWERbreathe International Ltd, Southam, Warwickshire, UK)	4 months	3 days a week	1 time a day	48 days/48 sessions	7 cycles of 2 min of training and 1 min interval	14 min	-	10 cm H_2O	Initially increased by 10 cm H_2O to 60% of baseline MIP at the end of the first month of training; then, increased every 2 weeks in order to maintain 60% of current MIP
Beaumont M, 2015[31]	Threshold IMT (Philips Respironics, Murrysville, PA, USA)	3 weeks	5 days a week	2 times a day	15 days/30 sessions	15 min	30 min	-	40% MIP	-
Beaumont M, 2018[32]	POWERbreath Medic (POWERbreathe International Ltd, Southam, Warwickshire, UK)	4 weeks	5 days a week	2 times a day	20 days/40 sessions	15 cycles (15 min) of 10 slow breaths with gradually increased respiratory volume and a short interval		-	50% MIP	Increased after 10 days to 60% of baseline MIP
Charususin N., 2018[33]	POWERbreathe KHP2 (z zaworem elektronicznym), (POWERbreathe International Ltd, Southam, Warwickshire, UK)	12 weeks	3-5 days a week	1 time a day	36-60 days/36-60 sessions	60 min		-	50% MIP	Gradually increased every week to the highest tolerated MIP value (increase from 47% ±2% to 84% ±4% of baseline MIP) – training intensity corresponding to levels according to Borg Scale CR-10 within the range of 4-6 for the feeling of dyspnoea after session
Charususin N, 2013[34]	POWERbreathe KH1 (with electronic valve), (POWERbreathe International Ltd, Southam, Warwickshire, UK)	12 weeks	7 days a week	3 times a day	84 days/252 sessions	2 cycles of 3.5 min of training (30 breaths) and 1 min of rest	21 min	-	40% MIP	Increased to min. 50% MIP measured the prior week
Chuang H-Y., 2017[35]	n.d.	8 weeks	5 days a week	1 time a day	40 days/40 sessions	7 cycles (21-30 min) of 2 min of training 1 min of rest	21 min	-	15 cmH_2O	Gradually increased - after a week – to 20 cm H_20 - after another 3 weeks – to 30 cm H_20 - after another 2 weeks – to 40 cm H_20
Dacha S., 2017[36]	TFLR Trainer	8 weeks	7 days a week	2 times a day	56 days/112 sessions	4-5 min (30 breaths)	8-10 min	-	50% MIP	Increased every week until reaching highest tolerated resistance (approx. 50% MIP)
Dellweg D., 2017[24]	Respifit S Trainer (Biegler, Mauerbach, Austria)	4 weeks	5 days a week	1 time a day	20 days/20 sessions	- Strength training: cycles of 20 breaths for 1 min and 20-30 sec interval - Endurance training: 3 cycles of 1 min of training and 3 min interval		-	80% MIP for strength training, 60% MIP for endurance training	Increased every week to maintain: - 80% of current MIP for strength training - 60% of current MIP for endurance training;

Medical Rehabilitation / Rehabilitacja Medyczna (Med Rehabil) 2018, 22 (4): 49-57 DOI: 10.5604/01.3001.0013.1474 eISSN 1896–3250

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Elmorsi A.S., 2016[37]	Threshold IMT (Healthscan, New Jersey, NJ, USA)	2 months	6 days a week	1 time a day	48 days/48 sessions	30 min	30 min (no information regarding intervals)	-	30% MIP	Gradually increased by 5-10% until reaching 60% MIP at the end of month 1
Heydari A., 2015[38]	POWERbreath, (POWERbreathe International Ltd, Southam, Warwickshire, UK)	4 weeks	4 days a week	2 times a day	16 days/32 sessions	15 min	30 min	-	40 % MIP	Increased by 5-10% at each session, reaching 60% MIP
Hoffman M., 2018[39]	POWERbreathe K3 (with electronic valve), (POWERbreathe International Ltd, Southam, Warwickshire, UK)	8 weeks	7 days a week	2 times a day	56 days/112 sessions	1 cycle of 30 breaths and 1 min of rest	unclear	-	50% MIP	Increased to 50% MIP if the patient achieved more than 6 or less on the Borg Scale for feeling of dyspnoea after the session
Langer D, 2015[40]	- Threshold IMT (Philips Respironics, Brussels, Belgium) - POWERbreath (POWERbreathe International Ltd, Southam, Warwickshire, UK) - POWERbreathe KH1 (POWERbreathe International Ltd, Southam, Warwickshire, UK)	8 weeks	7 days a week	2 times a day	56 days/112 sessions	3-5 min (30 breaths)	6-10 min	-	40% MIP	MIP Increased in such a way as to start the week with 40% MIP and end the week with 50% MIP
Leelarungrayub J., 2017[41]	Portex Inspiratory Muscle Trainer, (Smiths Medical ASD Inc., Minneapolis, USA)	6 weeks	7 days a week	1 time a day	42 days/42 sessions	4 cycles of 30 breaths and 3 min of rest	unclear	-	-	Decreasing the hole diameter in the trainer every 2 weeks
Lopez-Garcia A., 2016[42]	Treshold IMT (Philips Respironic, Murrysville, PA, USA), Prototype trainer	4 weeks	3 times a week	2 times a day	12 days/24 sessions	15 min	30 min	-	30% MIP	Increased every week up to the highest tolerated or 60% of baseline MIP
Majewska-Pulsakowska M., 2016[43]	Threshold IMT (Respironics; Philips Healthcare, DA Best, the Netherlands)	8 weeks	5 days a week	2 times a day	40 days/80 sessions	- 1 week – 2 x 5 min - 2 week – 2 x 8 min - 3 and 4 week – 2 x 11 min - 5 and 6 week – 2 x 13 min - 7 and 8 week – 2 x 15 min	10-30 min	Training duration increased every week: - 1 week – 2 x 5 min - 2 week – 2 x 8 min - 3 and 4 week – 2 x 11 min - 5 and 6 week – 2 x 13 min - 7 and 8 week – 2 x 15 min	30% MIP	Gradually increased: - 1 week – 30% MIP - 2 and 3 weeks – 40% MIP - 4 and 5 weeks – 50% MIP - 6, 7 and 8weeks – 60% MIP

Characteristics of inspiratory muscle training programmes in patients with chronic obstructive pulmonary disease

Mehani S.H.M.M., 2017[44]	Prototype trainer (built out of stainless steel with one-way spring valve)	2 months	3 days a week	1 time a day	24 days/24 sessions	6 cycles of 5 deep breaths	30 breaths	-	15% MIP	Increase by 10% every week up to 60% MIP from the middle of the previous week
Nikoletou D; 2016[45]	POWERbreath (POWERbreathe International Ltd, Southam, Warwickshire, UK)	7 weeks	6 days a week	2 times a day	42 days/84 sessions	30 constant breaths (earliest interval after 5 breaths and not longer than 1 min)		-	30% MIP	1 a week, the value tolerated by the exerciser was increased (approx. 5% of baseline MIP)
Ovechin AV., 2017[46]	Respironics Inc. (Cedar Grove, NJ) + Airlife 001504 (Allegiance Healthcare Corp., McGaw Park, IL)	1 month	5 days a week	1 time a day	20 days/20 sessions	6 sessions (45 min) of 5 min of training and 3 min of rest	30 min	-	20% MIP	Increased to 40% of baseline MIP at the end of the training programme
Schultz K., 2018[47]	POWERbreath Medic (POWERbreathe International Ltd, Southam, Warwickshire, UK)	3 weeks	7 days a week	1 time a day	21 days/21 sessions	7 cycles (21 min) of 2 min of training and 1 min of rest	14 min	-	min. 30% MIP	Gradually increased to min 60% MIP
Wang K., 2017[48]	Threshold IMT HS730 (Philips, Amsterdam, the Netherlands)	8 weeks	3 times a week	1 time a day	24 days/24 sessions	7 cycles of 2 min of training and 1 min of rest	14 min	-	30% MIP	increased every week if grade 12-14 RPE was reached
Wu W, 2017[49]	PFLEX (Respironics Inc, Pittsburgh, PA, USA) Threshold IMT (Respironics Inc, Pittsburgh, PA, USA)	8 weeks	7 days a week	2 times a day	56 days/112 sessions	15 min	30 min (no information regarding intervals)	-	60% MIP	Increased every 2 weeks to maintain MIP at 60% of the current value
Xu W., 2018[50]	Threshold IMT (Respironics, Pittsburgh, USA)	8 weeks	7 times a week	1 time a day	56 days/56 sessions	8 cycles of 3 min of training and 2 min of rest	24 min	-	30% MIP	Increased by 5% every 2 weeks until reaching 45% MIP

n.d. – no data; TFLR – Tapered Flow Resistive Loading; MIP – Maximal Inspiratory Pressure; RPE – Rating of Perceived Exertion tions in several publications/recommendations on how to conduct training (frequency 4-5 days a week, resistance at 30-40% MIP, duration – 1, 30-minute session a day or 2 sessions lasting 15 minutes, for a period of at least 2 months)[9,16,25], the methodology for performing IMT is very diverse. This is due to the lack of current and consistent recommendations regarding the manner in which IMT is to be performed. It seems that in many cases, the used methodology is discretionary, but this obviously does not undermine its effectiveness. Various types and models of trainers are also used. The effectiveness of this form of respiratory rehabilitation may be related to the way and intensity of performing breathing exercises. Thus, the next step should be a comparison of the effectiveness of IMT depending on the characteristics of the implemented training protocol and the type of trainer used. Such research would serve to optimise and refine the range of parameters used in IMT, including training with resistive or threshold loading. As a result, this may facilitate the development of a uniform protocol of exercises to be performed in patients with COPD, which will find its place in clinical practice as a method complementing other elements of therapy, as in the case of general training in patients with COPD, in which the methodology is strictly defined, guaranteeing the achievement of beneficial effects: 21, 30-minute sessions at least 3 times a week (continuous or interval training)[26-28]. In the case of upper and lower limb strength training, 2-4 series of 6-12 repetitions with a load requiring 50-85% of maximal force are recommended[29].

A different issue regards comparison and examination of the effectiveness of training in the form of supervised sessions and those performed without supervision at a patient's home. However, the results of research on home-based rehabilitation are not promising among patients with COPD. This is probably connected with experienced fatigue and shortness of breath during exercise (even at low intensities). The training criteria set for healthy people may be too strict for patients with symptomatic COPD. Perhaps the most effective way of implementing IMT, similar as in the case of general training, would be personal training, i.e. performing exercises whenever the patient has free time (not based strictly on the methodological regime, but based even on the patient's availability). Awareness of not being able to meet rigorous training criteria may be a reason for being discouraged and refraining from continuing exercise. Nonetheless, the effectiveness of such a training method requires further research.

Conflict of interest: none

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