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A Review on Respiratory Muscle Training Devices

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Abstract

Background and aim: There are currently many devices on the market, which have been used for training of the respiratory muscles. The knowledge of these devices may help professionals to carefully select the best one to be used. However, due to the numerous available devices available, this selection represents a challenge. Although previous studies have attempted to describe all respiratory muscle training devices, important ones with proven efficacy were not included. Therefore, the purpose of this review was to describe the mechanisms and characteristics of all available respiratory muscle training devices, and discuss their merits and limitations.

Methods: Searches were conducted in databases, books, website selling products related to rehabilitation, and reference lists of the retrieved papers.

Results: The present review included 14 devices currently available on the market and reported by published studies. However, three could not be described in details, due to lack of information. Amongst the 11 evaluated devices, all of them showed positive aspects and limitations that should be considered.

Conclusion: Although some devices appear to be more advantageous than others, it is not possible to choose the best one, based only upon their technical information and clinical utility. To select the most appropriate one, it is also necessary to consider the specific health condition, the nature of the impairments, the purpose of the training, and whether it is for use within research or clinical contexts.

Keywords: Respiratory muscles; Resistance training; Breathing exercises; Rehabilitation

Introduction

The respiratory muscles are unique amongst the skeletal muscles, since they must work without sustained rest throughout life [1]. However, conditions, such as respiratory diseases, neurological lesions, electrolyte disturbances, blood gas abnormalities, intense weight loss, and cardiac decompensation, may affect these muscles [2]. Weakness of the respiratory muscles is defined as a reduction in muscle contractility, resulting in the inability of the respiratory muscles to generate normal levels of pressure and air flow during inspiration and expiration [3]. This strength could compromise exercise performance in healthy individuals [4,5] and in those with stroke [6], chronic obstructive pulmonary disease [7], and heart failure [8]. Thus, the implementation of interventions, which has the potential to increase the strength of the respiratory muscles and, consequently, improve exercise performance and functional capacity is vindicated, since deconditioning is one of the most common preventable causes of morbidity and mortality [9].

One approach that has the potential to increase the function of the respiratory muscles is respiratory muscle training [10-12]. This intervention consists of repetitive breathing exercises against an external load, which can be controlled by factors, such as time, intensity, and/or frequency of the training [10,13,14]. However, to obtain a training response, the muscle fibers must be overloaded, by requiring them to work for longer, at higher intensities and/or more frequently, than they are accustomed to. Most training regimens combine two or three of these factors, to achieve adequate overload [14]. Furthermore, the adaptations elicited by the training depend upon the type of the stimulus, to which the muscle is subjected. The muscles tend to respond to strength-training stimuli (high intensity and short duration) by improving strength and to endurance-training stimuli (low intensity and long duration) by improving endurance [14]. Thus, when their fibers are overloaded, the respiratory muscles respond to training stimuli, by undergoing adaptations to their structure in the same manner, as any other skeletal muscles.

There are, currently, many devices on the market, which can be used for respiratory muscle training. The respiratory devices fall into two main categories: devices that impose a resistance-training stimulus and those that impose an endurance-training stimulus [14]. The resistance-training devices subject the muscles to an external load that is akin to lift a weight and fall into three main categories, based on how the load is generated: passive flow-resistance, dynamically adjusted flow-resistance, and pressure threshold valve. The endurance-training devices (or require that the respiratory muscles work at high shortening velocities for prolonged periods of time (30 minutes) and the only load imposed on the muscles is that of the inherent flow-resistance and elasticity of the respiratory system [14]. All the devices described by their commercial product brands belong to one of these two categories and each has specific mechanical principles and characteristics. Thus, the knowledge of these devices may help professionals to carefully select the best one to be used with each patient, to align the goals of the intervention with the mechanisms (flow-dependent resistance or pressure thresholds) and characteristics, such as overload range, portability, usability, and cost. However, due to the high number of available devices on the market, this selection represents a challenge for the professionals. Thus, although previous studies have attempted to describe all the respiratory muscle training devices [14-17], some devices with proven efficacy were not included.

Therefore, the purpose of this review was to describe the mechanisms

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and characteristics of all respiratory muscle training devices, currently available on the market, and discuss their merits and limitations.

Data Source and Study Selection

Searches were conducted in databases, books, website selling products related to rehabilitation, and reference lists of the retrieved papers. This review provides a list of the devices currently available on the market, and an evaluation of their characteristics, based upon their technical information and clinical utility. Dichotomous responses, based on "yes/no" responses, were chosen to evaluate the devices and, therefore, facilitate reading and, consequently, the choice by the professionals. The "yes" responses for each topic were: adequate load range: devices clearly stated in the literature with sufficient training load amplitude; portability: devices that can be easily carried in a pocket or in a small bag; usability: devices that do not need the help of a therapist to be handled; adequate mouthpiece sealing: devices with a flexible flanged mouthpiece, that is both comfortable and airtight; possibility of home-based training: devices that are portable and do not require the help of a therapist to be handled; easy/fast adjustment: devices that need less than one minute to be adjusted and connected (in the case of electronic ones); allows inspiratory and expiratory training: devices that allow for the training of both inspiratory and expiratory muscles; cost: devices that are inexpensive, i.e., cost less than 100 dollars. The characteristics of the devices were evaluated by collecting information from the literature and by the authors, who are physiotherapists with clinical experience in the area of neurological and respiratory rehabilitation.

Results

The present review included 14 devices, currently available on the market and reported by published studies. Overall, most of the devices can be easily carried-out (91%), are easy to use or can be used at home (88%), provide adequate load ranges, mouthpiece sealing, or are easy/fast to adjust (77%), and are inexpensive (66%). On the other hand, only three of the available devices allow both inspiratory and expiratory training. Table 1 summarizes their main technical characteristics, to facilitate comparison and selection by the professionals, according to the patients' conditions and training objectives.

Resistance-training devices: The resistance-training devices fall into the following three main categories, based upon how the load is generated: passive flow-resistance, dynamically adjusted flow-resistance, and pressure threshold valve.

Passive flow-resistance devices: In these devices, the load is given by a previously selected variable diameter orifice, so that for a given flow, the narrowest the orifice is, the greatest is the resistive load [15-17]. However, these devices show an important limitation, because the load is passively generated by the respired air flow, i.e., if there is no flow, there is no load. Thus, they are highly sensitive to the influence of respiratory flow rate, which makes loading unreliable [14].

1. Pflex

α) **Clinical applicability:** The Pflex® (Respironics Inc., Murrysville, PA, USA) is an inexpensive inspiratory muscle trainer (costs less than 20 dollars), commonly used for strength training [18,19]. This plastic device is 5.7 cm long and has a cylindrical shape and an opening at one end for the insertion of a removable plastic mouthpiece and is sealed at the other end by a one-way valve. The breathing resistance is controlled by an adjustable dial-like mechanism with six fixed orifice settings located on the shaft of the device [20]. This device is mainly used in patients with chronic obstructive pulmonary disease; however, it can be used in several other conditions, such as the elderly and neurological or cardiac conditions.

β) **Positive aspects:** The Pflex® has an adequate mouthpiece sealing and is easily adjustable and inexpensive.

χ) **Limitations:** Since that the training load varies with the flow and not just with the orifice size, it is impossible to quantify the training load and progression, without providing simultaneous feedback of the respiratory flow rate [14]. It is possibly to adapt another piece, so-called 'targeted flow-resistive training', to control the flow and make the loading reliable [14]. However, this adaptation adds considerably to the cost and bulk of the device.

2. TrainAir

α) **Clinical applicability: T**he TrainAir® (Project Electronics Ltd., Kent, ENG, UK) is also an inspiratory muscle trainer used for strength training [21,22]. This device has a passive flow-resistance mechanism with the addition of pressure measurement, making load setting reliable and quantifiable. This device may be used in patients, who have respiratory muscle weakness, such as chronic obstructive pulmonary disease, and neurological or cardiac conditions.

Device	Adequate load range	Portability	Usability	Adequate mouthpiece sealing	Possibility of home-based training	Easy/fast adjustment	Allows inspiratory and expiratory training	Cost effectiveness (inexpensive)
Resistance-training devices								
Pflex®	No	Yes	Yes	No	Yes	Yes	No	Yes
TrainAir®	Yes	No	No	Yes	No	No	No	No
POWERbreathe® K-Series	Yes	Yes	Yes	Yes	Yes	Yes	No	No
EMST 150	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Orygen-Dual Valve®	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
POWERbreathe®	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
PowerLung ®	*	Yes	Yes	Yes	Yes	Yes	Yes	No
Respifit-S	Yes	Yes	No	Yes	No	Yes	No	No
Threshold® IMT	No	Yes	Yes	No	Yes	Yes	No	Yes
Threshold™ PEP	No	Yes	Yes	No	Yes	Yes	No	Yes
Endurance-training device								
SpiroTiger®	Yes	Yes	No	Yes	No	No	Yes	No
* Not reported								

Table 1: Characteristics of the evaluated respiratory muscle training devices.

β) **Positive aspects:** The TrainAir® has an adequate mouthpiece sealing. Furthermore, as an advantage, this device enables continuous biofeedback of the training intensity and built-in assessment of inspiratory muscle function [14].

χ) **Limitations:** The required laptop and other pieces increase its cost and bulk (about 600 dollars), makes it the preserve of specialist clinics, besides the training being also very time consuming and strenuous [14].

Dynamically adjusted flow resistance devices: The mechanism of these devices, although similar to that of the passive flow-resistance ones, allows continuous and dynamic adjustments of the flow resistance. This adjustment allows that the surface area of the flow orifice vary within a breath, according to the prevailing respiratory flow rate [14]. Furthermore, the controlled variable can be either the pressure load or the respired flow rate [14].

3. POWERbreathe K-Series

α) **Clinical applicability:** The POWERbreathe® K-Series (POWERbreathe International Ltd., Southam, ENG, UK), an inspiratory muscle trainer with a response valve electronically controlled to generate the resistance, is a new approach to respiratory training that was launched in 2010, with few publications to date [23,24]. The index of the display of strength ranges from 10 to 240 cm H_2O and the battery life is about 60 minutes on the training mode. Although the published studies reported its use mainly with patients with chronic obstructive pulmonary disease, it can be used in any condition, as long as the patients have respiratory muscle weakness.

β) **Positive aspects:** The POWERbreathe® K-Series is programmable by the user and provides real-time computer-based biofeedback during training [14]. Furthermore, a history of use is recorded in the memory of the device, allowing for real-time training.

χ) **Limitations:** This device has a high cost (300 to 600 dollars), which makes this method the preserve of specialist clinics.

Pressure threshold devices: These devices require individuals to produce a respiratory pressure, sufficient to overcome a pressure load and, thereby, initiate the respiration [14,15]. The thresholds permit loading at a quantifiable, variable intensity, by providing near-flow-independent resistance to respiration [14,15].

4. EMST 150

α) **Clinical applicability:** The EMST 150 (Aspire Products, Gainsville, FL, USA) is a recently developed expiratory muscle trainer [25], that costs about 50 dollars and has been successfully used in previous studies [25-27]. This device uses a calibrated, one-way, spring-loaded valve, to mechanically overload the expiratory muscles [25]. The valve blocks the air flow, until a sufficient expiratory pressure is produced. The EMST 150 provides workloads up to 150 cm H_2O, with regular intervals of 30 cm H_2O. Although this device has been mainly used in healthy patients or with neurological conditions, it can also be used in any other condition, to increase the strength of the expiratory muscles, including healthy individuals.

β) **Positive aspects:** The EMST 150 is easily adjustable and inexpensive.

χ) **Limitations:** This device provides only a hard-plastic tube mouthpiece, that makes it challenging for some users to maintain an airtight sealing.

5. Orygen Dual Valve

α) **Clinical applicability:** The Orygen-Dual Valve® (Forumed S.L., Barcelona, CAT, ESP) is a relatively inexpensive (costs about 60 dollars) and portable respiratory trainer, that also allows patients to simultaneously work the inspiratory and expiratory muscles [28]. Furthermore, the Orygen-Dual Valve provides workloads up to 70 cm H_2O, with regular intervals for both cases of 10 cm H_2O [28]. Although it has been recently developed, studies have proven its efficacy in patients with chronic heart failure [28] and stroke [29].

β) **Positive aspects:** This device has two opposite chambers, an inspiratory and an expiratory, and these coupled mechanisms in a single device allow both simultaneous and sequential dual-training (inspiratory and expiratory), which has given its name to the valve itself [28].

χ) **Limitations:** Once the Orygen-Dual Valve® was developed by a group of Spanish researchers, it is available for internet sale only in Spain, with an estimated delivery time of three months.

6. Powerbreathe

α) **Clinical applicability:** The POWERbreathe® (POWERbreathe International Ltd., Southam, ENG, UK) is an inexpensive inspiratory muscle trainer (costs about 40 dollars), whose efficacy has been supported by previous studies [30-32]. This device is supplied in a range of models (POWERbreathe classic and POWERbreathe plus), with load setting spans of 17-98 cm H_2O, 23-186 cm H_2O, and 29-274 cm H_2O. Furthermore, it has a flexible mouthpiece that better fits the patient's mouth, making it more comfortable and airtight [14]. Similar to the POWERbreathe® K-Series, although the published studies reported its use mainly with patients with chronic obstructive pulmonary disease, it can be used in any condition, as long as the patients have respiratory muscle weakness.

β) **Positive aspects:** The POWERbreathe® has an adequate mouthpiece sealing, is easily adjustable and inexpensive. In addition, it separates inspiratory and expiratory flow paths, such that the inspiratory valve is protected from expiration [14].

χ) **Limitations:** It allows just inspiratory training.

7. PowerLung

α) **Clinical applicability:** The PowerLung ® (Powerlung Inc., Houston, TX, USA) is a recent hand-held respiratory muscle device developed for healthy people [33-35]. This device can control both inspiratory and expiratory airflow, by using a spring-loaded valve mechanism, that has separate controls for inspiration and expiration [36]. The PowerLung has the following four models (about 120 dollars each), that produce varying levels of resistance: AireStream: indicated for healthy lifestyle people, who are moderately active and not involved in athletics or exercise programs; BreatheAir: indicated for people, who are moderately active, exercise at least 2 to 3 days per week, and are engaged in low-intensity activities, such as walking, swimming, or practicing yoga; Sport: indicated for people, who are looking to improve their performance in sports or other rigorous activity; and Trainer: specifically designed for elite athletes and strenuous competitive training activities.

β) **Positive aspects:** The PowerLung ® has an adequate mouthpiece sealing and is easily adjustable. In addition, this device allows for varying resistance on inhalation and exhalation via hand-adjusted knobs [36].

χ) **Limitations:** This device is relatively expensive, which makes this method the preserve of specialist clinics.

8. Respifits-S

α) **Clinical applicability:** The Respifit-S (Biegler GmbH, Mauerbach, NOE, AUT) is an individualized respiratory muscle training device used to strengthen the inspiratory muscles of different populations, such as chronic obstructive pulmonary disease, stroke, and Parkinson disease [37-39]. This device is composed of a main shaft, into which a program card is inserted; a handle mouthpiece, to adjust the exhalation and inhalation volumes and modules; a program card, which is adjusted by the breathing capacity of each patient; and a transparent tube, that connects the main body to the mouthpiece [39]. The therapist operates the main shaft to initiate the training, which is displayed like a game on the main screen [39].

β) **Positive aspects:** The graphical display provides feedback of workloads up to 200 cm H_2O for the patient. Furthermore, the Respifit-S is also an endurance trainer.

χ) **Limitations:** This device is relatively expensive (costs about 1,000 dollars), which also makes this method the preserve of specialist clinics.

9. Threshold IMT (inspiratory muscle training)

α) **Clinical applicability:** The Threshold® IMT (Respironics Inc., Murrysville, PA, USA) is an inexpensive inspiratory muscle trainer (costs about 30 dollars), which has been widely used with various health conditions [40-42]. This device contains, at its end, a valve closed by the positive pressure of a spring, which can be graded from 9 to 41 cm H_2O and allows resistance changes by 2 cm H_2O increments. The Threshold IMT has a one-way spring-loaded valve, that closes during inspiration and requires that participants inhale hard enough, to open the valve and let the air enter. This device provides constant pressure for inspiratory muscle training, regardless of how quickly or slowly the participants breathe, and the optimal loading pressure can be adjusted, based upon the individual characteristics of the participants [43].

β) **Positive aspects:** The Threshold® IMT is easily adjustable, inexpensive, and allows increments in resistance by 2 cm H_2O. Furthermore, its use has been supported by the most extensive and high-quality published research.

χ) **Limitations:** This device provides only a hard-plastic tube mouthpiece, that makes it challenging for some users to maintain an airtight sealing. In addition, its small maximal load makes it difficult to achieve adequate levels of training.

10. Threshold PEP (positive expiratory pressure)

α) **Clinical applicability:** The Threshold™ PEP (Respironics Inc., Murrysville, PA, USA), which has been used in previous studies [42,44,45] also with various health conditions, has the same mechanism and cost of the Threshold IMT, but was developed for expiratory muscle training and can be graded from 5 to 20 cm H_2O. For this, the subjects have to overcome the resistance of the expiratory flow spring.

β) **Positive aspects:** The Threshold™ PEP is easily adjustable, inexpensive, and allows changes in resistance by 1 cm H_2O increments.

χ) **Limitations:** Similar to the Threshold® IMT, this device provides only a hard-plastic tube mouthpiece, that makes it challenging for some users to maintain an airtight seal [14]. Furthermore, the small maximal load of this device makes it difficult to achieve adequate levels of expiratory muscle training. To overcome this limitation, a possible option is the reverse use of the Threshold IMT device, which has twice the upper load limit [46,47]. For this, another plastic mouthpiece needs to be adapted at the end of the inspiratory trainer, enabling its use for both inspiratory and expiratory training with the same device [46]. However, even so, the loading range of the Threshold IMT renders it unusable by anyone, whose baseline maximal inspiratory pressure exceeds 60 cm H_2O. Considering a training load of 50%, someone starting training with a maximal inspiratory pressure of 60 cm H_2O and improving by 30%, will rapidly reach the limits of the spring [14].

11. Other respiratory muscle training devices

Other devices that have pressure threshold mechanisms can be found on the market, although they have been little used within clinical and research contexts. These devices are:

α) **Expand-a-Lung (Expand-a-Lung Inc, Miami, FL, USA):** An inspiratory and expiratory muscle trainer, that costs about 30 dollars [48].

β) **Sports Breather® (Health Fitness Center, Rockport, TX, USA):** an inspiratory and expiratory muscle trainer, that costs about 35 dollars [49].

χ) **Ultrabreathe® (Tangent Healthcare Ltd., Basingstoke, ENG, UK):** an inspiratory muscle trainer, that costs about 30 dollars [50,51].

Endurance-training devices: Endurance training, also named as voluntary isocapnic hyperpnea training, is time consuming and extremely strenuous, requiring a very high level of the user commitment, to achieve and sustain the prescribed training intensity [14]. This type of training requires individuals to maintain high target levels of ventilation for up to 30 minutes, needing a high degree of motivation [14]. The sessions are typically conducted 3 to 5 times per week at about 60 to 90% of maximum voluntary ventilation [14].

12. Respifits-S

The clinical applicability, positive aspects, and limitations of The Respifit-S were previously described, since this device allows both strength and endurance training.

13. SpiroTiger

α) **Clinical applicability:** The SpiroTiger® (Idag AG, Volketswill, ZH, CHE) is an electronic-endurance trainer, that had its efficacy supported by previous studies [52-54], and also may be used with various health conditions. This device consists of a hand-held unit with a respiratory pouch and a base station [52]. While sitting, the subjects are asked to hold the mouthpiece to their mouth, while watching the monitor. The base station is manipulated by the therapist, who pushes the start button. While watching the monitor, the subjects start the inspiration and expiration.

β) **Positive aspects:** The device‘s display and auditory feedback are very important for constraining the subjects' breathing within the threshold value of isocapnia [52]. The SpiroTiger is the only commercial product that provides this type of y training.

χ) **Limitations:** This device is relatively expensive (costs about 700 dollars), which also makes this method the preserve of specialist clinics.

Discussion

This review aimed at describing the mechanisms and characteristics of all respiratory muscle training devices, currently available on the market and discuss their merits and limitations. Although 14 available devices were found, lack of information prevented a detailed description of three devices (Expand-a-Lung, Sports Breather, and Ultrabreathe). Thus, this review described 11 devices, which has been frequently used within research contexts, considering eight characteristics: cost, adequate load range, portability, usability, adequate mouthpiece sealing, possibility of home-based training, easy/fast adjustment, and provision of both inspiratory and expiratory training.

It is well known that the POWERbreathe and IMT/PEP Thresholds are the two devices most supported by extensive and high-quality published research [14]. However, the POWERbreathe only allows inspiratory training. Already the IMT and PEP Thresholds have insufficient training load range and a hard-plastic tube mouthpiece, which makes it challenging for some users to maintain an airtight seal. Furthermore, to train both inspiratory and expiratory muscles with the Threshold devices, it is necessary to acquire both models or to adapt the Threshold IMT, which adds to the cost of the device. To resolve these problems, the recent developed Orygen-Dual Valve, that received "yes" in all characteristics, that is, besides showing all the advantages of the other devices, it has sufficient training load range, a flexible flanged mouthpiece, and is able to simultaneously train both inspiratory and expiratory muscles. However, once it has been recently developed, more studies are needed to prove its efficacy in different health conditions. Furthermore, the Orygen-Dual Valve and the most of the reported respiratory trainers are based on mechanical threshold loading. A recent study compared the effects of an inspiratory muscle training protocol on inspiratory function in patients with chronic obstructive pulmonary disease using either a traditional mechanical threshold (IMT Threshold and POWERbreathe) and an electronic-tapered flow-resistive loading (POWERbreathe K-Series) [24]. The results showed that the participants, who were trained using the electronic device, tolerated higher training loads and achieved larger improvements in inspiratory function, than those, who trained with the mechanical device [24]. Thus, although the electronic technology has made the POWERbreathe K-Series an expensive device, this change has apparently also made it more effective. However, this new device, similar to the previous model, only allows inspiratory muscle training.

It is important to address that all mentioned devices have the potential to be used in several healthy conditions. However, the mechanisms behind the respiratory muscle weakness of a patient with chronic obstructive pulmonary disease may be completely different from those with stroke, for example. Therefore, the selection of the devices should not only rely on their technical characteristics, but also on the health condition, the nature of the impairments, and the purpose of the training. Consequently, although some devices appear to be more advantageous than others, it is not possible to make a general recommendation of the most suitable ones.

Finally, although these devices were developed to increase strength and endurance of the respiratory muscles, they also have shown to be effective in improving other clinical outcomes, such as pulmonary function (forced vital capacity, forced expiratory volume in the first second, peak expiratory flow, maximum voluntary ventilation, forced expiratory flow between 25% and 75% of vital capacity, vital capacity, tidal volume, expiratory reserve volume, inspiratory reserve volume, and inspiratory capacity), dysphagia, perceived exertion, cough, swallow, diaphragm thickness, chest expansion, respiratory complications, and levels of activity and participation [10-13,18-47]. These findings demonstrate the importance of respiratory muscle training for various health conditions and clinical outcomes. Thus, respiratory muscle training could influence not only strength and endurance measures, but also other clinical outcomes.

Besides the 14 devices reported in the present review, many other can be found on the market, such as the Inflex® (Respironics Inc., Murrysville, PA, USA) inspiratory trainer; The Breather® (PN Medical, Orlando, FL, USA) inspiratory and expiratory trainer; the Portex IMT (Smiths Medical, St Paul, MN, USA) inspiratory trainer; the ECHOTM Expiratory Muscle Trainer (Galemed, Fenjihu, TW, TW); the DHD IMT (DHD Medical Products, Canastota, NY, USA) inspiratory trainer; the PrO2TM (DeVilbiss UK Ltd, Stourbridge, ENG, UK) inspiratory trainer; the Eolos (Aleas Europe, Miami, FL, USA) inspiratory and expiratory muscle trainer; the Dofin™ Breathing Trainer (Galemed, Fenjihu, TW, TW) inspiratory and expiratory trainer; the Bravo Breathing Strength Builder (BreatheHome, Taipei, TW, TW) inspiratory and expiratory trainer; the Breath Builder™ (Windsong, Gurnee, IL, USA) inspiratory trainer; the Bas Rutten O_2 Trainer (BRK Inc, Las Vegas, NV, USA) inspiratory trainer; and the Pulmo-Gym/Luft (Pulmo-gym, Alberton, GT, ZA) inspiratory and expiratory trainer. However, since their mechanisms and effectiveness were not investigated, these devices were not included in this review.

This review has both strengths and limitations. The first limitation is that, although there were found 14 available devices reported by the literature, three were not described in detail. Besides the absence of information due to the low number of studies related to these three devices, these studies had low-to-moderate methodological quality, which make it difficult to discuss their effectiveness. Furthermore, 12 others devices also available on the market were not included in this review, due to lack of information. The second limitation is that some studies reported the use of incentive spirometers, such as the Voldyne, for respiratory muscle training [55], which were not considered in the present review. However, this decision was based upon the fact that these devices are not recommended for respiratory muscle training. In addition, previous findings demonstrated that training with the threshold devices is more effective in increasing strength, compared with training with incentive spirometers [56]. On the other hand, the main strength of this review is that it is the first to include a substantial number of respiratory muscle training devices. Furthermore, besides the description, this review summarized the main characteristics of the evaluated devices and provided detailed technical information, regarding their operating mechanisms, loading ranges, musculature to be trained, mouthpiece, besides other characteristics related to their clinical utility, such as cost, portability, and usability, amongst others.

Conclusion

There were found 14 respiratory training devices available on the market and reported by published studies. However, three were not described in detail, due to lack of information. Amongst the 11 evaluated devices, all of them showed positive aspects and limitations that should be considered. Although some devices appear to be more advantageous than others, it is not possible to choose the best one, based only upon their technical information and clinical utility. To select the most appropriate one, it is also necessary to consider the specific health condition, the nature of the impairments, and the purpose of the training. Furthermore, the professionals should also consider the purpose of the device, including whether it is for use within research or clinical contexts. Future studies with good methodological quality should investigate the efficacy of the other devices, which were not described in detail in the present review.

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