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LITERATURE REVIEW

Inspiratory Muscle Training in Elderly

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ABSTRACT

Introduction: The World Health Organization (WHO) defines an elderly individual as someone aged 65 years or older. With aging, the respiratory system undergoes structural and functional changes, leading to reduced pulmonary function, diminished exercise capacity, and increased susceptibility to respiratory diseases due to anatomical, physiological, and immunological alterations. Inspiratory muscle training (IMT) has been proposed as an intervention to counteract these age-related declines. Evidence suggests that IMT enhances inspiratory muscle strength, improves lung function, increases exercise tolerance and mobility, and promotes diaphragmatic hypertrophy in older adults. Thus, IMT may serve as a viable strategy to mitigate respiratory deterioration associated with aging.

Method: A literature search was conducted using PubMed, Google Scholar, and the Cochrane Library to identify original research articles on inspiratory muscle training in the elderly.

Results: IMT has been demonstrated to counteract physiological changes associated with aging, leading to improved respiratory function and overall physical performance.

Conclusion: Given its documented benefits, IMT represents a promising adjunctive or alternative training modality for older adults. This literature review further explores the implementation and effectiveness of IMT in the elderly population.

Keywords: Inspiratory muscle training, aging, respiratory function, diaphragm

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INTRODUCTION

Elderly or elderly people are individuals who have entered the final stages of life. WHO states that the elderly are individuals aged 65 years and over. The definition of elderly in Indonesia is stated in Law No. 13 of 1998, namely someone who has reached the age of 60 years and over.[1] In individuals with this stage, the aging process will occur. Aging is a complex biological process that gradually impairs physiological function. The cause of the aging process occurs due to the accumulation of various damages at the cellular level, which are called Hallmarks of Aging.[2,3] All organ systems in humans must experience the aging process and one of them is the respiratory system.[4]

With aging, the respiratory system undergoes gradual changes that reduce function, performance, and resistance to lung disease due to anatomical, physiological, and immunological shifts.[5,6] These changes specifically affect respiratory muscle strength in the elderly, leading to breathlessness, increased effort during daily activities, reduced exercise response, and lower functional lung capacity and activity levels.[7,8] Seixas et al[7]. reported that declining respiratory muscle strength is linked to higher mortality in older adults. One approach to enhancing respiratory muscle strength is inspiratory muscle training (IMT).[8]

IMT is performed by breathing against an external inspiratory load using a special device. IMT is very easy to implement, and is a rehabilitation intervention that is quite cheap and easy to apply[8]. Several studies report that IMT improves lung structure and function, increases inspiratory muscle strength, exercise capacity, mobility and diaphragm thickness in the elderly. Considering the benefits mentioned above, IMT is an alternative or additional exercise modality that can be used in elderly people, especially when other types of exercise are not possible.[7–9] In this literature review we will discuss further regarding IMT training in the elderly.

METHODS

This literature review provides a comprehensive overview of the current evidence on inspiratory muscle training in the elderly. The search for relevant English literature was conducted using PubMed, Google Scholar, and the Cochrane Library, focusing on articles published within the last 15 years. The search terms used included "inspiratory muscle training", "respiratory muscle training", "elderly", "older adults", "older people", "aging", "lung aging", and "respiratory muscle strength". The inclusion criteria for the studies were: 1) participants aged 60 years or older, 2) the intervention being inspiratory muscle training, and 3) the study reporting outcomes related to respiratory muscle strength, exercise capacity, or functional status. Studies were excluded if they were not published in peer-reviewed journals, did not have full-text availability, or did not assess the impact of inspiratory muscle training in the elderly population.

RESULTS

A narrative review of 40 articles from journals, books, and online databases was conducted.

DISCUSSION

Functional decline in the elderly

The aging process leads to a functional decline in the elderly. Reduced lung elasticity, airway enlargement, parenchymal tissue loss, decreased chest wall compliance, and weakened respiratory muscles impair gas exchange. Elderly individuals also tend to experience lung inflammation due to congenital immune disorders. As they age, the cough reflex and ventilatory response to hypoxia and hypercapnia decrease as well[10]. This damage process is the accumulation of various cellular-level changes associated with the Hallmarks of Aging.[2,3]

Structural Changes in the Respiratory System

Structural changes in the respiratory system also occur with aging. In particular, the thorax undergoes alterations such as vertebral height loss, vertebral body collapse, and increased kyphosis. These changes, along with greater sternal convexity, contribute to an increased anteroposterior thoracic diameter. Additionally, spinal degeneration, rib cage stiffness, and decreased chest wall muscle thickness result in reduced chest wall compliance, leading to diminished energy efficiency and increased respiratory effort. These age-related modifications also reduce diaphragm curvature and respiratory muscle mass, placing the diaphragm in a biomechanically disadvantaged position for effective contraction, ultimately impairing respiratory function.[10]

Changes in lung function

In healthy individuals, lung function develops fully by the age of 20-25 years, remains stable until around 35 years, and then gradually declines. This decline is evident in spirometry measurements, with forced expiratory volume in one second (FEV1) decreasing by approximately 30 mL/year and forced vital capacity (FVC) by around 20 mL/year, leading to a progressive reduction in the FEV1/FVC ratio.[11,12] The decline in FEV1 and FVC accelerates between the ages of 65 and 93, resulting in a flow-volume loop with a more obstructed expiratory limb. Aging also reduces gas exchange efficiency, as evidenced by a decline in resting arterial oxygen pressure and uneven alveolar blood distribution despite changes in alveolar surface area. Age-related pulmonary circulatory changes lead to increased pulmonary artery systolic pressure and decreased CO2 diffusion capacity. The diffusion capacity for carbon monoxide (DLCO) declines annually by 0.2 mLCO/min/mmHg in men and 0.15 mLCO/min/mmHg in women.[13] Additionally, pulmonary capillary blood volume gradually decreases due to reduced alveolar-capillary density and pulmonary vascular changes, leading to increased ventilation-perfusion mismatch and lower resting arterial oxygen levels in older adults. Reduced expiratory flow, increased tidal volume, and diminished exercise performance further alter ventilatory responses to physical activity, contributing to increased CO2 production and O2 consumption at all activity levels.[13,14]

Decline in muscle strength of the respiratory muscle

Respiratory muscle strength declines significantly between the ages of 65 and 85 in both sexes. Several parameters are used to assess this decline, including Maximal Inspiratory Pressure (MIP), Maximum Trans-Diaphragmatic Pressure (Pdi max), and Maximal Voluntary Ventilation (MVV). Aging-related muscle deterioration, such as sarcopenia (loss of muscle mass) and dynapenia (loss of muscle strength), also affects respiratory muscles.[8]

The respiratory muscle group includes both inspiratory and expiratory muscles. The diaphragm serves as the primary inspiratory muscle, supported by the parasternal internal intercostals, external intercostals, and accessory muscles. Expiratory muscles consist of the abdominal muscles and lateral internal intercostals. Beyond their role in ventilation, these muscles facilitate nonventilatory functions such as coughing, sneezing, the Valsalva maneuver, speaking, singing, and swallowing. Age-related declines in respiratory muscle strength can impair these essential functions, contributing to decreased respiratory efficiency and overall functional capacity.[14,15]

Changes in exercise capacity

Given the decline in lung function with age, it is expected that exercise physiology is also affected in the elderly. Aging is associated with increased expiratory flow limitation during exercise, elevated end-expiratory lung volume, and a higher dead space fraction at rest, all of which contribute to greater breathing effort.[3,15,16] Normally, exercise elicits an increase in tidal volume followed by a rise in respiratory rate; however, in older individuals, respiratory patterns shift toward lower tidal volumes and higher respiratory rates due to increased chest wall stiffness.

Maximal oxygen consumption (VO_2max), a key indicator of exercise capacity, declines with age, primarily due to cardiovascular changes and muscle mass loss. However, recent studies suggest that ventilation factors may also contribute to this decline[3,15,16]. Between the ages of 25 and 80, both lung function and aerobic capacity decrease by approximately 40%. While exercise training can help maintain ambulation muscle function, the age-related decline in lung function remains irreversible.

Airway clearance impairment

As individuals age, airway clearance becomes increasingly compromised due to several pathophysiological changes, including reduced respiratory muscle strength, a weakened cough reflex, and impaired mucociliary function. The decline in cough reflex sensitivity is linked to an increased activation threshold of the vagus and occipital nerves, decreased bronchial smooth muscle tone, and impaired cortical perception. Additionally, the weakening of respiratory muscles diminishes the effectiveness of cough in clearing secretions, increasing the risk of aspiration pneumonia in older adults.[13,17]

Changes in response to hypoxia and hypercapnia

Although tidal volume declines with age, minute ventilation is preserved through an increased respiratory rate. However, the elderly exhibit an inadequate ventilatory response to hypoxemia and elevated carbon dioxide levels. Studies indicate that the hypoxic response decreases by 50%, while the hypercapnic response declines by 40% in older adults. There is a progressive decrease in CO2 pressure thresholds associated with age. The underlying mechanism for this is still unclear, but it is thought that these changes may be caused by chemosensory receptor dysfunction and structural changes in the lungs and chest wall. Another study states that the need for ventilation to produce carbon dioxide increases during the aging process in elderly people aged between 56 and 85 years. These changes are caused by increases in end-expiratory-arterial carbon dioxide concentrations due to aging and ventilation or perfusion imbalances.[10,13]

IMT

Inspiratory Muscle Training (IMT) is an exercise or intervention aimed at increasing muscle strength and respiratory muscle endurance or delaying respiratory regression and increasing exercise tolerance. IMT is designed to strengthen the diaphragm and other inspiratory muscles. Extensively studied for decades, it has been recognized as both a rehabilitation tool and an ergogenic aid across healthy, clinical, and athletic populations, with generally positive outcomes. IMT is typically performed using an inspiratory muscle trainer, a cost-effective and easily accessible device.[8,18–20]

Types of IMT

Multiple forms of IMT exist, all of which primarily target the diaphragm, the main inspiratory muscle. Numerous studies have demonstrated that IMT effectively enhances inspiratory muscle strength and endurance, leading to improved dyspnea management, increased exercise capacity, better performance in daily activities, and an overall enhanced quality of life.[21] IMT can be performed either with or without specialized equipment. Non-device-based methods include diaphragmatic breathing, glossopharyngeal breathing, pursed-lip breathing, and segmental breathing exercises. IMT using equipment is generally classified into two types: inspiratory resistive trainers and inspiratory threshold trainers.[22]

The primary difference between these methods lies in their device mechanism, intensity control, and training load application. Inspiratory resistive trainers apply variable resistance during inspiration, where the patient inhales through a fixed-diameter orifice. A smaller orifice increases the training load, requiring greater inspiratory effort. However, this method lacks a consistent inspiratory load, as resistance is influenced not only by the diameter but also by the patient's inspiratory flow rate, leading to variability in training effectiveness.[22–24]

In contrast, inspiratory threshold trainers provide a fixed and constant inspiratory load, maintained throughout the inspiratory phase. These devices use a spring-loaded valve that requires the patient to generate a predetermined negative pressure to initiate airflow. The resistance level can be adjusted using a resistive load knob. Unlike resistive trainers, threshold trainers provide a consistent load independent of inspiratory flow, ensuring a more controlled training stimulus. However, their primary limitation is the inability to dynamically adjust resistance during exercise, potentially reducing adaptability to an individual's respiratory capacity.[22,23,25,26]

Training Load Optimization in IMT

The training load plays a pivotal role in maximizing the effectiveness of IMT prescription, as individualized programs typically determine intensity based on the subject's Maximal Inspiratory Pressure (MIP). While variations in load settings exist, the commonly used training range falls between 30% and 70% of MIP. IMT applied at intensities exceeding 30% of MIP has been shown to enhance the inspiratory muscles' pressure-generating capacity, leading to significant improvements in respiratory function. Additionally, higher training loads tend to produce greater gains in MIP. Evidence suggests that initiating IMT at 30-40% of MIP, with progressive increases of 5-10% every 7-10 days, optimally enhances inspiratory muscle strength, endurance, and overall respiratory performance. This progressive overload approach aims to gradually reach 60-80% of baseline MIP for maximal benefit. However, these adaptations are not permanent, as the beneficial effects of IMT diminish without continued training. To maintain the physiological adaptations induced by IMT, maintenance training should be conducted 2-3 times per week at the last prescribed training load.[25,27]

Benefits of IMT

The physiological adaptations associated with IMT include: (1) increased diaphragmatic hypertrophy, (2) a higher proportion of type I fibers and enlargement of type II fibers in the external intercostal muscles, (3) attenuation of the respiratory muscle metaboreflex, (4) reduced inspiratory muscle motor drive while maintaining pressure production, (5) improved respiratory muscle economy with lower oxygen consumption, (6) decreased perception of breathlessness or Rating of Perceived

Exertion (RPE), (7) reduced work of breathing, (8) enhanced respiratory muscle endurance, (9) improved ventilation efficiency, (10) reorganization of respiratory muscle recruitment patterns, (11) optimized breathing patterns during hyperpnea exercise, and (12) reduced cytokine release. While some of these physiological adaptations have been well documented in previous research, others remain subjects of ongoing study, with conflicting findings. Overall, these adaptations contribute to improved exercise performance and functional capacity in both athletic and clinical populations. IMT has demonstrated effectiveness in enhancing work and exercise capacity, likely due to increased ventilation demands and workload associated with load bearing activities. Consequently, strengthening respiratory muscle function may help optimize daily performance.[20]

IMT exercises are recommended in specific medical conditions or circumstances, particularly for individuals with inspiratory muscle weakness. Current consensus suggests IMT for those with a maximal inspiratory pressure (MIP) of less than 60 cmH_2O or a predicted forced expiratory volume in one second (FEV1) below 50%, as prior studies have demonstrated significant improvements in dyspnea, exercise tolerance, and daily functional capacity. However, even patients with higher MIP values have exhibited positive outcomes following IMT interventions.[28–31]

IMT has been widely applied in the management of chronic respiratory diseases, neuromuscular disorders, athletic conditioning, preoperative optimization, postoperative rehabilitation, and heart failure. Despite its benefits, certain contraindications must be considered. Patients with chronic obstructive pulmonary disease (COPD) requiring long-term oxygen therapy, those with a history of pneumothorax without a water seal drainage (WSD) system, individuals with tympanic membrane disorders, or those presenting with tachypnea, oxygen saturation abnormalities, costal fractures, or pulmonary bullae may not be suitable candidates. Additionally, IMT is contraindicated in patients with cognitive impairment, hemoptysis, pulmonary hypertension, or progressive neuromuscular disease, as these conditions may pose risks or limit the effectiveness of the intervention.[24,32–34]

IMT Effects

IMT has been extensively utilized in the elderly population, with numerous studies demonstrating its beneficial effects on respiratory function. IMT primarily enhances respiratory muscle strength in healthy older adults, contributing to improved pulmonary efficiency and overall physical performance. One of its key mechanisms involves delaying diaphragmatic fatigue by increasing the workload necessary to activate the metaboreflex while simultaneously improving the efficiency of the respiratory pump. Additionally, IMT induces structural adaptations, such as increased respiratory muscle thickness, which can indirectly enhance airway clearance, particularly by strengthening the cough reflex—a critical function often impaired with aging.[34]

Furthermore, IMT has been associated with improvements in lung function among the elderly, although findings remain inconsistent across studies. While some research highlights its positive impact on parameters such as forced vital capacity (FVC) and forced expiratory volume in one second (FEV1), others suggest that these effects are variable and may depend on individual baseline characteristics, training protocols, and underlying respiratory conditions. Further investigations are needed to clarify the extent of IMT's role in improving pulmonary function in older adults and to establish standardized training regimens for optimal outcomes.[34]

The Impact of IMT on the Structural Adaptations of the Respiratory System in Older Adults

With aging, the mechanics of breathing become increasingly inefficient, leading to greater work of breathing even during rest. Healthy aging is characterized by a progressive decline in lung compliance, contributing to airflow limitation, air trapping, and an increase in residual volume. These changes alter the curvature of the diaphragm, shortening its length tension relationship and placing it in a mechanically disadvantageous position. Consequently, inspiratory muscle strength and endurance decline, while oxygen consumption for breathing increases. In this context, interventions aimed at increasing diaphragm muscle thickness could provide significant mechanical benefits.[34]

A study by Mills et al.[35] demonstrated that an IMT regimen consisting of a 30-breath program, initiated at 50% of maximal inspiratory pressure (MIP) and progressively increased as tolerated, performed twice daily for eight weeks, significantly increased diaphragm muscle thickness. The study reported a mean increase of 0.53 mm (38%) in diaphragm thickness, as assessed by residual volume, with a statistically significant P-value of <0.05. These findings suggest that IMT induces a hypertrophic response in the inspiratory muscles of older adults.[35]

Similarly, research conducted by De Souza et al.[36] investigated the effects of an eight-week IMT program in elderly women, involving two sessions per day, seven days a week, consisting of eight sets of two-minute exercises with one-minute rest intervals at an intensity of 40% MIP. The study reported an increase in diaphragm motility and thickness at total lung capacity by 0.5 mm, reinforcing the role of IMT in promoting structural adaptations in respiratory muscles.[35,36]

In contrast, age-related changes in chest wall compliance remain a subject of debate. A study by Reychler et al.[37] found that while IMT resulted in minor improvements in chest wall expansion among elderly participants, the effect was statistically insignificant, suggesting that this parameter may not be meaningfully altered by IMT and warrants further investigation.[37]

The effect of IMT on muscle strength of the respiratory system in the older adult

Aging leads to reduced respiratory muscle strength, resulting in increased residual volume, functional residual capacity, and consequently greater work of breathing and associated dyspnea during daily activities in the elderly population. Inspiratory muscle training has been identified as an effective intervention to address this inspiratory muscle weakness.[7] The maximal inspiratory pressure is the most commonly utilized metric in studies to assess respiratory muscle strength. A study by Rodrigues et al.[24] enrolled elderly female participants and implemented an IMT regimen of 30 repetitions, twice daily, 5 days per week for 5 weeks, with an initial intensity of 30% MIP and progressive increases up to 50% MIP. This investigation reported a statistically significant improvement in MIP values from pre-IMT to post-IMT, with a p-value of less than 0.01.[34]

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Multiple studies have demonstrated that inspiratory muscle training can significantly improve maximal inspiratory pressure in elderly populations. Ferraro et al.[38] found a 45.9% increase in MIP after an 8-week IMT program of 30 breaths twice daily at an initial intensity of 50% MIP. Similarly, Mills et al.[35] reported a 34% MIP improvement with a statistically significant p-value of 0.008. Souza et al.[36] also observed a 26.3 cmH2O increase in MIP among elderly participants following IMT, though their study additionally noted improvements in maximal expiratory pressure. This finding is supported by Iranzo et al.[9], who found that IMT combined with yoga breathing therapy enhanced MEP in frail elderly, whereas IMT alone did not. In contrast, Reychler et al.[37] did not observe significant MEP changes with IMT in healthy older adults. These mixed results suggest that IMT may have secondary effects on expiratory mechanisms, warranting further investigation.[37] A systematic review and meta-analysis by Manifield et al.[7] assessed 7 randomized trials involving 212 elderly participants over 60 years old and concluded that IMT can significantly increase inspiratory muscle strength in the elderly. The reviewed studies generally employed IMT programs of 5-8 weeks, with intensities of 40-80% MIP and frequencies of 5-12 sessions per week.[7]

The effect of IMT on elderly lung function

Aging is associated with changes in lung function and capacity, characterized by reduced elastic recoil of the lungs, decreased chest wall compliance, and respiratory muscle weakness. Several studies have investigated the impact of IMT on lung function in the elderly, with conflicting results. Reychler et al.[37] conducted a study on healthy elderly individuals, involving a 4-week IMT program consisting of 15-minute sessions, 5 times per week, with a respiratory rate of 15-20 breaths per minute and a progressive increase in exercise intensity by 10 cmH2O per week. This study reported a modest increase in lung function, with a 12% improvement in forced expiratory volume in 1 second and a 16% increase in forced vital capacity[35]. However, these findings contrast with the studies by Mills et al.[35] and Rodrigues et al.[34], which did not observe any significant improvements in lung.

The effect of IMT on the exercise capacity of the elderly

Several studies have reported that inspiratory muscle training can enhance exercise capacity in older adults. For instance, a randomized controlled trial by Aznar-Lain et al.[39] found that IMT using an inspiratory threshold device led to improvements in inspiratory muscle strength, peak oxygen uptake (VO_2peak), time to exhaustion during a treadmill test with a fixed load, and the duration of moderate-to-vigorous physical activity in elderly individuals. The IMT program consisted of an incremental protocol implemented over 8 weeks, with an intensity ranging from 50% to 80% of maximal inspiratory pressure, 8-10 sets of 5-6 repetitions, 3-5 sessions per week, and a 1-minute rest break between sets. While this study reported an increase in the average VO2peak, the magnitude of change was relatively modest at 2.8 mL/kg/minute.[38]

The effect of IMT on airway clearance in the elderly

The underlying mechanism contributing to poor airway clearance in older adults involves a decline in respiratory muscle strength, a diminished cough reflex, and reduced mucociliary function. Coughing plays a crucial role in clearing mucus from the airways. The inspiratory muscles contribute to generating a large tidal volume, which in turn increases expiratory flow, leading to an effective cough. Kaneko et al.[40] conducted a study on healthy elderly individuals, where they implemented an IMT program consisting of 5 sets per day, 5 repetitions, 5 days per week, at an intensity of 50% MIP, over a 4-week period. While the IMT group exhibited a 23% increase in MIP, over a 4-week period. While the IMT group exhibited a 23% increase in MIP from baseline, this effect size did not yield a significant improvement in cough peak flow, MEP, FEV1, or FVC. Therefore, further research is needed to investigate whether a longer duration of IMT can effectively enhance CPF by increasing diaphragm mobility.[4]

CONCLUSIONS

The aging process that occurs in the elderly will progressively cause a decline in function in all physiological systems, one of which is respiration. IMT in the elderly has been proven to be useful in improving physiological changes due to aging, such as structure, function, muscle strength, exercise capacity and airway clearance. Specifically, IMT will increase inspiratory muscle strength in the elderly, however, in several studies such as lung function, exercise capacity and airway clearance, further research is needed to find out the right IMT program to achieve maximum results.

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