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Creating home-based pulmonary rehabilitation programs for patients with asthma: insights from practice

Cahidenur Koçak[1], Massimiliano Polastri[2], Esra Pehlivan[3]

[1]Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Esenyurt University, Istanbul, Türkiye
[2]Department of Continuity of Care and Integration, Physical Medicine and Rehabilitation, IRCCS Azienda Ospedaliero-Universitaria di Bologna, Bologna, Italy
[3]Department of Physiotherapy and Rehabilitation, Hamidiye Faculty of Health Sciences, University of Health Sciences, Istanbul, Türkiye

Pulmonary rehabilitation (PR) plays a crucial role in the management of asthma symptoms and addresses the physical, psychological, and social consequences of asthma. However, difficulties in accessing hospital-based PR programs could result in underutilization of these services. Alternative models such as home-based PR and telerehabilitation are promising in their potential to mitigate barriers and improve adherence. It is well known that PR has a significant positive impact on both respiratory and physical functions, as well as individual well-being. Indeed, such effects have been confirmed in several studies in which psychological symptoms (i.e., anxiety and depression), physical capacity, and health-related quality of life improved in patients with asthma. Nonetheless, to sustain treatment-related benefits in the long term, PR programs must be tailored to individual needs and planned using a multidisciplinary and holistic approach. Given the high prevalence of asthma in children, home-based PR programs may offer substantial benefits to the pediatric population and warrant further investigation. The present review describes the characteristics of home-based PR and provides evidence on current practices for the management of asthma and the development of a patient-centered therapeutic approach.

Keywords: Asthma; Bronchial hyperreactivity; Dyspnea; Exercise; Quality of life

Introduction

Asthma is a chronic, noncommunicable disease that affects both children and adults and has a higher morbidity and lower mortality rate than other chronic diseases [1,2]. The prevalence of asthma is increasing in both developed and developing countries, and it is estimated that 300 million people are affected worldwide [2-6]. Asthma is associated with airway hypersensitivity caused by chronic inflammation. Hypersensitivity is triggered by several factors, such as viruses, allergens, and intense physical activity. As a result, excessive narrowing of the airways occurs, and intermittent wheezing, dyspnea, cough, and chest pain of varying severities are observed [2,7]. Symptom intensity in asthma can vary from mild (managed with asthma action plans) to severe (requiring hospitalization) [8]. Remodeling of the airways may lead to bronchial hyperreactivity and consequently decreased physical activity levels and quality of life (QoL) [9,10]. The onset of asthmatic crises during physical activity is generated by exercise-induced bronchoc-

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Corresponding author: Massimiliano Polastri, PT, MSc
Department of Continuity of Care and Integration, Physical Medicine and Rehabilitation, IRCCS Azienda Ospedaliero-Universitaria di Bologna, Via G. Massarenti 9, Bologna 40138, Italy
Tel: +39-51-214-4980 • Fax: +39-51-214-4980 • E-mail: gbptap1@gmail.com

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onstriction (EIB). In people with asthma, the transitory airway narrowing occurring during or following exercise is produced by airway dehydration (resulting from increased ventilation during exercise), causing airway smooth muscle contraction [11,12].

There is growing scientific evidence supporting both pharmacological and non-pharmacological interventions for the prevention and management of asthma. Although medication is the mainstay of asthma treatment, non-pharmacological strategies can also play a supportive role. In particular, patients with asthma experiencing one or more exacerbations should consider non-pharmacological methods and interventions to control symptoms and reduce risks [13].

Pulmonary rehabilitation (PR) is recognized as one of the most effective non-pharmacological treatment modalities for the management of chronic obstructive pulmonary disease (COPD) and other chronic respiratory diseases. PR is a multidisciplinary intervention that includes exercise training, behavioral changes, patient education, and psychosocial and motivational support in a holistic manner [14,15]. Smoking cessation, acquisition of regular physical activity habits, and a meticulous review of pharmacological therapies are essential to induce changes in an individual's habits. PR aims to increase both exercise tolerance and health-related quality of life (HRQoL), and to preserve activities of daily living (ADL), and social roles as much as possible [16].

PR is primarily performed in hospitals or rehabilitative centers; however, it has been reported that home-based or hospital-home combination programs are at least as effective as center-based interventions, and that benefits related to treatment can last longer [17]. Despite the evidence and strong recommendations from guidelines, PR services remain insufficient. Factors such as scheduling programs at inconvenient times for patients and distances to centers play a critical role in low participation and completion rates. Poor transportation infrastructure, especially in low- and middle-income countries (LMICs), exacerbates these barriers [18]. In this sense, services offered in community-based centers, and programs such as telephone-assisted home-based PR and telerehabilitation are becoming increasingly important [19,20]. Rapid developments in telehealth and digital platforms have added new dimensions to home-based PR approaches, particularly for chronic respiratory diseases. These models increase access to rehabilitation, facilitate continuous patient follow-up, and provide access to educational resources, contributing to improved clinical outcomes [21].

Telehealth methods, including remote monitoring, telecounseling, and telerehabilitation, are becoming increasingly promising tools in the management of chronic respiratory diseases. In particular, interactive telehealth programs have provided significant benefits in chronic diseases such as COPD by reducing travel costs, increasing patient participation, and facilitating access to rehabilitation, and have emerged as effective alternatives [22]. In particular, the coronavirus disease 2019 (COVID-19) pandemic has led to the rapid evolution of PR programs to remote delivery models for infection control [23]. In a study conducted in individuals recovering from COVID-19 in Türkiye, telerehabilitation programs were shown to improve respiratory functions, lower extremity strength and functional status, and cardiac parameters, supporting the assumption that telerehabilitation is a safe and effective option, especially for individuals who live far from the center or have limited access to healthcare facilities [24]. Therefore, these concepts can be extended to patients with asthma, and in addition to pharmacological treatments, the integration of holistic, individual-oriented strategies is vital to reduce the burden of disease, increase symptom control, and improve QoL in such patient populations.

This review provides evidence of current practices in the management of asthma and the development of a patient-centered therapeutic approach.

Core components of pulmonary rehabilitation for patients with asthma

PR has been shown to reduce respiratory symptoms and hospitalization rates [25,26]. Various studies have shown that PR increases exercise capacity and symptom control in patients with asthma at any stage of the disease, improves QoL, and is effective in reducing wheezing, anxiety, depression, and bronchial inflammation [27,28].

The Global Asthma Initiative (GINA) 2025 report emphasizes the importance of PR and physical activity [29]. Indeed, PR offers multifaceted benefits such as decreased dyspnea, increased exercise capacity, improved HRQoL, and reduced healthcare utilization in patients with COPD [14,30]. However, it is important to note that much of the existing evidence primarily stems from COPD populations, and owing to the limited number of asthma-specific studies, direct generalization of these findings to patients with asthma should be approached cautiously.

Symptoms such as dyspnea, exercise intolerance, fatigue, anxiety, and depression are not only specific to COPD but also are common in many chronic respiratory diseases, including asthma. Indeed, a growing number of studies have shown that PR positively affects exercise capacity and QoL in patients with asthma [27,31]. Therefore, the presence of similar pathophysiological processes supports the use of PR as an effective therapeutic approach for asthma.

PR programs implemented to address respiratory conditions

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such as COPD and asthma, adopt a comprehensive and multidisciplinary model that integrates various elements, including clinical evaluation, aerobic and strength-focused exercise training, occupational and nutritional therapies, educational sessions, smoking cessation guidance, and psychological support [32]. Such a comprehensive approach includes the development of self-management skills, psychological assessment and management, adaptations for comorbidities, and nutritional support, and aims to improve not only the physical but also the psychological and social well-being of patients [33].

Although rehabilitation programs for chronic respiratory diseases were initially established in inpatient models, the increasing number of patients and the need to support outpatient or home-based care present challenges to current treatment approaches [34]. Difficulties in accessing rehabilitation, financial constraints, limitations in patient mobility, and the need for regular supervision have emerged as significant barriers in the management of chronic respiratory diseases, especially asthma [35]. Home-based applications offer practical and feasible rehabilitation options when access to PR is limited [36].

Different exercise modalities that produce different effects [37] are the core components of PR programs, together with other aspects related to personal domains (Fig. 1).

Self-management training

Self-management is defined as the actions that patients take to control their asthma, including engagement in health-promoting practices to prevent and manage acute symptoms [38]. Self-management training enables patients to recognize respiratory symptoms, use medications correctly, participate regularly in exercise programs, and take appropriate measures in case of asthmatic attacks. Such training positively affects QoL by increasing treatment adherence and enabling a more conscious management of disease processes [39]. Although reliable and comprehensive information was lacking for patients with asthma until the 2010s [40], skills such as energy-saving techniques and strategies to cope with dyspnea are part of self-management and can be effectively improved now with remote delivery of care, web-based self-management systems, social media, and mobile health applications [41,42]. Telehealth behavioral support provided more than once per month can enhance asthma control [43]. Self-management education in asthma can significantly reduce disease burden and improve outcomes, particularly if implemented early in life and at the primary school level, because of poor adherence to treatment in youths and children [8,44-46].

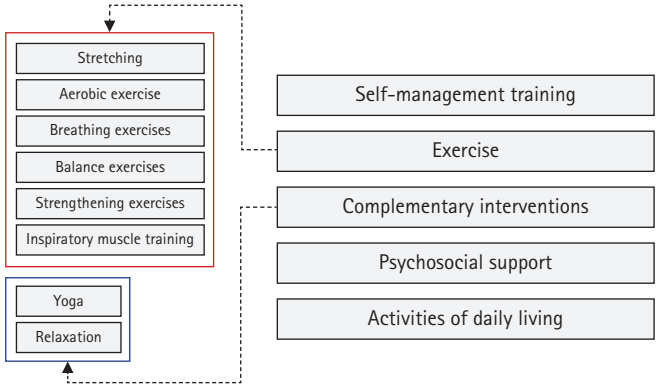


Fig. 1. Core components of pulmonary rehabilitation in asthma.

Exercise

1. Stretching

In asthma and chronic respiratory diseases, warm-up exercises play an important role in preparation for more intense physical activity. These exercises consist of active stretching movements targeting the upper and lower extremity muscle groups (with each position executed for an average of 30 seconds). Sessions include light-paced breathing and muscle warm-up movements lasting approximately 5 minutes, abdominal breathing practices, and simple movements focused on relaxation [47]. While warm-ups and stretching exercises contribute to alleviating respiratory symptoms and preparing for more complex activities, they also improve asthma control [48,49].

2. Aerobic exercise

Exercise training is widely accepted as an adjunct therapeutic option for drug-based treatments [4,11,50,51]. Individuals with asthma are less likely to engage in exercise than those without asthma, although exercise has positive effects on muscle function, lung function, and QoL [52]. Aerobic exercise is an essential component of home-based PR, increasing cardiopulmonary endurance, improving oxygen utilization, and facilitating participation in daily life. Easily accessible activities such as brisk walking, stair climbing, stationary bicycling, and stepping in place are frequently preferred [47]. A typical format could be 3 to 5 days per week for 20 to 40 minutes per session for 12 weeks, with the intensity determined according to the clinical condition of the patient (usually maintained at a moderate level [Borg scale 4–6] and 60% to 80% of the maximum heart rate), although the frequency, intensity, duration, and type of exercise for patients with asthma can vary [53-55]. Regular aerobic exercise increases exercise capacity and respiratory efficiency and has positive effects on QoL and mental health [56,57]. A systematic review involving 543 adults (mean age, 36.5 years) with

mild to moderate asthma found that exercise training had a median length of 12 weeks and consisted of both supervised and unsupervised exercises that included indoor cycling, treadmill use, walking, and unspecified aerobic training, with most studies targeting an exercise intensity of 70% of the maximal heart rate [58]. In that study, exercise training resulted in improved asthma control, as determined by the Asthma Control Questionnaire (ACQ) score decreasing from 2.0 to 1.4; lung function also improved with a standardized mean difference of –0.36, while the intervention had no effects on markers of airway inflammation [58].

These findings were confirmed by another systematic review, in which aerobic exercise (outdoor exercise, high-intensity interval training, and rowing) intensity was predominantly measured using maximal heart rate, peak power output, and step-based measurements [59]. Aerobic activities contributed to improving asthma control, with ACQ scores decreasing from 2.0 (initial) to 1.3 (2 weeks post-intervention) to 1.2 (3 months post-intervention) [59]. Aerobic training has been found to specifically elicit improvements in the following domains: QoL—measured using the Asthma Quality of Life Questionnaire (AQLQ)—and pulmonary function, namely forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), and peak expiratory flow (PEF) [37]. Eventually, different aerobic exercise intensities (moderate versus vigorous) seem to result in overlapping outcomes, suggesting that both are suitable for integration into the non-pharmacological treatment of asthma [60]. Indeed, in a 12-week randomized trial, 27 patients were allocated to moderate-intensity (45 minutes, three times per week, 55%–70% of maximum heart rate) and vigorous-intensity (30 minutes, three times per week, 70%–90% of maximum heart rate) aerobic-training groups. In the moderate-intensity group, there were clinically significant improvements in both ACQ and AQLQ scores, whereas in the vigorous-intensity group, the improvements were not clinically significant [60].

3. Breathing exercises

Breathing exercises are essential components of home-based PR to improve respiratory function, reduce breathlessness, and enhance QoL, and are recommended to improve asthma control [61]. Diaphragmatic breathing is the most used technique and is usually practiced for two to three sessions per day, each lasting 10 to 15 minutes. During the exercises, slow and controlled inspirations through the nose and expirations through the mouth are encouraged and supervised. In addition, the pursed-lip breathing technique and diaphragmatic breathing can help reduce dyspnea by slowing expiratory airflow [62,63].

The effects of breathing exercises in the form of relaxed breathing focusing on nasal and diaphragmatic breathing were compared with those of aerobic training (40-minute sessions at 60% of the maximum heart rate) in a trial conducted among patients with asthma [64]. Individuals who were allocated to the breathing-exercise group showed fewer improvements in ACQ, fewer symptom-free days per month, and performed worse on the incremental shuttle walk test than those who were allocated to the aerobic-training group. Patients performing aerobic training had a lower percentage of eosinophils than those performing breathing exercises at baseline; in both groups, post-intervention, the total hospital anxiety and depression score improved by ≥ 1.5 points, as well as daily life physical activity. Indeed, daily steps increased from 9,186 to 11,192 in the aerobic-training group and from 8,809 to 10,796 in the breathing-exercise group [64].

In another study, breathing exercises were added to usual care in a group of 94 patients with asthma, resulting in sustained improvements in the Mini-AQLQ at the 3-, 6-, and 12-month follow-up [65]. In that study, the breathing techniques primarily consisted of nasal inhalation; breathing from the diaphragm and lower chest; normalization of the tidal volume; shoulder, neck, tongue, and jaw relaxation; exhalation to functional residual capacity; exhalation prolongation and/or a breath-hold technique (if respiration frequency was elevated); and starting at a relaxed body position progressing to use during physical activity [65].

4. Balance exercises

Balance exercises play a crucial role in lowering the risk of falls and increasing functional independence, especially in individuals in advanced age groups and those with severe respiratory disease who are more prone to develop changes in posture and balance [66,67]. Indeed, in patients with asthma and an FEV_1 < 74%, the degree of hyperinflation may contribute to increased trunk muscle activity, resulting in increased body rigidity [67]. Balance exercises consist of various components such as posture correction, standing, walking, and coordination exercises to improve static and dynamic balance. Regular balance exercises increase the safety of patients in daily life activities by strengthening postural control, positively affecting QoL. In a study of patients with asthma, core stabilization exercises resulted in improved dynamic balance after a 6-week intervention program [67]. Balance training has been shown to be effective at enhancing postural control in children with asthma; in a study of 19 children (mean age, 11.1 years), significant differences in the total center of pressure velocity were observed [68]. The duration and frequency of the exercises are tailored according to the general health status and individual needs, although they are usually scheduled for several sessions per week [57].

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5. Strengthening exercises

In patients with chronic respiratory diseases, decreased peripheral muscle strength results in a more sedentary lifestyle, as the patients become prone to long-term exercise intolerance [69]. Such a condition is more pronounced when combined with physical inactivity, which is frequently observed in patients with asthma. Furthermore, medications commonly used in the treatment of respiratory diseases, such as glucocorticoids and β2-agonists, can cause muscle atrophy and loss of muscle strength [70]; these physiological changes result in a decrease in patient fitness levels, an increase in dyspnea, and a greater need for ventilation during exercise [71]. In this context, the significant decrease in peripheral muscle strength observed in children and adolescents with severe asthma highlights the need for interventions aimed at supporting muscle function [72]. Muscle-strengthening exercises have become a fundamental component of home-based physical rehabilitation programs. These exercises, performed with elastic bands or light weights, target the upper and lower extremity muscle groups. The frequency of application generally varies between 2 and 3 days per week, with 8 to 10 repetitions and 1 to 2 sets recommended for each muscle group. Exercise intensity is gradually increased according to individual capacity, and the session duration is typically scheduled for 20 to 30 minutes [47,57].

Exercise training not only contributes to the development of muscle endurance but also helps individuals become more independent and functional in their daily activities [71]. Studies demonstrating the positive effects of resistance exercise in patients with asthma have further reinforced the importance of strengthening exercises. For example, one study reported that resistance training improved clinical control levels in individuals with asthma [73]. Additionally, a Cochrane review found that physical training programs combining aerobic and resistance exercises are generally well-tolerated by patients with asthma with clinical stability and are associated with positive clinical outcomes [74]. These programs should be designed to include low-resistance (Borg scale, 5–6) and high-repetition (10–15 repetitions, two to four sets) exercises, and sets with long rest periods (3–4 minutes) between sets, focusing on large muscle groups, reducing the risk of EIB, and increasing exercise sustainability [75]. Findings indicating that such structured resistance programs are safe and effective are particularly noteworthy. One study demonstrated that resistance training safely improves muscle conditioning in individuals with asthma and reduces the risk of developing EIB. These findings suggest that physical activity plays a supportive role in asthma management [76]. Similarly, a randomized study compared the effects of aerobic and resistance exercises on QoL and reported that both interventions resulted in significant improvements ($p = 0.01$) [77]. This finding suggests that the combined use of different types of exercise has positive effects.

In addition, in a 12-week randomized controlled intervention study, one group participated in a program that included aerobic and resistance exercises, whereas the other group received only nutritional and psychological support. The results showed that the exercise group achieved a statistically significant increase of 0.9 points on the asthma control test ($p < 0.001$), whereas no such improvement was observed in the group that received supportive care only. These results clearly demonstrate that exercise-based interventions can positively affect not only symptom management but also overall disease control and QoL [78].

6. Inspiratory muscle training

Respiratory muscle dysfunction can also occur in patients with asthma [79,80]. Inspiratory muscle training (IMT) is an effective method to increase respiratory muscle endurance, improve exercise capacity, and reduce dyspnea in patients with asthma [81]. Inspiratory muscles respond to training like skeletal muscles and can be trained using inspiratory training devices (resistive and threshold devices) [82]. A systematic review found that threshold devices are the most used for IMT with load training ranging from 15% to 80% of the maximal inspiratory pressure, with durations varying from 10 to 30 minutes per session or 60 to 90 repetitions twice per day, and frequencies from 2 to 7 days per week in programs lasting from 3 weeks to 6 months [83]. IMT can produce a significant gain in maximal inspiratory pressure (21.95 cmH_2O), which is above the minimal clinically important difference for COPD (17.2 cmH_2O), and reduce the use of short-acting β2-agonists [83]. In a recent randomized controlled trial, IMT was performed at home and supervised via videoconferencing for 8 weeks; respiratory muscle strength, exercise capacity, dyspnea intensity, and QoL were evaluated. The study findings showed that high-intensity training was more effective in achieving asthma control and increasing exercise capacity, supporting the applicability of IMT at home and revealing that it can provide important clinical gains when personalized [84]. Similarly, in another randomized controlled study, IMT was applied at home with telerehabilitation support for 8 weeks; the intervention resulted in significant increases in inspiratory muscle strength and consequent improvements in functional exercise capacity and dyspnea [85]. By strengthening the respiratory muscles, patients can perform their ADL more easily, increase their participation in social life, and significantly improve their QoL. In addition, increased respiratory muscle endurance can alleviate symptoms both during the day and night, thereby reducing the frequency of bronchodilator administration [86].

Complementary interventions

Complementary methods such as relaxation techniques and yoga-based practices can be included in programs to reduce respiratory-related stress and anxiety, leading to patient relaxation and improvement in respiratory function [87]. Stress can elicit increases in parasympathetic vagal activity and could be related to worsening symptoms in patients with asthma [88,89].

1. Relaxation

A study conducted in 30 patients with asthma found that relaxation is a valid option for improving QoL and anxiety [90]. In that specific research, relaxation (six sessions for 6 weeks) was proposed in the form of the Papworth method, which is behavioral training that focuses on more effective breathing and positions to facilitate breathing. In this technique, patients are taught to use the diaphragmatic muscle and nasal breathing, and to recognize and control stressful conditions. Patients are encouraged to integrate appropriate breathing and relaxation techniques into daily activities [90,91]. Relaxation can modify respiratory parameters as demonstrated in a study where patients with asthma were subjected to functional relaxation; FEV_1 (% predicted) improved by 7.6% ± 13.2% post-intervention, which was sustained at 1-year follow-up [92]. In that study, functional relaxation consisted of positive stimulation of the autonomic nervous system and facilitation of proprioceptive awareness with minute movements of the small joints performed during expiration, accompanied by a focus on perceived differences in body feelings triggered by movements [92].

2. Yoga

Yoga involves an ethical lifestyle, spiritual practice, physical activity, breathing exercises, and meditation [93]. Yoga is mostly practiced for increasing energy, enhancing immune function, promoting health, preventing disease, maintaining emotional well-being, seeking pain relief, and feeling a sense of community, although personal time available for practice, costs, lack of information about access to yoga classes, and stereotypes related to flexibility are common barriers to its practice [94]. Yoga is used as a complementary treatment for dozens of conditions, including physical fitness, cognitive function and emotional well-being, stress and psychological disorders, cardiovascular conditions, pain syndromes, auto-immune and immune disorders, and aging [94]. Although yoga is safe, adverse effects have been reported; therefore, yoga should be practiced under the supervision of a qualified instructor [94,95]. In a study where patients with asthma attended 30-minute daily yoga lessons, 5 days per week for 6 months, the intervention resulted in increased hemoglobin (from 11.7 ± 1.43 to 12.58 ± 1.46 g/dL), decreased eosinophils (from 9.05% ± 1.62% to 4.71% ± 1.19%), and decreased monocytes (from 5.24% ± 1.54% to 1.98% ± 1.09%) [96]. A meta-analysis found that yoga was effective in improving pulmonary function (FEV_1, FVC, and PEF) and HRQoL if breathing techniques were employed [93]. Practicing yoga for 90 days produced positive effects on QoL, anxiety and depression, and pulmonary function (FVC, 1.4–2.3 L; FEV_1, 0.8–1.45 L; PEF, 1.2–2.2 L/min) among a group of patients with asthma [97]. Improvements in pulmonary function have been confirmed in other studies: a meta-analysis where the standardized mean differences for FEV_1 and FVC in favor of yoga were 0.96 and 0.95, respectively [98]. In a randomized trial, FEV_1 and FVC improved after treatment, increasing from 2.66 ± 0.77 L to 3.14 ± 0.83 L, and 3.37 ± 0.80 L to 3.82 ± 0.92 L, respectively [99].

Psychosocial support

Stress exposure at both the individual and community levels has been linked to increased asthma morbidity [100-103]. Indeed, emotional arousal (produced by vagal activation) elicits airway constriction in patients with asthma [104]. Concurrently, consistent associations between asthma and anxiety disorders (panic disorder, panic attacks, generalized anxiety disorder, and phobias) have been confirmed in several studies [105-107]. Poor asthma control—with approximately 50% of patients not adhering to inhaled corticosteroid medication—altered perceptions of airway obstruction (underperception and overperception of symptoms), illness beliefs, and general health behaviors can influence clinical outcomes [104].

Psychophysical interventions include relaxation techniques, motivational approaches, and social support mechanisms (Fig. 2). These approaches support the psychophysical well-being and improve treatment adherence and QoL of patients [104]. The integration of psychosocial support into the rehabilitation process is of great importance for reducing patient anxiety and contributing to more effective self-management [53,108].

Activities of daily living

ADL are tasks of daily life and include essential activities necessary for independent daily life such as eating, bathing or showering, dressing, getting into or out of a bed or chair, getting around inside the home, climbing stairs, doing housework, gardening, and walking [109]. These activities, performed at an intensity close to the dyspnea threshold, play an essential role in maintaining the physical capacity of patients and improving their QoL. In addition, such

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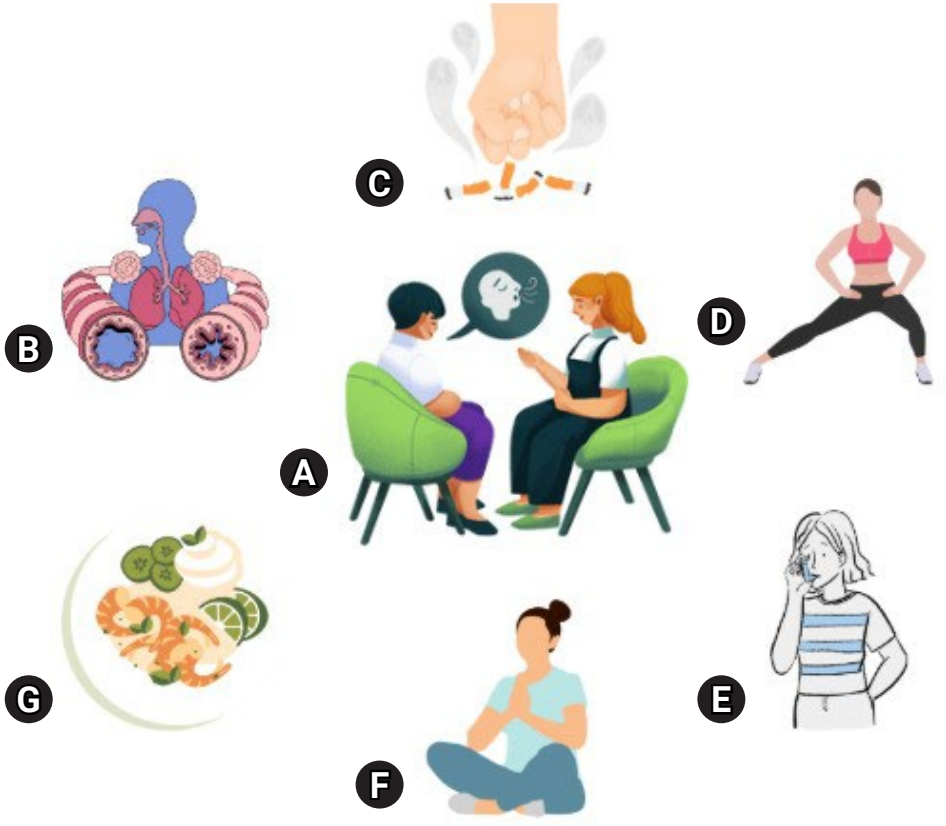


Fig. 2. Psychophysical interventions in asthma. (A) Psychotherapy, (B) perception of airway obstruction, (C) smoking cessation, (D) exercise, (E) adherence to inhaled medication, (F) relaxation, and (G) nutrition and diet.

activities strengthen the independence of individuals, and thanks to the training and guidance provided by PR, it is possible to maintain activities safely and effectively [27]. The most prevalent problematic ADL in asthma patients are walking, household activities, and climbing stairs [110]. This is essential information because it supports the assumption that exercise and physical interventions can ameliorate ADL in patients with asthma.

Home-based pulmonary rehabilitation and asthma

Home-based PR programs offer an attractive alternative for improving functional capacity and respiratory parameters in adults with asthma who cannot be fully supervised for various reasons. Home-based PR is a practical and effective alternative to hospital-based programs to overcome access limitations, reduce costs, and minimize patient mobility problems, thus strengthening treatment strategies for chronic respiratory diseases, such as asthma [27]. Home-based PR aims to provide patients with essential core components and low-cost resources remotely. In a randomized controlled trial, home-based models were equivalent to center-based programs in short-term outcomes [111]. In addition, home-based programs have been reported to be safe, increase functional exercise capacity, and improve clinical outcomes [112-115]. Home-based PR is usually conducted using a structured teaching program that includes comprehensive diagnostic assessments and motivational interviews [116]. Home-based PR can provide significant benefits by increasing access and utilization rates for different chronic respiratory diseases. Nevertheless, sustaining the long-term effects and ensuring that patients adopt a more active lifestyle remain significant challenges [117,118]. Randomized controlled trials should focus on defining the optimal components, intensity, duration, and patient selection criteria of home-based PR programs to establish standardized evidence-based protocols tailored to diverse asthma populations [112,113].

Studies of patients with different respiratory diseases have shown that home-based PR programs are safe and effective. For example, home-based PR applied 5 days per week for 2 months in patients with COPD provided similar results to hospital-based PR in terms of exercise capacity, dyspnea perception, and QoL [119]. Furthermore, a systematic review of 49 studies, including patients

with COPD, bronchiectasis, and interstitial lung diseases, showed that home-based PR led to safe and clinically meaningful outcomes [120]. In another study conducted in patients with bronchiectasis, an 8-week home-based PR program led to significant improvements in physical capacity, QoL, and muscle strength [47]. These results demonstrate that home-based rehabilitation is an effective method in the treatment regimen of various respiratory diseases and suggest that similar applications may be helpful for patients with asthma.

Although there have been findings on the efficacy of home-based PR for different chronic respiratory diseases, studies on patients with asthma are limited. The necessity of PR in asthma becomes more evident when additional psychosocial factors are frequent determinants of asthma severity and control, especially in severe cases [103,121-123]. Accordingly, in a study examining the effects of home-based PR on hyperventilation symptoms, anxiety, depression, general fatigue, HRQoL, and exercise capacity in adults with severe asthma exposed to psychosocial chronic stressors, patients participated in an 8-week program that included supervised home sessions of 90 minutes once per week, and muscle-strengthening equipment such as bicycle ergometers, dumbbells, and elastic bands were additionally provided. At the end of the study, the group exposed to chronic stressors scored higher in anxiety symptoms and hyperventilation, and lower in HRQoL than those not exposed to chronic stressors. Minimal clinically significant improvements in anxiety, depressive symptoms, fatigue, and QoL were observed in both groups [124]. In another study conducted in patients with severe asthma, the short- and long-term effects of home-based PR were compared to those in patients with COPD. In this study, a program consisting of 1.5-hour home visits once per week for 8 weeks, exercise training, physical activity reinitiation, therapeutic education, and self-management components was implemented. Follow-up evaluations were performed before, after, and 12 months after PR. The results showed that there were significant long-term increases in exercise tolerance and QoL in patients with severe asthma, but there were no significant changes in anxiety and depression parameters [53].

Therefore, it is essential to determine the components of home-based PR. The limited reach of center-based programs has increased the importance of alternative approaches such as home-based PR and telerehabilitation. The 2021 American Thoracic Society (ATS) workshop report, organized to reach a consensus on the basic components of PR and to determine the requirements for the successful implementation of new program models, addressed the safety and effectiveness of these models and stated that programs including exercise training, structured education, and behavioral change are consistent with the definition of PR [15]. The report defined the core components of PR as comprehensive patient assessment, program-content planning, determination of the implementation method, and quality assurance. These core components of PR identified through the Delphi process were found to be consistent with the results of a global survey involving PR professionals representing 430 programs. In this context, home-based PR should include not only aerobic and resistance exercises but also elements such as structured education, self-management support, psychosocial interventions, and nutritional counseling. However, evidence on how education and other components should be delivered in different models remains limited, highlighting the need for further research on standardization and effective delivery methods [125].

The success of home-based rehabilitation programs largely depends on patient adherence. However, treatment adherence is often low. For example, it was reported that patient adherence to home-based programs was only 51% [126]. Barriers to adherence arise not only from clinical factors such as disease flare-ups, anxiety, and depression but also from social factors such as low socioeconomic status and limited social support [127,128]. A study conducted in China emphasized that monitoring was limited because approximately half of older individuals lived separately from their children, and that limited health resources in underdeveloped regions and high out-of-pocket costs in western areas hindered long-term rehabilitation guidance [129]. These findings reveal that despite the accessibility advantages of home-based PR, it may encounter significant challenges in different social contexts.

In a randomized controlled trial comparing home-based and center-based programs, home-based programs requiring minimal resources were effective in the short term; however, neither home-based nor center-based models were able to maintain their benefits at 12 months [111]. This indicates that the effectiveness of home-based PR must be made sustainable in the long term. High dropout rates, methodological limitations, and lack of implementation of basic PR components in some programs are prominent issues in the literature [112,130]. Therefore, home-based PR is an accessible and effective option in the short term; however, for long-term success, strategies to increase patient adherence and supportive policies at the healthcare system level need to be developed. Furthermore, the ATS/European Respiratory Society (ERS) statement from 2015 highlights that telerehabilitation is an important alternative that could increase patient participation in the long term [131]. Future studies examining how exercise training, self-management support, and psychosocial components can be implemented more effectively and sustainably using this method could help to strengthen patient adherence and generate more cost-effective solutions for healthcare systems. However, for home-

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based PR to be widely adopted, certain conditions must be met not only in terms of clinical effectiveness but also in terms of health policies [132]. Reimbursement mechanisms are critical for the sustainability of programs and long-term patient participation. For example, reimbursement practices under Medicare and the Centers for Medicare & Medicaid Services in the United States remain limited, and virtual PR payments, which were supported for a short period during the pandemic, ended in 2023. This situation makes it difficult for patients with limited access to center-based PR to benefit from home-based and telerehabilitation programs [133]. The ATS and ERS report also emphasizes that telerehabilitation is an alternative model that could increase long-term participation, while patient associations and professional organizations continue their advocacy efforts in this area [131,133]. The "Sustainable Cardiopulmonary Rehabilitation Services in the Home Act" (H.R. 1406 and S. 3021) introduced in the United States aims to include permanent telerehabilitation applications within the scope of reimbursement [134]. Such regulations can contribute to reducing practical problems, such as long distances, travel costs, and barriers to accessing centers, thereby enabling improved participation and health outcomes. However, the current reimbursement policies are inadequate and unequal in many countries. Therefore, raising awareness among patient associations, professional organizations, and policymakers and strengthening reimbursement policies are critical for the sustainability of home-based PR [133].

Integrating home-based pulmonary rehabilitation into clinical practice

The updated GINA recommendations emphasize that non-pharmacological interventions, such as improving medication adherence, ceasing smoking, encouraging physical activity, eating a healthy diet, avoiding indoor allergens, including respiratory exercises, and managing emotional stress, play an important role in improving asthma control, and these elements constitute the core components of PR programs [29]. Home-based PR programs are recommended, especially for adults with severe asthma, because they significantly improve hyperventilation symptoms, anxiety, depressive symptoms, fatigue, QoL, and exercise capacity [124]. A meta-analysis showed that regular physical activity may reduce the risk of developing asthma in children, adolescents, and adults. Furthermore, a review covering individuals aged ≥ 8 years with varying degrees of asthma severity revealed that structured physical education significantly improves cardiopulmonary fitness and exercise capacity [31,135]. Similarly, the fact that asthma is one of the most common causes of hospitalization in children and that lung function and QoL play critical roles in the development of children [136-138] makes home-based PR programs prominent for pediatric patients. Therefore, there is a critical need to expand both the research and clinical applications of PR specifically tailored for children with asthma. Such efforts should focus on developing age-appropriate multidisciplinary interventions that address the physiological growth and psychosocial challenges unique to pediatric populations. These programs, which are cost-effective, accessible, and significantly improve QoL, offer important advantages, especially for children [49]. In addition, PR should be defined as an evidence-based, multidisciplinary, and comprehensive approach for patients with chronic respiratory conditions who are symptomatic and have restricted ADL [139]. An increasing number of outpatient and home-based practices have begun to replace inpatient programs in the face of increasing patient burdens [30]. Such a framework paves the way for home-based PR programs, which are also economically advantageous and recommended owing to their potential to reduce exacerbation frequency and improve physical capacity in patients with persistent asthma who are under optimal pharmacological treatment [56].

Guidelines published by the ATS and the ERS emphasize that home-based PR programs can be safely implemented as long as they are supervised by a healthcare professional at least once per week [140]. In addition, it has been demonstrated that short-term (i.e., 3-week) PR programs can provide clinically significant improvements in asthma control and secondary outcome measures [141]. However, maintaining the long-term effects of home-based PR programs is not always feasible. The literature indicates that this situation is associated with high dropout rates, methodological limitations, and the lack of implementation of basic PR components in some programs [112,130]. To reduce adherence issues, it is recommended that alternative models such as home-based PR and telerehabilitation provide regular feedback, encourage family participation, and use motivational interviewing techniques [22,111]. However, limited reimbursement policies in many countries make it difficult to integrate home-based programs into clinical practice consistently. At this point, patient associations and professional organizations must strengthen reimbursement policies, considering the cost-effectiveness of home-based models, to increase patient adherence and reduce the burden on the healthcare system [131,133,134].

Barriers to home-based pulmonary rehabilitation in low- and middle-income countries

The World Bank classifies economies into four income groups:

low, lower-middle, upper-middle, and high income [142]. According to the World Bank classification, the gross national income per capita in LMICs is between ≤ $1,145 (low-income countries) and $1,146 to $4,515 (middle-income countries). Most low-income countries are in Africa (e.g., Mali, Mauritania, Malawi, Niger, Chad, Sudan, and Zimbabwe), the Middle East (e.g., Syrian Arab Republic, Jordan, and Yemen), and Asia (e.g., Pakistan, Bangladesh, India, Nepal, and Kyrgyzstan), with some countries in Central America (e.g., Nicaragua and Honduras) and South America (e.g., Argentina and Bolivia) [142]. LMICs contribute 85% of the global burden of COPD [143], and it can be assumed that asthma is likely to shadow these figures. The impact of asthma on LMICs has stimulated research on how asthma is addressed in resource-limited settings. In this regard, one study defined 18 clinical standards to address appropriately the diagnosis and management of asthma in LMICs, including the importance of personalized action plans and receiving education on asthma, all of which have been identified as crucial aspects of the diagnostic and therapeutic regimen [144].

As already outlined in the Introduction, PR could be challenging to implement in LMICs because of several factors such as distance to centers and poor transportation infrastructure [18]. From a professional perspective, a qualitative interview-based study conducted among seven participants (five physiotherapists, one family physician, and one pulmonologist) found that the principal barriers to PR were limited resources, including the availability and quality of equipment needed, a shortage of PR expertise, and related costs for the patient. Tele-PR has also been found to facilitate access to care, particularly during the COVID-19 pandemic [145].

From a patient's perspective, in a study involving 15 patients with chronic respiratory diseases (including asthma), participants expressed a lack of clarity regarding the utility of home-based PR, as they affirmed that it was unclear how home-based PR could help their respiratory symptoms [146]. A few respondents preferred center-based PR because of reduced anxiety and depression and the opportunity to share views with people facing similar problems, while all participants emphasized the importance of increasing individual motivation and raising awareness as key strategies for overcoming barriers to implementing PR [146]. The same study also showed that video calls were not always feasible owing to limited or unstable technology infrastructure, especially in remote areas, and that telephone calls were unable to capture nonverbal information that would have been conveyed through in-person interactions [146].

A virtuous attempt to transfer high-quality service PR from developed countries to LMICs is being realized with the involvement of four low-income countries (i.e., Kyrgyzstan, India, Sri Lanka, and Uganda) and the United Kingdom to create a harmonized data set enabling researchers to address important health issues globally in a time-efficient and cost-effective manner compared with isolated approaches to data acquisition [147].

Facilitating the development of home-based PR in LMICs requires an articulated process with the participation of many actors, namely patients, professionals, and politicians, because home-based PR should be supported with parallel actions aimed at enhancing infrastructure and financing local projects, even in remote areas. Technological and financial biases, together with awareness of PR, are the principal barriers to home-based PR, which can be resolved only with a global approach where citizens and national and local institutions act to break down such barriers.

Conclusion

In addition to improving respiratory functions in patients with asthma, home-based PR programs improve self-care skills, boost treatment adherence, and strengthen multidisciplinary approaches. Home-based PR models that include group sessions and individual follow-ups seem to produce results similar to those of center-based programs; however, home-based PR is more cost-effective. Additionally, telerehabilitation and smartphone-supported applications allow these programs to reach a broader audience and enhance their sustainability. Therefore, it is crucial to consider psychosocial factors, particularly in patients with severe asthma.

Future research should focus on well-designed randomized trials that identify and assess important elements such as the components of interventions, their duration and intensity, and patient characteristics such as asthma phenotypes, severity, age groups (especially pediatric patients), and psychosocial dimensions. This approach will help to establish robust, evidence-based, and personalized home-based PR protocols. The inclusion of home-based PR in therapeutic protocols is recommended because of its potential to enhance QoL, improve asthma control, and reduce pressure on healthcare systems. By implementing these programs with careful patient selection and regular follow-up, asthma management can become more effective and sustainable.

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Conflicts of interest

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ORCID

Cahidenur Koçak, https://orcid.org/0000-0003-3362-2415
Massimiliano Polastri, https://orcid.org/0000-0001-8548-0813
Esra Pehlivan, https://orcid.org/0000-0002-1791-5392

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