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Review

Inpatient paediatric rehabilitation in chronic respiratory disorders

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EDUCATIONAL AIMS

- to understand general indications and aims of paediatric rehabilitation programs
- to review essential components of a comprehensive rehabilitation for children and adolescents with respiratory diseases
- to discuss outcome, impact and cost-effectiveness of such interventions

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SUMMARY

Inpatient pulmonary rehabilitation programs have evolved from tuberculosis sanatoriums to modern medical centres providing standardized comprehensive care in a multidiciplinatory environment. Goals of rehabilitation programs for children and adolescents include restoration of professional activity, improvement of health condition, compliance and disease management as well as restoration of quality of life. Eligibility for an intervention is assessed by defined social and medical criteria. Comprehensive pulmonary rehabilitation programs provide a wide range of health care recourses, including diagnostic procedures, specific medical care, educational interventions and a multiprofessional team. Paediatric rehabilitation programs for chronic respiratory diseases, such as asthma or cystic fibrosis, have been shown to reduce symptoms, increase aerobic fitness and physical strength, improve pulmonary function and inflammation and enhance compliance, self-management, quality of life and psychological symptoms. Regional climatic effects have demonstrated an additional positive effect on the rehabilitation outcome. In addition, first evidence suggests an overall reduction of health care costs.

REHABILITATION IN CHILDHOOD: CHANCE AND CHALLENGE

Inpatient pulmonary rehabilitation programs have become a major component of disease care and management in chronic respiratory disorders in many countries. While rehabilitation programs for adults often focus on restoring or maintaining the work ability, such interventions in children and adolescents target to a great extent preventive measures aimed at preventing worsening of the disease, improving self-management of the disease for the patients as well as their families, and enhancing quality of life of both the patients and their parents. It is anticipated that the child, or the adolescent, shall be enabled to fully participate in daily life, such as school, social activities and sports, in the same ways as his or her healthy peers, despite her or his disease. In addition, inpatient programs provide the possibility of an individual, daily monitoring of the patients over several weeks in order to optimize therapeutic interventions and complete diagnostic procedures beyond the possibilities of an outpatient-setting, especially in times where physicians increasingly face troubles with national health budgets and, consequently, reduced time capacities for each of their patients. However, improvements in outpatient care and, as a result, a decreasing number of severely affected patients as well as financial cut downs all around Europe have challenged rehabilitation centres and resulted in shutdowns of hospitals in various countries.

This review provides an overview over developments of paediatric pulmonary rehabilitation programs, focusing on inpatient interventions. It describes essential components of those interventions, and discusses the available literature on rehabilitation outcomes in respect to different pulmonary disorders and cost-effectiveness.

The available English and German literature in PubMed and the Cochrane Library was searched for "rehabilitation" in combination with "children" or "adolescents", as well as "respiratory/pulmonary", "asthma", "cystic fibrosis" or "lung transplantation", and various other respiratory diseases, respectively. Case reports,

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articles on non-pulmonary disorders and publications focusing on adults were excluded. In addition, searches were performed for "rehabilitation" in combination with "health education" or "costs/cost-effectiveness", respectively, and articles covering respiratory aspects were selected for further review. An additional Wikipedia search was performed for historical aspects of pulmonary rehabilitation.

PULMONARY REHABILITATION OVER THE CENTURIES

The concepts of pulmonary rehabilitation can be traced back more than 200 years all around Europe. In the early 1800s, Thomas Beddoes established The Pneumatic Institute for the treatment of patients with heart diseases and asthma in Bristol, UK.[1] In that time, the French physician and inventor of the stethoscope René Laennec described the use of rehabilitation in patients with chest diseases.[1] Another germ cell of a number of today's regional or national pulmonary rehabilitation programs and centres can be found in the 19th and early 20th century, when the industrialized nations started to launch centralized institutions and programs to battle one of the greatest scourges of that time, tuberculosis.[1] The first sanatorium for tuberculosis worldwide was opened in 1855 in the German town of Görbersdorf (today Sokolowsko, Poland), and many hospitals followed all over Europe.[2] One of the centres of patient care became the then remote mountain village of Davos in Switzerland, where several countries established sanatoriums for tuberculosis treatment, though treatment in those days mainly meant fresh air, sun exposure and physical work or activity. In his famous novel "The Magic Mountain", Thomas Mann characterized the medical and social conditions in one of those sanatoriums in Davos. The impact of the disease on the society before efficient treatment became available is also well documented in various other works of art and literature, such as Giuseppe Verdi's' "La Traviata", a realistic (and at that time scandalous) description of the suffering and death of the main protagonist from tuberculosis.

After the Second World War, tuberculosis become treatable by antibiotics, and tuberculosis sanatoriums were no longer the only hope for these patients. Many of those hospitals closed down, but some managed to take advantage of their expertise in pulmonology and transformed into modern respiratory rehabilitation centres. At that time, the definition of "rehabilitation" developed more and more towards the modern idea of "restoration of the patient to the fullest physical, mental, social, vocational, and economic usefulness of which he is capable".[3] Lung diseases such as asthma and COPD emerged as new frequent chronic health threats during the last decades. The first multidisciplinary rehabilitation programs for adults, and soon also for children and adolescents appeared in the middle of the last century all around the western world and included modern treatment components such as oxygen therapy, exercise training and physical therapy techniques.[4,5] Today, pulmonary rehabilitation is defined as "an evidence-based, multidisciplinary, and comprehensive intervention for patients with chronic respiratory diseases who are symptomatic and often have decreased daily life activities". Integrated into the individualized treatment of the patient, pulmonary rehabilitation is designed to reduce symptoms, optimize functional status, increase participation, and reduce health care costs through stabilizing or reversing systemic manifestations of the disease".[6] Today, a broad spectrum of chronic respiratory conditions is addressed by paediatric rehabilitation programs, including preschool wheezing, asthma, cystic fibrosis, bronchopulmonary dysplasia, primary ciliary dyskinesia, neuromuscular disorders, interstitial lung diseases, cardiovascular diseases, and, most recently, subjects after lung transplantation.

GOALS AND CRITERIA OF MEDICAL REHABILITATION PROGRAMS FOR CHILDREN AND ADOLESCENTS

In recent decades, the objectives for rehabilitation programs have evolved from conditions such as failure to thrive, susceptibility to infections or increased psychosocial stress, which were addressed in so-called "cures", to distinct, disease-specific programs and today consist of a defined medical treatment in qualified, specialized hospitals.[7,8] Even though each individual patient or family might have a specific motivation to participate in a rehabilitation intervention, objectives for medical rehabilitation today include various specific considerations independent of the rehabilitation setting (e.g., inpatient versus outpatient, short-term versus long-term), as depicted in Table 1.[7,9]

To achieve the specific goals of a modern, qualified medical rehabilitation, there are some general requirements which are, these days, to a great extent defined by the sponsors of the national rehabilitation programs, e.g. health and/or annuity insurances. The sponsors assess the need for rehabilitation intervention by a number of social and medical criteria. The German annuity insurance (Deutsche Rentenversicherung), e.g., defines the following prerequisites for admitting children and adolescents into an inpatient medical rehabilitation program[7]:

- Ability for rehabilitation (willingness to actively participate in the program, capacity to fulfil rehabilitation aims, ability to integrate into groups)
- Improvement of prognosis can be achieved (improvement of health, restoration of professional activity)
- Measures of outpatient care are achieved but not sufficient to adequately ameliorate health or suspend health impairment
- Secondary health damage is imminent or has already occurred
- Psychosomatic or psychosocial problems are difficult to address in an outpatient setting (demarcation form the social environment)
- Interventions to promote coping are necessary

In addition, specific criteria might be defined for individual patients depending on health-related or social aspects. If the criteria for rehabilitation are met, patients/parents, health workers and physicians must cooperate to successfully apply funding of a medical intervention at the appropriate sponsor.

ESSENTIAL COMPONENTS OF PAEDIATRIC PULMONARY REHABILITATION PROGRAMS

Today, medical rehabilitation programs consist of well-defined, multidisciplinary interventions carried out by a broad spectrum of highly-qualified health professionals. It must be stressed, however, that scientific evidence on type or content of rehabilitation programs is largely lacking; therefore any information given in the following is purely based on expert opinions including our own experience. The duration of the interventional period of inpatient programs varies between countries and institutions and usually stretches between 2 and 12 weeks. Depending on the disease spectrum and severity addressed by pulmonary rehabilitation centres, potentially essential components are displayed in Table 2

Table 1
Goals of medical rehabilitation programs in children and adolescents.

Maintenance and restoration in social and professional activities
Improvement of health condition
Preventive measures for diseases worsening or health damage
Amendment of disease perception and management
Correction of compliance
Restoration of quality of life
Change of lifestyle

Table 2
Essential components of a comprehensive paediatric pulmonary rehabilitation program.

Respiratory diagnostics including body plethysmography
Comprehensive allergy testing including provocation tests
Routine laboratory including blood gas analysis
(Chest) X-ray
Disease-specific nursing
Separation of patients according to microbiological profile
Monitoring of vital parameters and possibility of oxygen application
Physiotherapy
Physical exercise training and sports therapy
Occupational therapy
Nutritional intervention and advice by a dietician
Psychological counselling and family support
Standardized specific education in disease understanding and management
Advice in matters of financial, educational and occupational aspects

and include a wide range of resourses, including diagnostic procedures, specific medical care, educational interventions and a multidisciplinary team consisting of different health professionals.[8] A qualified, standardized care also may include consultation of specific medical professionals in case of multi-organ or psychiatric symptoms and diseases. In many institutions, children and adolescents participate in educational pre-school or school programs for the duration of the hospitalization period in order to make them keep up with the subject matter of their school at home. Several rehabilitation centres offer a family-oriented intervention and admit parents and other family members together with their children. Individuals who are not accompanied by their parents are often supervised by social workers or other health care professionals.

A multidisciplinary team closely follows each patient or family during the whole interventional period. This approach facilitates an individual treatment in the context of an often group-based rehabilitation program. As patients can be monitored intensively over a longer period of time, individual symptoms and risk factors as well as psychological aspects can be evaluated continuously and, as a result, specific diagnostic procedures can be applied. In the same way, treatment modifications can be carried out and the subsequent course of the disease can be observed over the time. In summary, the multidisciplinary approach of a comprehensive rehabilitation program provides a powerful requisite to define individualized rehabilitation aims in order to improve health condition and psychosocial factors of the patient and her or his family.[8]

HEALTH EDUCATION, A CENTRAL ELEMENT OF DISEASE MANAGEMENT

As mentioned above, educational programs are increasingly important components of contemporary rehabilitation programs. General key features of those programs are theoretical instructions accompanied by practical exercises. They include knowledge transfer to promote disease understanding and recognition of individual risk-factors, coping strategies and practical training to improve skills and techniques of medication application. Written action plans foster the adherence to the individual treatment strategy.[10] As a result, compliance, self-management and outcome of the disease are often significantly increased.

Educational programs for children and adolescents have been developed for various diseases in many countries, e.g. for diabetes, obesity or atopic dermatitis. In the pulmonary field, the most widespread and best standardized protocols exist for asthma education, the vast majority coming from the US and from Europe.[11–14] Asthma education programs have often been developed independently of pulmonary rehabilitation programs and are often performed in an outpatient setting. Inpatient rehabilitation programs have integrated parts or whole protocols of national or regional asthma education programs, resulting in standardized en-bloc interventions. In some countries, such as Germany, asthma education programs have been standardized on a national level and are financed by the health insurances, and rehabilitation centres participate next to outpatient centres in the nation-wide educational program.[11]

The goals of asthma education programs are improvement of asthma control and reduction of exacerbations, with the resulting decrease in physician visits, emergency department visits, hospitalization and death.[15] To accomplish these goals, patients and families are empowered to undertake ongoing self-care, which leads to an improved compliance and, thus, asthma control. The efficacy of educational interventions for children and adolescents with asthma and their families to achieve these goals, and the superiority of standardized education programs compared to medical care without education have been demonstrated in a vast number of studies.[12–14,16] Moreover, education in asthma was associated with improved lung function, reduced absenteeism from school and reduced number of days of restricted activity. Findings from studies comparing different types of asthma education interventions suggest that providing more sessions and more opportunities for interactive learning may produce better outcomes.[14] Though these data on the outcome of asthma education programs come from outpatient interventions, the value of such education programs for the inpatient setting are undoubted. One advantage of inpatient health education programs is the relatively high number of participants wherever those programs are mandatory for the hospitalized patient, in comparison to voluntary outpatient programs that may lack in acceptance in some regions. Another aspect in favour of inpatient programs is the possibility to closely follow the patient and their families over the hospitalization period in order to optimize the educational content according to the individual needs. Recognizing the importance of educational programs for inpatient rehabilitation interventions, health sponsors such as the German annuity insurance have started to make such programs an essential prerequisite for rehabilitation centres.

Though data on structure and outcome of educational programs are much less extensive compared to asthma, preliminary evidence exists also for other chronic lung diseases such as cystic fibrosis (CF), as reviewed by Bernard et al.[17] As CF treatment regimes are complex and time-consuming, non-adherence is wide-spread especially among children, adolescents and young adults. This phenomenon is particularly pronounced for airway clearing techniques, inhalation therapy and nutritional aspects.[18,19] Behavioural techniques tailored to different age groups and the family's needs, including contracting, differential attention, contingency management, use of reinforcers versus time out, and settling realistic goals have been shown to increase adherence to high-calorie diet and respiratory physiotherapy.[17] This may also account for exercise, however, sufficient data are still lacking. Inpatient rehabilitation programs provide the opportunity to work intensively with the patients and their families on such techniques for a prolonged period of time and can potentially take an important place in modifying adherence to CF treatment, though to date there are no studies published addressing this question.

In conclusion, educational programs for asthma are widely accepted as a pivotal part of the routine medical care. Though the degree of standardization of these programs may vary depending on the country or centre, they have been successfully implemented in most paediatric pulmonary rehabilitation programs. Current efforts to develop and implement similar standardized programs for other chronic respiratory diseases, such as cystic fibrosis, will likely contribute to further improve the outcome of pulmonary rehabilitation programs in children and adolescents.

OUTCOME AND IMPACT OF INPATIENT PAEDIATRIC PULMONARY REHABILITATION PROGRAMS

A recent joint statement of the American Thoracic Society and the European Respiratory Society on pulmonary rehabilitation highlights the great progress that has been made in evidence-based support for pulmonary rehabilitation in the management of patients with chronic respiratory disease, focusing on adults with COPD.[6] Rehabilitation programs for COPD have been shown to reduce pulmonary symptoms, increase exercise endurance, improve health-related quality of life and reduce health care costs. Likewise, there is a growing body of evidence that inpatient rehabilitation programs for chronic respiratory diseases in the paediatric population are efficient in terms of health improvement. Most published studies investigated outcome in asthmatic and cystic fibrosis patients, as these disorders constitute the majority of indications for pulmonary rehabilitation in the first two decades of life. As the literature is vast for both disorders, focus will be given on the most recent findings and selected important aspects. In addition, rehabilitation programs for severely affected patients before and after lung transplantation will be discussed, as the number of patients and programs are likely to increase in future due to the rising number of transplanted individuals.

ASTHMA

The impact of asthma education and climatic conditions on rehabilitation success are discussed elsewhere in this review.

In the U.S., so-called asthma camps for children and adolescents are organized by lung organizations with large experience and staffed by a variety of health care professionals who have volunteered their time and expertise.[20] It has to be mentioned that asthma camps are not equivalent to medical rehabilitation programs; however, as outcome data from asthma camps may also have an impact on design and composition of medical inpatient interventions they are discussed here. Asthma camps often focus on health education and interaction with peers, and there is evidence that the interventions can increase parent and child asthma knowledge, increase a child's locus of control, improve self-efficacy and disease attitude, improve asthma-related behaviour and pulmonary function measures, and improve metered dose inhaler and peak flow meter technique.[20] Furthermore, asthma camps decrease anxiety, symptoms, exacerbations, school absences, emergency department visits, and hospitalizations. More recent studies have corroborated these findings, indicating improvements in self-efficacy supported adaptation, self-concept and asthma management, as well as short- and long-term increase in asthma knowledge and problem-solving.[21,22] However, one study also demonstrated no significant differences in change of psychosocial variables between the intervention group and a control group, concluding that interventions may be more effective if targeted to patients with identified problems of disease management.[22]

Several studies have implicated lifestyle changes, specifically decreased physical activity, as a contributor to the increase in asthma prevalence and severity.[23] Moreover, the capacity for asthmatic subjects to exercise safely and to significantly improve their cardiovascular fitness and quality of life has been demonstrated.[24] From this perspective it seems logical to subject asthmatic patients to exercise training to increase fitness and strength. Indeed, many rehabilitation centres focus on exercise interventions with remarkable success on quality of life and exercise capacity, and some authors claim that exercise training should be part of each asthma rehabilitation program.[23,25]

Though asthma camps also exist in Europe, standardized inpatient asthma rehabilitation programs in specialized hospitals are predominant. Literature on outcome of the intervention, nevertheless, is relatively limited. A larger German study examined the effectiveness of an inpatient rehabilitation program for children and adolescents with asthma and found significant improvements in functional restriction and pulmonary function, as well as a decrease in days absent from school and in visits to a physician, supporting the importance of multidisciplinary rehabilitation programs for disease management and compliance modification.[26] In addition, the study suggested more pronounced long−term improvement of disease management and lung function parameters after inpatient rehabilitation compared to an outpatient setting. Another study, also from Germany, looked at the long-term effects 12 months after an inpatient intervention and observed better lung function parameters, less asthma-related school absence, and improved asthma management and quality of life in the rehabilitation group compared to an outpatient reference group.[27] The findings corroborate a Swiss study on asthmatic children with sensitization to house dust mite and persistent respiratory symptoms despite anti-inflammatory treatment. In this group, an inpatient rehabilitation program in a high-altitude alpine hospital lead to an improvement in mid expiratory flows and in bronchial inflammation, as shown by a significant decrease in nitrites in breath condensate.[28] Interpretation of these results in lack of a control group, however, is limited, as it is difficult to clearly distinguish the effect of the intervention from the possible effect of the high altitude climate in patients with allergy to house dust mite, as discussed further below.

In summary, these studies suggest that standardized pulmonary indoor rehabilitation programs achieve remarkable short- and long-term results and participate in efficient disease management.

CYSTIC FIBROSIS

In recent years, the fear of cross-infection especially with *Pseudomonas aeruginosa* has determined the evolution of rehabilitation programs for cystic fibrosis patients. Reports from cystic fibrosis centres and rehabilitation camps have come to the conclusion that infection control precautions, such as segregation measures, prevent strain transmission and are of benefit in reducing the proportion of chronically infected patients.[29,30] To date, rigorous hygiene standards addressing disinfection and segregation (special and temporal) are a widely accepted prerequisite to qualify centres for inpatient cystic fibrosis rehabilitation programs. Still, in the view of potential cross-infections, the expected benefit from participating in such programs must be individually evaluated, and close contact between the CF centres and the rehabilitation clinics is advisable to foster mutual trust, minimize any risk for the patient and optimize intervention outcome. Structured interventions need to take into account all aspects of cystic fibrosis multi-organ disease and therefore exceed the general requirements of pulmonary rehabilitation programs. Physiotherapists, sports therapists, psychologists, dieticians, diabetologists, gastroenterologists, pulmonologists and other health care specialists need to closely work together in a multidisciplinary setting.

Pulmonary rehabilitation programs for children, adolescents and adults with CF have significantly improved short and long-term quality of life of affected individuals as well as their parents,[31,32] and to improved symptom score, pulmonary function and weight.[30,33,34] Several programs emphasize exercise and endurance training interventions, resulting in significant improvements in exercise tolerance, aerobic fitness, peak work capacity, strength, coordination, or ventilation parameters, respectively.[33,35,36] Some studies reported associated amelioration in pulmonary inflammatory parameters; however, the results are conflicting. An earlier study suggested a reduction in neutrophil-dominated inflammation

during a 3-week multidisciplinary rehabilitation program in stable cystic fibrosis patients.[37] In contrast, a recent investigation came to the conclusion that a comparable intervention did not influence airway obstruction and airway inflammation, despite significant improvements in pulmonary symptoms and lung function parameters.[34] Different training settings may play a decisive role in the course of inflammation: single bouts of exercise might elicit an aggravated inflammatory response, whereas chronic endurance exercise training is likely to attenuate systemic or local inflammation.[38] Future studies need to address recent findings in immunity of cystic fibrosis lung disease, including IL-17-related mechanisms, in order to enhance the understanding on the impact of rehabilitation programs on pulmonary inflammation.[39]

PRE AND POST LUNG TRANSPLANTATION

There are limited data on protocols and outcome of rehabilitation programs for patients with chronic lung diseases before and after lung transplantation. However, with the increasing number of adult and paediatric transplanted patients, rehabilitation programs will have to be established in more and more regions. The majority of the transplanted paediatric population mainly consists of patients with cystic fibrosis, followed by pulmonary fibrosis.[40] Rehabilitation programs for those severely affected individuals exceed the general requirements of pulmonary rehabilitation. Next to medical experience and know-how, specific psychological and educational conditions have to be provided by the rehabilitation centre. Access to acute interventions and intensive care units should be available, as well as an emergency laboratory including blood level determination for antibiotics and chemotherapeutics, and advanced respiratory diagnostics such as bronchoscopy should be at hand.[8]

Major objectives for programs before transplantation are the stabilisation of general and pulmonary health condition next to psychological priming in respect of the intervention. The effect of rehabilitation for adults awaiting lung transplantation has been demonstrated by a significant increase in the physical efficiency and endurance.[8]

Rehabilitation programs for patients after lung transplantation have to consider various complex aspects, from education in compliance and adherence to treatment to early recognition of organ rejection and, in the same time, promoting physical fitness to prepare the individual for the re-entry into the society, including school or occupation.[8] Next to inpatient interventions, protocols for outpatient rehabilitation programs following lung transplantation in children and adolescents have been established, with reported success in terms of patient satisfaction.[41] Nevertheless, both inpatient and outpatient interventions need to be scientifically evaluated in future to meet the complexity of the requirements of paediatric transplant rehabilitation programs and to improve their outcome.

PSYCHOLOGICAL IMPACT OF INPATIENT REHABILITATION PROGRAMS

It has been shown that quality of life of children and adolescents with asthma does not only depend on disease severity but also, maybe even to a larger extent, on emotional and behavioural symptoms.[42] Moreover, psychological symptoms such as anxiety have direct impact in asthma outcome.[43] Presumably, these observations are true for other chronic diseases. A very limited number of studies have investigated the psychological impact of inpatient rehabilitation programs in childhood. Children and adolescents with asthma, atopic dermatitis and obesity have been shown to benefit from rehabilitation programs in respect of quality of life including psychological and psychosocial factors.[44] The observed short-time improvement remained significant when assessed 12 months after the intervention. Another more recent study investigated a large number of children and adolescents with cystic fibrosis and other chronic diseases and found that their psychological symptoms, assessed by a difficulties score of strengths and a difficulties questionnaire, improved significantly after a family-oriented inpatient rehabilitation program.[45] Also in this case, improvements persisted on the level of discharge for another 6 months.

In conclusion, though a sufficient number of larger studies is lacking, it can be speculated that inpatient rehabilitation programs are a successful strategy to improve psychological functions in children and adolescents with chronic respiratory disorders as well as in their families and that benefits possibly can be preserved on a long-term scale.

INFLUENCE OF CLIMATE: AN OLD-FASHIONED IDEA?

Early rehabilitation concepts focused to a great extent on climatic effects that were considered to benefit the patients' health. Sanatoriums located at the seaside or in high altitude have ever since claimed supportive effect of the climate to rehabilitation outcome. In recent years, such claims could at least partly be corroborated by a growing body of research. The climatic conditions in high altitude have been shown to be beneficial for patients suffering from allergic diseases and asthma, mainly from studies conducted in the Italian and Swiss Alps. The absence of house dust mite in mountain regions above 1500 meters altitude as a result of the dry, cool air, reduced burden of aeroallergens and the impaired impact of pollutants such as diesel particles, nitric oxides and ozone mark evident reasons for this observation.[46] In this context, several studies came to the conclusion that pulmonary inpatient rehabilitation programs in allergen-deprived high altitude improve disease symptoms in patients, increase lung function and significantly reduce pulmonary inflammation.[28,47–49] Furthermore, it has been shown that these effects are independent of asthma severity. On an immunological basis, the systemic activity of Th2 cells and monocytes were significantly reduced after the intervention, and a shift from a pro-inflammatory towards a pro-regulatory phenotype on T cell level could be observed.[50] These findings may contribute to the demonstrated improvement of respiratory symptoms in high altitude, in addition to the specific effects of the rehabilitation program itself.

Early reports from the 1970s from rehabilitation centres at the Dead Sea, the Baltic Sea and the North Sea suggest beneficial effects of maritime climate on various diseases such as dermatologic and rheumatologic disorders. Clinical studies regarding pulmonary conditions, however, are only available for rehabilitation programs located at the Dead Sea, and the health benefits are discussed rather in the context of the altitude descent (390 meters below sea level) than the sea side climate. The Dead Sea has for many years been considered a unique nature health resort. The barometric pressure changes due to low altitude causes a 10 mmHg increase in inspired oxygen pressure and a subsequent increase of 4–6 mmHg in arterial oxygen tension. As a result, peak oxygen consumption and blood oxygen saturation during sub-maximal exercise improved at the Dead Sea in CF patients, as compared with sea level, suggesting physiological benefits in subjects with moderate to severe lung disease.[51] Another study demonstrated improved pulmonary status and body composition in CF patients during a rehabilitation program at the Dead Sea.[52] An earlier report observed that arterial oxygenation, exercise capacity, sleep oximetry and quality of life improved in adult hypoxemic patients suffering from COPD and in patients with advanced lung disease, respectively, after staying in the region.[53,54]

The currently available data suggest positive effects of different climatic conditions on the course of various diseases, including respiratory disorders. Further studies are urgently needed to enhance our understanding of the specific influence factors related to climate in general and in respect to pulmonary rehabilitation programs.

COSTS VERSUS HEALTH BENEFITS: CHALLENGES AND OUTLOOK

Despite the growing evidence that rehabilitation programs improve the outcome of chronic respiratory disorders, rehabilitation centres increasingly face financial challenges in times of diminishing health care resources and cut-downs of health systems budgets. This challenge needs to be met not only by clinical long-term outcome studies, but also by providing evidence that rehabilitation programs for chronic respiratory disorders significantly reduce the costs of chronic diseases for the health systems. Studies addressing this issue in adults are extremely limited, and investigations in children and adolescents are lacking. No research on inpatient rehabilitation programs has been published so far, but there are a few studies available investigating economical aspects of outpatient rehabilitation programs for COPD in adults.[55,56] These studies concluded that the total direct costs for medical follow-up care significantly decreased after the intervention and pulmonary rehabilitation programs can be considered to be cost-effective as they are likely to result in financial benefits to the health service.

Some, albeit limited evidence for cost-effectiveness also comes from the evaluation of outpatient asthma education programs.[13,16,57] The few available economic studies have demonstrated a net saving of health costs for patients participating in educational programs. This savings for each individual patient increased with the severity of disease and might exceed the intervention costs in patients with moderate or severe asthma within 1 year. However, due to the lack of sufficient quality research, firm conclusions on the impact of asthma education on health-related costs in children and adolescents can not be drawn at present.

In summary, health care systems and rehabilitations centres have to increase efforts in conducting sound economic outcome studies along with clinical long-term evaluation of paediatric pulmonary rehabilitation programs to clearly demonstrate that those interventions constitute an efficient use of healthcare resources for patients with chronic respiratory disorders.

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