Complementary Therapies in Clinical Practice 48 (2022) 101609

Contents lists available at ScienceDirect

Complementary Therapies in Clinical Practice

journal homepage: www.elsevier.com/locate/ctcp

Pulmonary rehabilitation in subterranean chambers combined with neuro-orthopedic activity-dependent plasticity therapy influences patients' quality of life – A preliminary study

Sylwia Mętel [a,*], Magdalena Kostrzon [b], Justyna Adamiak [a], Halina Gattner [c], Harri Pekka Sintonen [d], Renata Horst [e]

[a] Institute of Applied Sciences, University of Physical Education in Krakow, Poland
[b] 'Wieliczka' Salt Mine Health Resort in Wieliczka, Poland
[c] University of Physical Education in Krakow, Poland
[d] Department of Public Health, University of Helsinki, Finland
[e] Private Practice and Institute for Further Education, Berlin and Ingelheim, Germany

ARTICLE INFO

Keywords:
15D instrument
Exercise therapy
Vagus nerve
Speleotherapy
Chest mobility
Back scratch

ABSTRACT

Objective: The aim of the study was to evaluate if Neuro-orthopedic Activity-dependent Plasticity (N.A.P.) therapy combined with standard subterranean pulmonary rehabilitation (SPR) conducted in the salt mine influences the health-related quality of life (HRQoL) and chest mobility in patients with asthma or chronic upper respiratory tracts diseases.

Methods: 54 patients enrolled for the study completed a 3-week SPR. The 15D questionnaire, chest mobility and back scratch flexibility tests were conducted before and after SPR. In the study group (N = 23,16 women, 7 men) the N.A.P. therapy was added to SPR, while the control group (N = 31, 21 women and 10 men) completed the SPR program.

Results: After the SPR statistically significant improvements were observed on the 15D dimensions of breathing and vitality dimensions, in the chest mobility and back flexibility in both groups.

With the baseline gender distribution, age, generic 15D score, chest mobility and back scratch adjusted, the change in the 15D score was 0.068 greater in the study group than in the control group. This difference is clinically important and statistically significant (p = 0.022). There was no statistically significant difference in the chest mobility and back scratch flexibility between the groups.

Conclusions: Adding N.A.P. therapy techniques to the SPR program in the underground part of the 'Wieliczka' Salt Mine Health Resort results in a statistically significant and clinically important improvement in the subjects' HRQoL.

1. Introduction

The main goal of physiotherapy is to improve the patient's quality of life through the use of various rehabilitation methods leading to pain relief and restoration of optimal body functions. The basis for restoring functional and motor fitness is the optimization of breathing.

Pulmonary rehabilitation (PR) has been recommended as an integral part of treatment for patients suffering from chronic respiratory diseases. According to American Thoracic Society and the European Respiratory Society definition, PR is a comprehensive action based on patient assessment and therapy tailored to his needs, including physical training, education and changes in behavior aimed at improving the psycho-physical condition and promoting long-term regularity in leading a healthy lifestyle. One of the main goals of PR is to improve health-

Abbreviations: N.A.P., Neuro-orthopedic Activity-dependent Plasticity; SPR, subterranean pulmonary rehabilitation; HRQoL, Health Related Quality of Life; PR, pulmonary rehabilitation; ANS, autonomic nervous system; FHP, forward head posture.

* Corresponding author. Institute of Applied Sciences, Motor Rehabilitation Department University of Physical Education in Krakow, Poland al. Jana Pawła II 82, 31-579, Kraków, Poland.

E-mail addresses: sylwia.metel@awf.krakow.pl (S. Mętel), mkostrzon@interia.pl (M. Kostrzon), justyna.adamiak@awf.krakow.pl (J. Adamiak), halinagattner@gmail.com (H. Gattner), harri.sintonen@helsinki.fi (H.P. Sintonen), info@renatahorst.de (R. Horst).

https://doi.org/10.1016/j.ctcp.2022.101609
Received 19 March 2022; Received in revised form 8 May 2022; Accepted 24 May 2022
Available online 27 May 2022

related quality of life (HRQoL) [1].

The autonomic nervous system (ANS) regulates a number of functions of the upper respiratory tract (the tension of the internal muscles of the larynx, the condition of the pharyngeal sphincters and the function of the paranasal sinuses, salivation) [2,3] and the lower respiratory tract (the condition of the trachea, mucus density, bronchospasm and bronchodilation) [4–6]. It also affects the quantitative and qualitative factors related to breathing, e.g., the number of breathing cycles at rest, the occurrence of dyspnea, and hyperventilation. In anxiety related to the lack of breath, it is crucial to recognize, understand and control a panic attack that often leads to the vicious cycle of hyperventilation. Therefore, it is important to implement actions that primarily affect the nervous system, especially its autonomic part, directly dependent on emotional factors. One form of therapy influencing the functioning of the ANS is Neuro-orthopedic Activity-dependent Plasticity - N.A.P. therapy, which aims to ensure the best possible required biomechanical situation within a meaningful activity such as breathing. This enhances postural control, neural plasticity and motor learning [7].

PR programs conducted in karst caves or salt mine excavations bring a significant improvement in the health condition of people with chronic respiratory diseases [8–10]. Speleotherapy (subterraneotherapy) is a type of climatotherapy, based on the use of the underground environment for healing purposes [11,12]. PR combined with subterraneotherapy is used in chronic pulmonary, laryngological and allergic diseases.

A recent pilot study has shown that speleotherapy combined with pulmonary rehabilitation improves the functional fitness of the older adults with pulmonary disorders as measured by the Senior Fitness Test, in terms of upper and lower body strength, lower body flexibility, and dynamic balance [13].

The aim of the study was to assess the impact of applying an additive intervention - N.A.P. therapy, on HRQoL, chest mobility and flexibility of the upper trunk in patients with upper and lower respiratory tract disorders undergoing standard pulmonary rehabilitation in underground salt chambers (SPR).

2. Material and methods

The study included patients with chronic diseases of the upper respiratory tract and people diagnosed with bronchial asthma who obtained medical qualifications for participating in a rehabilitation stay in the underground part of the 'Wieliczka' Salt Mine Health Resort in the city of Wieliczka. The patients gave their written consent to participate in a research experiment consisting of completing a HRQoL questionnaire and measuring the mobility of the chest and elasticity of the upper trunk. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Bioethical Commission of the Regional Medical Chamber in Krakow No. 65/KBL/OIL/2016.

The subjects were divided into two groups: control group (SPR) and study group (SPR combined with N.A.P. therapy). Due to the specific, underground environment of the treatment stay and patient safety requirements related to the number of patients, recruitment to the groups was carried out within two years. The procedure of assigning patients to the groups was non-random - during the medical qualification for five rehabilitation stays, all people with respiratory diseases (asthma, upper respiratory tract disorders) were invited to participate in the research: the control group was gathered during three separate rehabilitation stays in 2016 - a total of 31 people, and the study group during one stay in 2015 and 1 stay in 2016 - a total of 23 people (Table 1).

Table 1
General characteristics of the patients.

Groups	SPR + N.A.P. n = 23	SPR n = 31
Variable	n (%) Mean (SD)	n (%) Mean (SD)
Sex		
Female	16 (70)	23 (74)
Male	7 (30)	8 (26)
Age (years)	55,82 (14,35)	65,25 (8,01)
Female	53,25 (14,84)	64,5 (8,11)
Male	61,71 (11,1)	67,11 (7,43)

2.1. 15D instrument

The Polish language version of the 15D questionnaire was used to measure HRQoL. The questionnaire is composed of 15 dimensions: mobility, vision, hearing, breathing, sleeping, eating, speech (communication), excretion, usual activities, mental function, discomfort and symptoms, depression, distress, vitality and sexual activity with five ordinal levels of severity on each. The single index score (15D score), representing the overall HRQoL on a 0–1 scale (1 = full health, 0 = being dead) and the dimension level values, reflecting the goodness of the levels relative to no problems on the dimension (=1) and to being dead (=0), are calculated from the health state descriptive system by using a set of population-based preference or utility weights [14]. The minimum clinically important change or difference in the 15D score has been estimated to be ±0.015 on the basis that people can on average feel such a difference [15].

2.2. Chest mobility

The measurement of chest mobility with an accuracy of 0.5 cm was performed by a physiotherapist at the height of the nipples in a relaxed standing position of the patient, with the upper limbs loosely positioned along the body. The difference in chest circumference was measured with a centimeter tape by measuring at the top of inspiration, with the airway being filled to the maximum with air, and at the top of exhalation. The patient was encouraged to breathe in as much as possible into the mid-chest [16,17].

2.3. Back Scratch Test

The flexibility of the upper body was assessed by the Back Scratch Test - part of the Senior Fitness Test (SFT) (also known as the Fullerton Functional Fitness Test). Back scratch measurement was performed by a physiotherapist in a patient in a relaxed standing position. The subject was asked to perform an attempt to join the hands behind his/her back. The dominant hand was placed behind the head and back over the shoulder with the fingers directed downwards, and the other hand was placed from the lower back side with the fingers stretched upwards. The distance between the tips of the middle fingers was measured with the result in centimeters as a negative value if the subject was unable to join the hands, or positive if the fingers overlapped each other [18,19].

2.4. Rehabilitation stay

The SPR program at the 'Wieliczka' Salt Mine Health Resort lasted three weeks and began with a qualifying examination carried out by a physician specializing in lung diseases, medical rehabilitation or balneology and physical medicine. After the medical qualification, a cycle of fiftee treatment stays in salt chambers was carried out, led by a therapeutic team (physiotherapists, nurse, physician). The duration of the supervised pulmonary rehabilitation program was 90–110 min a day. The pulmonary rehabilitation program included:

- 700 m march from the downhill shaft to the salt chambers under the supervision of medical staff (20 min - twice a day),
- breathing exercises including general breathing exercises, breathing through a closed mouth, breathing exercises with accessories (tubes, feathers, ping-pong balls), breath control exercises coordinated with physical exertion, correction of the breathing pattern, exercises for chest flexibility (30 min a day),

- general fitness exercises including elements of integration dances, aerobics and stretching conducted with music, with the use of large and small balls, gymnastic sticks and mattresses,
- resistance exercises of the upper and lower limbs with the use of weights and Thera-band tapes and endurance training with the use of steps and devices such as cycloergometers and elliptical bikes (30 min - twice a week),
- health education that included broadening the knowledge needed to monitor one's health condition and cope with the disease as well as motivating to cooperate with medical staff in the process of treatment and taking up physical activity (30 min - once a week).

Each training panel started with a short, 5-minwarm-up. Between the different types of activities, rest was provided, possible in a sitting position, for a duration of 20–30 min.

In the study group, the SPR program described above was enriched with group activities as part of N.A.P. therapy, which were conducted five times a week for 30 min (Fig. 1).

Moreover, during the program, each of the subjects from the study group participated 1 or 2 times in a N.A.P. therapy session conducted individually for 30 min. The main aim of the N.A.P. therapy was to strengthen postural control, improve coordination and regulate the activity of the autonomic nervous system. In order to stimulate the work of the parasympathetic system and activate regenerative mechanisms, and in particular to activate the abdominal part of the vagus nerve, tasks using the phonation of the "L" sound were used, paying particular attention to the linear position of the head in relation to the body and the inhibition of the increased activity of auxiliary respiratory muscles. In addition, in this phonation task, attempts were made to obtain the correct position of the tongue (vertical-horizontal), which is important for sealing the airways and regulating the position of the body's diaphragm system (relationship of the suprahyoid and subhyoid diaphragms to the proper diaphragm, pelvic floor structures and the support and locomotion function of the feet). During this form of rehabilitation, special attention was paid to postural and motor control exercises, in order to improve the functioning of the antigravity muscles necessary for the vertical posture of a human, using, among others, tasks involving the use of eyesight fixation on objects of everyday use, e.g., an unscrewed bottle with water that required dexterity in the distal part of the body to hold it in one hand while propping one leg up. The training of flexibility and motor control of the trunk was carried out in goal-oriented tasks: for example, from the position of an active four-point kneeling (training in closed biokinematic chains, i.e., loading the body with its own weight), people were asked to move to a side sit on a blanket. As well as tasks related to the dorsal tilt of the pelvis were performed, paying attention to the axis of rotation in the hip line (activity of the gluteal muscles and the thoracolumbar fascia), and a backward gait with retropulsion in the corrected foot position was used (sagittal axis). Moreover, for each patient in the study group, one or two individual N.A.P. therapy sessions were conducted taking into account the improvement of the selected activity with which the patient had the most difficulties, trying to improve the quality of its performance and remembering it as a task to be performed at home.

Fig. 1. N.A.P. therapy - activity on the ball aimed at the sliding of the nervous structures, regulation of the activity of the autonomic system, stimulation of low-rib breathing and normalization of muscle tone [7].

3. Statistical methods

In both groups, for each dimension of the HRQoL (15 dimensions and the 15D score) and two additional functional tests (chest mobility, back scratch), the arithmetic mean before and after rehabilitation was calculated. Student's paired samples t-tests were carried out to check whether the changes in the examined parameters from baseline to the follow-up were statistically significant. Student's independent samples *t*-test was used to check, whether there were statistically significant differences between the groups in the variables at baseline. As the groups were not assigned randomly, comparability of changes in the 15D score, chest mobility and back scratch between the groups was improved by adjusting for baseline differences in gender distribution, age, 15D score, chest mobility and back scratch in linear regression analyses. P-values <0.05 were considered statistically significant.

4. Results

The analysis of the results included patients who completed the entire program and participated in the research conducted immediately before and after its completion. The study group (SPR + N.A.P.) consisted of 23 patients, including 16 women and seven men. The control group (SPR) consisted of 31 patients, including 21 women and 10 men. The groups did not differ significantly in terms of gender distribution ($p > 0.05$), but the age difference was statistically significant ($p = 0.002$) - the control group was older. In the study group, favorable and statistically significant changes after the stay were found on the following 15D dimensions: breathing, sleeping, discomfort and symptoms, depression, distress, vitality, sexual activities and in the total 15D score. The changes after the treatment in chest mobility and elasticity of the upper trunk were also favorable and statistically significant. In the control group, positive and statistically significant changes after the rehabilitation stay were found on two 15D dimensions: breathing and vitality, and in the mobility of the chest and elasticity of the upper trunk (Table 2).

When comparing the studied variables before the stay between the study and control groups, statistically significant differences were observed only in chest mobility, upper body elasticity and on the baseline 15D dimension of breathing (Table 3).

The results of the regression analysis for the 15D score change are shown in Table 4. The explanatory power (adjusted R square) was 15.1% ($p = 0.033$). With the explanatory variables adjusted for (standardized), the change in the 15D score is 0.068 greater in the SPR + N.A.P. group than in the SPR group (Table 4). This difference is clinically important and statistically significant ($p = 0.022$).

With the explanatory variables adjusted for (standardized), there was no statistically significant difference in the chest mobility and back scratch flexibility between the groups (regression tables not shown).

5. Discussion

Chronic respiratory diseases are among the most common non-communicable diseases worldwide [33]. Various forms of treatment are possible to dilate major air passages and improve shortness of breath to help control symptoms and increase the quality of life [34]. In the study of Freidl et al. [35] an intervention with natural forms of treatment was used: the speleotherapy group (n = 23) participated in a ten-day combined winter exercise and speleotherapy programme and the exercise group (n = 18) joined a full-day winter sports program. The authors of this experiment emphasized the complexity of speleotherapy

Table 2
Results for the study group (SPR + N.A.P.) and the control group (SPR) before and after the rehabilitation stay.

Groups		SPR + N.A.P. n = 23			SPR n=31		
		Mean	SD	P	Mean	SD	P
Mobility	After the stay	0,89	0,14	0,714	0,79	0,23	0,350
	Before the stay	0,90	0,14		0,83	0,20	
Vision	After the stay	0,86	0,18	0,607	0,70	0,26	0,092
	Before the stay	0,84	0,23		0,79	0,26	
Hearing	After the stay	0,93	0,16	0,328	0,87	0,21	0,600
	Before the stay	0,92	0,17		0,88	0,21	
Breathing	After the stay	0,79	0,14	0,019	0,66	0,23	0,031
	Before the stay	0,70	0,16		0,57	0,20	
Sleeping	After the stay	0,83	0,20	0,026	0,75	0,28	0,689
	Before the stay	0,72	0,23		0,73	0,23	
Eating	After the stay	1,00a	0,00	No difference	1,00	0,00	0,325
	Before the stay	1,00a	0,00		0,99	0,06	
Speech	After the stay	0,97	0,09	0,328	0,94	0,14	0,572
	Before the stay	0,95	0,11		0,93	0,14	
Excretion	After the stay	0,92	0,17	0,067	0,82	0,22	0,719
	Before the stay	0,82	0,24		0,81	0,21	
Usual activities	After the stay	0,92	0,13	0,078	0,78	0,28	0,949
	Before the stay	0,82	0,24		0,77	0,26	
Mental function	After the stay	0,85	0,25	0,982	0,76	0,27	0,543
	Before the stay	0,85	0,20		0,79	0,21	
Discomfort and symptoms	After the stay	0,90	0,14	0,002	0,67	0,27	0,869
	Before the stay	0,65	0,31		0,66	0,29	
Depression	After the stay	0,94	0,11	0,030	0,81	0,27	0,480
	Before the stay	0,88	0,16		0,84	0,21	
Distress	After the stay	0,86	0,14	0,026	0,76	0,23	0,059
	Before the stay	0,72	0,25		0,70	0,21	
Vitality	After the stay	0,89	0,12	0,001	0,77	0,20	0,033
	Before the stay	0,78	0,15		0,72	0,22	
Sexual activity	After the stay	0,89	0,23	0,011	0,74	0,40	0,437
	Before the stay	0,82	0,24		0,70	0,38	
15D score	After the stay	0,89	0,08	0,001	0,79	0,15	0,588
	Before the stay	0,83	0,12		0,78	0,13	
Chest mobility	After the stay	4,80	2,14	0,004	2,90	1,46	0,019
	Before the stay	3,61	2,31		2,40	1,19	
Back scratch	After the stay	0,22	8,31	0,007	−10,97	12,15	0,002
	Before the stay	−3,39	8,46		−14,71	15,63	

and the challenge to separate specific from non-specific effects of subterranean treatment. However, considering the biological effects they observed that the changes in the differential blood count were more evident in the speleotherapy group than in the exercise group and in both groups the white blood cell count was decreasing, but this effect was more evident in the speleotherapy group. They also noticed a trend for the interaction effect for the eosinophilic blood cell count, which seems to increase in the speleotherapy group. The study concluded that winter exercise alone and winter exercise in combination with speleotherapy improve quality of life in adults with allergic rhinitis and/or asthma. Our study did not include white blood cell counting but in both studies the improvement in HRQoL was observed.

A change in HRQoL takes into account the subjective assessment of the areas of quality of life related to the clinical state, mobility, mental state and somatic experiences [14,20]. In the research project, the 15D instrument was used, which, in addition to assessing the above-mentioned areas of quality of life, also includes relevant dimensions such as breathing, vitality and sexual activity, and enables the assessment of a clinically important change in the HRQoL. People with chronic respiratory diseases have excessive activity of auxiliary respiratory muscles leading to dysfunction of the upper limbs and difficulties in performing everyday activities related to unsupported arm movements, such as: dressing, bathing, combing, lifting objects, doing shopping and many other duties home due to early fatigue and shortness of breath [1,21]. For this reason, the study included the measurement of chest mobility and the flexibility of the upper trunk.

A number of scientific premises show a relationship between the results of measurements of the difference with a measuring tape of the chest circumference between the maximum inspiration and exhalation, and the strength of the respiratory muscles and the tidal volume. However, these measurements were carried out in different starting positions (standing, lying down) and with different arm positions, and the anatomical reference points for these measurements made with the use of a centimeter tape were not unequivocally established [22–26]. Back scratch measurement is a recognized measure of functional efficiency for people over 60 years of age, also used to assess the effects of therapy in patients treated under speleotherapy conditions [13]. Studies by Lanza et al. [22] carried out in healthy people aged 20–30 showed a significant relationship between the mobility of the chest, assessed with the use of a centimeter tape, and the strength of the respiratory muscles in measurements performed in a standing position. The results obtained by these authors indicate that the higher the value of the difference in chest circumference between inspiration and exhalation, the greater the maximum inspiratory and expiratory pressure and tidal volume. On the other hand, Malagutii et al. [23], in a study involving 26 patients with COPD, assessing the difference in chest circumference between maximal inspiration and exhalation with a tape measure performed in the supine position at the thoracic and abdominal level, observed a significant relationship between inspiratory volume and the measurement of chest mobility, but only at the abdominal level.

Statistically significant improvements on the 15D dimensions of breathing and vitality were noted in both groups. This is an important confirmation of the effectiveness of the pulmonary rehabilitation program conducted in the conditions of subterranean salt chambers. At the same time, patients who were additionally treated with N.A.P. therapy obtained a significant improvement in HRQoL on the dimensions related to sleep, discomfort and symptoms, but also with the feeling of depression, distress and sexual activity, as well as in the total 15D score.

Table 3
Comparison of parameters between the study group (SPR + N.A.P.) and the control group (SPR) before the rehabilitation stay.

Variables	Groups	Mean	SD	p
Mobility	SPR	0,83	0,20	0,150
	SPR + N.A.P.	0,90	0,14	
Vision	SPR	0,79	0,26	0,449
	SPR + N.A.P.	0,84	0,23	
Hearing	SPR	0,88	0,21	0,485
	SPR + N.A.P.	0,92	0,17	
Breathing	SPR	0,57	0,20	0,009
	SPR + N.A.P.	0,70	0,16	
Sleeping	SPR	0,73	0,23	0,860
	SPR + N.A.P.	0,72	0,23	
Eating	SPR	0,99	0,06	0,394
	SPR + N.A.P.	1,00	0,00	
Speech	SPR	0,93	0,14	0,692
	SPR + N.A.P.	0,95	0,11	
Excretion	SPR	0,81	0,21	0,868
	SPR + N.A.P.	0,82	0,24	
Usual activities	SPR	0,77	0,26	0,497
	SPR + N.A.P.	0,82	0,24	
Mental function	SPR	0,79	0,21	0,277
	SPR + N.A.P.	0,85	0,20	
Discomfort and symptoms	SPR	0,66	0,29	0,877
	SPR + N.A.P.	0,65	0,31	
Depression	SPR	0,84	0,21	0,542
	SPR + N.A.P.	0,88	0,16	
Distress	SPR	0,70	0,21	0,758
	SPR + N.A.P.	0,72	0,25	
Vitality	SPR	0,72	0,22	0,262
	SPR + N.A.P.	0,78	0,15	
Sexual activity	SPR	0,70	0,38	0,159
	SPR + N.A.P.	0,82	0,24	
15D score	SPR	0,78	0,13	0,177
	SPR + N.A.P.	0,83	0,12	
Chest mobility	SPR	0,83	1,19	0,029
	SPR + N.A.P.	0,90	2,31	
Back scratch	SPR	0,79	15,63	0,001
	SPR + N.A.P.	0,84	8,46	

Table 4
Regression analysis for the 15D score change.

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	p
	B	Std, Error	Beta		
(Constant)	0,214	0143		10,494	0,142
Age	0,000	0001	0,019	0114	0,910
Gender	−0,018	0028	−0,096	−0,665	0509
Baseline chest mobility	0,005	0008	0,108	0641	0,525
Baseline back scratch	0,000	0001	−0,058	−0,373	0711
Baseline 15D score	−0,286	0118	−0,408	−20,417	0,020
Group (0 = control, 1 = study)	0,068	0029	0,383	20,366	0,022

Kendrová et al. in their studies assessed the impact of speleotherapy on the quality of life, anxiety and depression in COPD patients. 128 adult people qualified for the study, out of which 2 groups were selected. The experimental group (29 patients) completed the spa treatment in combination with speleotherapy in a cave, while the control group (99 patients) underwent the spa treatment only. After the completion of the 20-day stay, the improvement in the quality of life measured by Saint George's Respiratory Questionnaire in the 'Symptoms' domain was significantly higher than in the control group. Additionally, the reduction of anxiety and improvement in exercise tolerance was observed only in the experimental group [10]. In other study conducted by Kostrzon et al. long-term effects of pulmonary rehabilitation carried out in the underground salt chambers of the 'Wieliczka' Salt Mine and the rehabilitation carried out in the standard conditions (on the surface) were compared in 42 COPD patients. The results obtained by the authors show that pulmonary rehabilitation program combined with speleotherapy has greater and more durable effects in reducing disease symptoms and increasing exercise tolerance than similar program carried out overground [11]. The effect of speleotherapy may result from one of the proposed mechanisms of action of speleotherapy on the human body, which is the improvement of the immunological status [36]. Salt particles also promote ciliary transport in the lung, allowing mucus plugs to be coughed up and it also reduces IgE inflammatory levels (immune system sensitivity) [37].

Our results are consistent with the key recommendations of the American Thoracic Society and the European Respiratory Society indicating the need to improve the respiratory function in pulmonary rehabilitation programs also by correcting body posture [1]. Postural control disorders observed in people with chronic respiratory diseases, such as increased thoracic kyphosis, anteroposterior enlargement of the chest diameter, shoulder elevation and protraction, and the flexion position of the torso along with the protrusion of the head in front of the body axis led to low back pain, and this in turn changes the mechanics of breathing [1]. The reported differences in HRQoL may result from the introduction of an additional factor to the SPR program: N.A.P. therapy sessions, the main purpose of which was to strengthen postural control and neuromuscular coordination with the regulation of the activity of the autonomic nervous system [7]. The quality of body posture and breathing are also determined by the efficiency of the nervous system, especially the cranial nerves, between which there are also structural connections causing their mutual interaction [27]. The IX, X, XI cranial nerves together influence the functions of the pharynx and larynx as well as the quality of breathing (through their autonomous influence on the bronchi and lungs), speaking and swallowing. Forward head posture (FHP), which is unfavorable for human postural control, may also be the result of slip disorders of the nerve tracts, e.g., the V cranial (trigeminal) nerve [28] or dysfunction of the XI cranial nerve - additional innervating the sternocleidomastoid muscles [7] and the descending actons of the trapezius muscles, or the limitation of the dura mater slip through its connection with the suboccipital muscles [29]. Szczygieł et al. [30] and Koseki et al. [31] proved that FHP limits the amplitude of respiratory movements in the lower part of the chest, especially in the anterior-posterior plane.

In the training of the study group with the use of N.A.P. therapy, the activities in the prone position on a Swiss ball were applied, taking into account the slip of the nerve structures and the mechanical effect on the ganglia of the autonomic system located in the area of the transverse ribs (Fig. 1). In addition, bearing in mind that irritation of the nerve of the pterygoid canal (Vidian nerve) [32] may cause persistent nasal discharge, especially allergic rhinitis, in order to improve its neurodynamics, tasks related to the slip of the cranial nerves and the inhibition of excessive tension in the suboccipital muscles (Fig. 2) are conducted [7,27,32].

It is worth adding that in the spring last year in the underground salt chambers of the 'Wieliczka' Salt Mine Health Resort, specialist pulmonary rehabilitation for people after Covid −19, recognized by the National Health Fund, was introduced, both in adulthood, as well as the elderly and children.

In the recommendations of Key Concepts and Advances in Pulmonary Rehabilitation, prepared under the supervision of Spruit et al. [1], it was reported that pulmonary rehabilitation may lead to positive effects irrespective of the lung function impairment in relation to the patient's individual clinical status. Therefore, despite the fact that no data on the severity of the disease and the pharmacological treatment were obtained, the results of the study conducted confirm the need to include special techniques in the field of neuro-orthopedic therapy in the pulmonary rehabilitation program under speleotherapy conditions. The

Fig. 2. Group, supervised activities in the field of N.A.P. therapy with the use of tasks with the tongue to affect the cranial nerves and proactive stabilization of the cervical spine and alignment of the head in the body axis [7,27].

research project showed that a 3-week rehabilitation stay in the conditions of the underground salt chambers at the 'Wieliczka' Salt Mine Health Resort has a positive effect on the functional parameters of the chest mobility and flexibility of the upper body, and in terms of HRQoL on areas related to breathing and vitality.

The limitations of this study include the small and non-randomly assigned groups to be compared. These limitations were mitigated by standardizing the results for known baseline characteristics of the groups with multivariate regression analysis. Especially the inclusion of the generic baseline 15D score in the explanatory variables may capture the effects of different conditions and health issues the groups may have. This does not exclude the possibility of other unknown, non-controlled variables having affected the results. However, taking into account the effects of subjective assessment of the HRQoL with 15 dimensions, the results of the performed functional measurements and the result of the regression analysis, the following conclusions can be drawn:

1. SPR improves the subjective perception of HRQoL (breathing, vitality) and increases trunk flexibility and chest mobility.
2. Adding N.A.P. therapy to the SPR results in a statistically and clinically important improvement in the HRQoL.

Author statement

Sylwia Mętel – Conceptualization, Project administration, Visualization, Investigation, Validation, Formal analysis, Data Curation, Writing- Reviewing and Editing, Funding acquisition, **Magdalena Kostrzon –** Conceptualization, Project administration, Validation, Investigation, Data Curation, Writing- Reviewing and Editing, **Justyna Adamiak –** Investigation, Validation, Resources, Writing- Reviewing and Editing, **Halina Gattner –** Investigation, Validation, Writing- Reviewing and Editing, **Harri Sintonen –** Visualization, Data Curation, Validation, Formal analysis, Writing- Reviewing and Editing, **Renata Horst –** Conceptualization, Methodology, Supervision, Writing and Editing.

Funding

Open Access financed within the framework of the program of the Minister of Science and Higher Education under the name 'Regional Initiative for Perfection' within the years 2019-2022, project No. 022/RID/2018/19 in the total of 11,919,908 PLN.

References

[1] M.A. Spruit, S.J. Singh, C. Garvey, et al., An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation, Am J. Respir. Crit. Care. 188 (2013) 13–64.
[2] L.B. Helou, W. Wang, R.C. Ashmore, C.A. Rosen, K.V. Abbott, Intrinsic laryngeal muscle activity in response to autonomic nervous system activation, Laryngoscope 123 (11) (2013) 2756–2765.
[3] A. Yao, J.A. Wilson, S.L. Ball, Autonomic nervous system dysfunction and sinonasal symptoms, Allergy Rhinol (Providence) 9 (2018), 2152656718764233.
[4] J.J. Wine, Parasympathetic control of airway submucosal glands: central reflexes and the airway intrinsic nervous system, Auton. Neurosci. 133 (1) (2007) 35–54.
[5] M.A. Haxhiu, A.S.P. Jansen, N.S. Cherniack, A.D. Loewy, CNS innervation of airway-related parasympathetic preganglionic neurons: a transneuronal labeling study using pseudorabies virus, Brain Res. 618 (618, Issue 1) (1993) 115–134.
[6] M.A. Haxhiu, A.D. Loewy, Central connections of the motor and sensory vagal systems innervating the trachea, J. Auton. Nerv. Syst. 57 (1–2) (1996) 49–56.
[7] R. Horst, N.A.P - Neuroorthopädische therapie. Untersuchen, üben, eigentraining, Georg. Thieme Verlag. 2 (2022) edition.
[8] T. Horvath, Speleotherapy: a special kind of climatotherapy, its role in a respiratory rehabilitation, Int. Rehabil. Med. 8 (1986) 90–92.
[9] S. Beamon, A. Falkenbach, G. Fainburg, K. Linde, Speleotherapy for asthma, Cochrane Database Syst. Rev. 2 (2001), CD001741.
[10] L. Kendrová, P. Takáč, A. Kubincová, W. Mikuláková, P. Nechvátal, Effect of spa treatment and speleotherapy in the treatment of chronic obstructive pulmonary disease – a pilot study, Clin. Soc. Work Health Interv. 7 (2016) 7–15.
[11] M. Kostrzon, A. Śliwka, T. Włoch, M. Szpunar, D. Ankowska, R. Nowobilski, Subterranean pulmonary rehabilitation in chronic obstructive pulmonary disease, Adv. Exp. Med. Biol. 1176 (2019) 35–46.
[12] M. Kostrzon, K. Czarnobilski, E. Czarnobilska, The influence of pulmonary rehabilita-tion in the Wieliczka Salt Mine on asthma control – preliminary results, Przegl. Lek. 72 (12) (2015) 716–720.
[13] S. Mętel, M. Kostrzon, J. Adamiak, H. Gattner, D. Kościelecka, A. Sosulska, et al., The influence of speleotherapy combined with pulmonary rehabilitation on functional fitness in older adults – preliminary report, Ther. Adv. Respir. Dis. 14 (2020) 1–11.
[14] H. Sintonen, The 15D instrument of health-related quality of life: properties and applications, Ann. Med. 33 (2001) 328–336.
[15] S. Alanne, R.P. Roine, P. Räsänen, T. Vainiola, H. Sintonen, Estimating the minimum important change in the 15D scores, Qual. Life Res. 24 (3) (2015 Mar) 599–606.
[16] S. Debouche, L. Pitance, G. Liistro, G. Reychler, Reliability and reproducibility of chest wall expansion measurement in young healthy adults, J. Manip. Physiol. Ther. 39 (6) (2016) 443–449.
[17] M.F. Olsén, H. Lindstrand, L.J. Broberg, E. Westerdahl, Measuring chest expansion; A study comparing two different instructions, Adv. Physiother. 13 (3) (2011) 128–132.
[18] R.E. Rikli, C.J. Jones, Development and validation of a functional fitness test for community-residing older adults, J. Aging Phys. Activ 7 (1999) 129–161.
[19] C.J. Jones, R.E. Rikli, Measuring functional fitness in older adults, J. Active Ageing. 3/4 (2002) 25–30.
[20] W. Mazur, H. Kupiainen, J. Pitkäniemi, M. Kilpeläinen, H. Sintonen H, et al., Comparison between the disease - specific Airways Questionnaire 20 and the generic 15D instruments in COPD, Health Qual. Life Outcome 9 (2011) 4.
[21] B.R. Celli, J. Rassulo, B.J. Make, Dyssynchronous breathing during arm but not leg exercise in patients with chronic airflow obstruction, N. Engl. J. Med. 314 (23) (1986) 1485–1490.
[22] C. Lanza Fde, A.A. de Camargo, L.R. Archija, J.P. Selman, C. Malaguti, S. Dal Corso, Chest wall mobility is related to respiratory muscle strength and lung volumes in healthy subjects, Respir. Care 58 (12) (2013) 2107–2112.
[23] C. Malaguti, R.R. Rondelli, L.M. de Souza, M. Domingues, S. Dal Corso, Reliability of chest wall mobility and its correlation with pulmonary function in patients with chronic obstructive pulmonary disease, Respir. Care 54 (12) (2009) 1703–1711.
[24] K.T. La Pier, T. Kinney, Chest wall expansion values in supine and standing across the adult lifespan, Phys. Occup. Ther. Geriatr. 21 (1) (2002) 65–81.
[25] S. Reddy, K. Alahmari, P. Silvian, I. Ahmad, V.N. Kakarparthi, K. Rengaramanujam, Reliability of chest wall mobility and its correlation with lung functions in healthy nonsmokers, healthy smokers, and patients with COPD, Cancer Res. J. 4 (2019) 1–11.
[26] S.E. Bockenhauer, H. Chen, K.N. Julliard, J. Weedon, Measuring thoracic excursion: reliability of the cloth tape measure technique, J. Am. Osteopath. Assoc. 107 (2007) 191–196.
[27] J.L. Cobo, A. Sole-Magdalena, I. Menendez, J.C. Vincente, J.A. Vega, Connections between the facial and trigeminal nerves: anatomical basis for facial muscle proprioception, JPRAS Open 12 (2017) P9–P18.
[28] A. Cuccia, C. Caradonna, The relationship between the stomatognathic system and body posture, Clinics 64 (1) (2009) 61–66.
[29] F. Scali, E.S. Marsili, M.E. Pontell, Anatomical connection between the rectus capitis posterior major and the dura mater, Spine 36 (25) (2011) E1612–E1614.
[30] E. Szczygieł, K. Węglarz, K. Piotrowski, T. Mazur, S. Mętel, J. Golec, Biomechanical influences on head posture and the respiratory movements of the chest, Acta Bioeng. Biomech. 17 (2) (2015) 143–148.
[31] T. Koseki, F. Kakizaki, S. Hayashi, N. Nishida, M. Itoh, Effect of forward head posture on thoracic shape and respiratory function, J. Phys. Ther. Sci. 31 (1) (2019) 63–68.

[32] R.S. Tubbs, E.G. Salter, Vidius vidius (guido guidi): 1509-1569, Neurosurgery 59 (1) (2006) 201–203. ; discussion 201-3.
[33] J.B. Soriano, P. Kendrick, K. Paulson, V. Gupta, T. Vos, Prevalence and attributable health burden of chronic respiratory diseases, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017, Lancet Respir. Med. 8 (2020) 585–596.
[34] online access date: https://www.who.int/health-topics/chronic-respiratory-diseases#tab=tab_1. (Accessed 4 May 2002).
[35] J. Freidl, D. Huber, H. Braunschmid, C. Romodow, C. Pichler, R. Weisböck-Erdheim, M. Mayr, A. Hartl, Winter exercise and speleotherapy for allergy and asthma: a randomized controlled clinical trial, J. Clin. Med. 9 (10) (2020) 3311.
[36] I. Nurov, Immunologic features of speleotherapy in patients with chronic obstructive pulmonary disease, MHSJ 2 (2010) 44–47.
[37] A.A. Wasik, T. Tuuminen, Salt therapy as a complementary method for the treatment of respiratory tract diseases, with a focus on mold-related illness, Alternative Ther. Health Med. 27 (S1) (2021) 223–239.

Halina Gattner has been an academic teacher at the Podhale State College of Applied Sciences in Nowy Targ at the Institute of Health since 2014. She received her PhD in physical education from the University of Physical Education in Kracow in 2020. She completed studies at the University of Physical Education in Krakow in 2013 and obtained a Master's degree in physiotherapy. Additionally, she obtained a Bachelor's degree in cosmetology at the Andrzej Frycz Modrzewski Kracow University in 2014. Her special interests are focused on pulmonary rehabilitation and impact of vibration training on the human body, as well as on effectiveness of application of various physical stimuli in biological regeneration and cosmetology.

Harri Pekka Sintonen – he is currently Emeritus Professor of Health Economics, Department of Public Health, University of Helsinki. He received PhD in 1981. Previously, he was Professor of Health Economics at the University of Helsinki in the Department of Public Health (50%), and Research Professor of Health Economics at the Finnish Office for Health Technology Assessment (FinOHTA) (50%) (2000–2010). His research interests are: measurement of health-related quality of life, development of generic instruments for that purpose (e.g., "father" of the 15D instrument family) and economic evaluation of health care technologies. He is an author of about 300 peer-reviewed articles in international journals, altogether over 500 publications. Additionally, he is a member of Finnish Society for Health Economics, The EuroQol Group, formerly also iHEA and ISTACH (THAi).

Justyna Adamiak is an academic teacher at the University of Physical Education in Kraków at the Motor Rehabilitation Department and a member of Polish Chamber of Physiotherapists and Polish Society of Physiotherapy. She received her Master's degree in Physiotherapy in 2005, and then she earned her Doctorate in Physical Education in 2013. Additionally, in 2014 she obtained a Master's degree in English Philology at the Tischner European University in Kraków. Her special interests are focused on health education, benefits of vibration training on the human body function and application of physical agents in cosmetology. She also works as an editor for English Language in the Medical Rehabilitation Journal.

Magdalena Kostrzon was a head specialist for research and analyses in the "Wieliczka" Salt Mine Health Resort. In 2019 Doctoral degree (PhD), Jagiellonian University Collegium Medicum - Faculty of Health Sciences. In 2001 Master degree (MSc), Biology, Jagiellonian University. Responsible for scientific and research cooperation and the development of medical activities. By coordinating research and presenting the results of scientific projects of the Health Resort at international conferences, she contributed to broadening the knowledge of treatment with the use of the underground climate and raw materials of the "Wieliczka" Salt Mine. She is the author of publications on the properties of the salt workings climate. Since 2014, she has been the Adjunct Secretary at the Permanent Commission on Speleotherapy (UIS) – an international committee of centres dealing with treatment with the use of mine or cave climate.

Renata Horst is a founder of N.A.P therapy (1999) and head instructor of the N.A.P. Academy (2009). She became physiotherapist in 1986 and part of the instructor team in orthopedic manual therapy (Kaltenborn - Evjenth) as well as international instructor in Proprioceptive Neuromuscular Facilitation in 1993. Her master's degree in neurological rehabilitation was written on the topic of N.A.P. which is based on the principles of motor learning, which has been her main topic of interest since her studies in the USA in the late 1970's. She is an author of many publications and specialist books and has been travelling as guest lecturer to various countries within Europe and Asia.

Sylwia Mętel – a lecturer at the Motor Rehabilitation Department, University of Physical Education in Krakow. She runs courses in Neuro-ortopaedic therapy, Physical Medicine and Sensorimotor training. In 2005 she obtained a Doctorate degree (PhD) at the University of Physical Education in Krakow and in 1995 a Master's degree (MSc) in Physiotherapy. She has been working as a physiotherapist for over 20 years. She is a head of research projects focused on application of N.A.P. therapy in pulmonary rehabilitation and also assessment of functional performance, chest mobility, state of voice and quality of life of elderly people who participate in the rehabilitation and treatment stay in "Wieliczka" Salt Mine Health Resort. She is the author of publications and conference presentations on the influence of speleotherapy combined with pulmonary rehabilitation on functional fitness and chest mobility in older adults and also the effects of N.A.P. therapy in patients with voice disorders. She is a member of Polish Association of Rehabilitation.