Review paper

The effects of respiratory muscle training in chronic kidney disease patients on haemodialysis and peritoneal dialysis: a review

Ocena efektów treningu mięśni oddechowych u pacjentów z przewlekłą chorobą nerek hemodializowanych i dializowanych otrzewnowo – przegląd literatury

Grzegorz Kowal[1], Andrzej Rydzewski[2]

[1]Physiotherapy Centre, Kielce, Poland
Head: mgr Grzegorz Kowal
[2]Department of Pathobiomechanics, Institute of Physiotherapy, Faculty of Medicine and Health Sciences, Jan Kochanowski University in Kielce, Poland
Head of the Department: prof. zw. dr hab. n. med. Andrzej Rydzewski

Medical Studies/Studia Medyczne 2018; 34 (1): 78-85
DOI: https://doi.org/10.5114/ms.2018.74825

Key words: chronic kidney disease, chronic kidney failure, respiratory muscle training, breathing exercises, respiratory muscles.
Słowa kluczowe: przewlekła choroba nerek, przewlekła niewydolność nerek, trening mięśni oddechowych, ćwiczenia oddechowe, mięśnie oddechowe.

Abstract

Introduction: Recently, there has been a steady increase in the number of people diagnosed with chronic kidney disease (CKD). Reduction of respiratory muscle strength may be secondary to CKD. This article summarises available studies that evaluate the effect of respiratory muscle training in patients with CKD on haemodialysis and peritoneal dialysis.
Material and methods: The following databases were reviewed: Medline (PubMed), Scopus, Web of Science, Academic Search Complete, and Embase. For this analysis all published studies that investigated the effect of any form of respiratory muscle exercise on respiratory muscle strength, and the maximum inspiratory and expiratory pressure in adult patients chronically haemodialysed or on peritoneal dialysis, were included.
Results: Only four clinical trials that met inclusion criteria were identified (two randomised and controlled, one uncontrolled, and one non-randomised) involving a total of 108 patients. Threshold IMT (Inspiratory Muscle Trainer) and respiratory biofeedback methods were used for respiratory muscle training. Duration of training program tract was from six weeks to 10 weeks. The effects of respiratory muscle training were evaluated by PI_{max}, PE_{max}, FVC, PEF, and 6MWT.
Conclusions: Our review indicates that respiratory muscle training during haemodialysis may improve respiratory muscle strength and therefore improve exercise capacity in patients with chronic kidney disease. We did not find any data on the effects of respiratory muscle training on strength, pulmonary functional parameters, and exercise capacity in patients with chronic kidney disease on peritoneal dialysis.

Streszczenie

Wprowadzenie: W ostatnich latach wzrasta liczba osób z rozpoznaną przewlekłą chorobą nerek (PChN). Zmniejszenie siły mięśni oddechowych może być wtórne do PChN. Opracowanie to jest przeglądem badań określających ocenę efektów treningu mięśni oddechowych u pacjentów z PChN hemodializowanych i dializowanych otrzewnowo.
Materiał i metody: Dokonano przeglądu baz danych: Medline (PubMed), Scopus, Web of Science, Academic Search Complete i Embase. Do niniejszej analizy włączano wszystkie opublikowane badania, w których w jakiejkolwiek formie występowały ćwiczenia dotyczące mięśni oddechowych i siła mięśni oddechowych została oceniona wartością maksymalnego ciśnienia wdechowego i wydechowego u dorosłych pacjentów z przewlekłą chorobą nerek hemodializowanych i dializowanych otrzewnowo.
Wyniki: Kryteria włączenia do analizy spełniały 4 badania kliniczne W publikacjach odnaleziono 2 randomizowane, kontrolowane oraz 1 niekontrolowane i 1 nierandomizowane, eksperymentalne badania kliniczne, w których uczestniczyło łącznie 108 pacjentów. Do treningu mięśni oddechowych stosowano Threshold IMT (Inspiratory Muscle Trainer) i metodę biofeedbacku oddechowego. Czas trwania programów treningu oddechowego wynosił od 6 do 10 tygodni. Efekty treningu mięśni oddechowych oceniane były przez PI_{max}, PE_{max}, FVC, PEF i 6MWT.
Wnioski: Na podstawie dokonanego przeglądu piśmiennictwa można przypuszczać, że trening mięśni oddechowych podczas hemodializy zwiększa siłę mięśni oddechowych, przez co może poprawiać wydolność fizyczną u pacjentów z przewlekłą chorobą nerek. Nie odnaleziono doniesień na temat wpływu treningu mięśni oddechowych na ich siłę, parametry funkcjonalne płuc i na wydolność fizyczną u pacjentów z przewlekłą chorobą nerek dializowanych otrzewnowo.

Introduction

Recently there has been an increase in the number of people affected by chronic kidney disease (CKD). It is estimated that in Poland around 4.2 million people may be suffering from CKD. In 2015 the number of patients on haemodialysis (HD) stood at 18,809, while the number of patients treated with peritoneal dialysis (PD) was 1091 [1].

In CKD multiple organs and systems are affected. Within the respiratory system the most common changes include: impaired lung function and weakening of respiratory muscles, caused mainly by the consequences of CKD, i.e. anaemia, cardiovascular complications, secondary hyperparathyroidism [2, 3], accumulation of uremic toxins [4], electrolyte disturbances [5], uremic myopathy [6], vitamin D deficiency [7], malnutrition-inflammation-atherosclerosis syndrome (MIA) [8], and oxidative stress causing muscle tissue loss [9].

An additional factor, which lowers the physical performance of the organism and adversely affects the respiratory system, is immobilisation during haemodialysis. The HD procedure is usually undertaken three times per week and lasts from four to six hours. Throughout the year the average patient is inactive for approximately 800 hours (corresponding to one month) [10]. In patients with CKD subjected to peritoneal dialysis, the respiratory mechanics are additionally hindered by increased intra-abdominal pressure due to the presence of the dialysis solution in the peritoneal cavity. Dialysis fluid increases the pressure in the abdominal cavity and disturbs the respiratory mechanics [11]. The pressure inside the peritoneal cavity increases linearly with the increase of the dialysate volume. It was also noted that the pressure inside the peritoneal cavity is significantly higher in patients having higher body mass index (BMI), while it is not affected by age, sex, weight, height, body surface area (BSA), diabetes, or past surgeries of the abdominal cavity [12]. The strength of the inspiratory muscles in the peritoneal dialysis group (49.9%) was significantly lower than in kidney transplant recipients and haemodialysis patients (respectively, 54.7% and 66.5%) [13]. HD and PD patients have weaker electrical activity of some muscles that are involved in breathing, among others the pectoralis major, abdominal oblique, and abdominal rectus [14]. Taking into account all changes occurring during CKD, the introduction of targeted workout, especially to improve the chest mechanics, through the muscle performance may be successful.

The aim of this paper was to systematically review the literature that specifies the evaluation of respiratory muscle training in patients with CKD treated by haemodialysis or peritoneal dialysis.

Material and methods

Eligibility criteria

This analysis includes all published research on respiratory muscle exercise in any form, in which the strength of respiratory muscles was evaluated (maximal value of the inspiratory and expiratory pressure). The participants included subjects of both sexes suffering from CKD (> 18 years old), treated by haemodialysis or peritoneal dialysis.

Procedures

We aimed to find articles focusing on respiratory muscle training in CKD patients maintained on haemodialysis or peritoneal dialysis, published from 1993 to April 2016. Studies were identified by searching the following databases: Medline (PubMed), Scopus, Web of Science, Academic Search Complete, and Embase. Researching throughout the databases was made using combinations of the following terms: "chronic kidney failure", "chronic kidney disease", "renal replacement therapy", "kidney transplantation", "breathing exercises", "respiratory muscle training", and "respiratory muscle". Potentially relevant articles were screened first by the information specified in titles and abstracts. Only papers that met all the prespecified criteria were included in this review.

Results

During the initial search 224 reports were identified, from which, on the basis of information con-

Table 1. The number of patients who completed the respiratory training in the current study

Year of publication	Publication	Type of study	Number of patients
2010	Giendruczakda Silva *et al.*	Non-controlled	15
2010	Rocha *et al.*	Nonrandomised, experimental	13
2012	Figueiredo *et al.*	Randomised, controlled	24
2013	Pellizzaro *et al.*	Randomised, controlled	25
Total			77

tained in titles and summaries, 28 studies were selected as potentially relevant. Full text was obtained for 19 papers, which provided detailed information on the rehabilitation program (respiratory exercises in various forms), and criteria for inclusion were met only by four papers. There were two randomised, controlled and one uncontrolled, non-randomised, experimental clinical studies. Specific details are presented in Table 1.

All there search was carried out in Brazil. The main parameters used for evaluation of the respiratory strength were maximal inspiratory and expiratory pressures (PI_{max} and PE_{max}).

Sample sizes

The four identified studies involved a total of 108 patients, all of them treated with haemodialysis. The number of patients who completed the respiratory muscle training is presented in Table 1. There were no articles on respiratory muscle training in peritoneal dialysis patients.

The duration of training programs

Duration of the respiratory muscle training program varied from six weeks [15], through eight weeks [16, 17], to 10 weeks [18].

The period of haemodialysis devoted to respiratory training

In research by Figueiredo *et al.* the respiratory training was performed between the second and the third hour of the haemodialysis procedure [15]. In papers by Pellizzaro *et al.* [18] and Rocha *et al.* [17] the peripheral and respiratory muscle training were performed during the first two hours of the procedure. This time period was chosen because after 2 h of haemodialysis cardiovascular decompensation, due to the haemodynamic effect of dialysis, may preclude exercise [19].

Characteristics of the intervention

Pellizzaro *et al.* [18] used a Threshold IMT (Inspiratory Muscle Trainer) device for training of the respiratory muscles. This device is equipped with a single flow valve, independent of the airflow, ensuring a constant resistance (linear load), and it allows appropriate adjustment of the air flow pressure. The training program of the peripheral muscles involved only the extension of a knee. Patients performed exercises with the load placed in a distal part of the bottom limb.

In a study done by Figueiredo *et al.* [15] patients performed respiratory exercises in a semi-recumbent sitting position during haemodialysis. The respiratory muscle training was monitored by a physiotherapist, who also encouraged patients to maintain breathing cycles. Patients were told to use their lung capacity in a scheduled and slow way, while breathing. During exhalation, they were also told to use the accumulated volume of air that remains, initially to extend the respiratory muscle fibres in order to stimulate them for better contraction. Patients performed the respiratory muscle training with the use of the Threshold IMT device or medical apparatus for controlling the activity of the diaphragm with clearance feedback. This method of respiratory biofeedback relies on placing a tape on the patient's abdomen. Tape is connected to a manometer, which processes the displacements of the abdominal wall to pressure. The system produced a sound signal during the inhalation phase and illustrated the activity of the diaphragm. It presented also visual phases of inspiration and expiration, which ranged from –40 up to +40 cm H_2O. Patients could observe the rising of the chest and abdomen and the effort connected to the work of respiratory muscles. Subjects were familiarised with the functioning of the device prior to the start of the program. They were also encouraged not to change their respiratory muscle activity pattern during the research period. The system was calibrated before training for each patient after sitting and resting for five minutes. All the time, patients were accompanied by a physiotherapist, who controlled the spontaneous, slow pace of breathing on the level of 6–10 breaths/min.

The threshold IMT device was also used for respiratory muscle exercises by da Silva *et al.* [16].

In research done by Rocha *et al.* [17] training sessions consisted of upper and lower limb exercises performed in a sitting position during haemodialysis. For upper limbs with arteriovenous fistula, a small ball was used to increase the grip strength. Upper limbs without fistulas, apart from ball training, were also subjected to patterns of upper limb activity according to PNF method (flexion-inversion with external rotation/flexion-eversion with internal rotation/flexion-eversion with external rotation and extension-eversion with internal rotation/extension-inversion with internal rotation), with 1 kg dumbbells connected with prolonged inspiration and expiration, eversion of the arm to 90°, and inversion to the central line and flexion and extension of the elbow. Training of the lower limbs consisted of the following three exercises: bending and extending the knee with a 2-kg load on the distal part of the calf, plantar, and dorsal flexion, and the circulation of the feet around the ankle.

Duration of training sessions

The duration of training sessions varied. In the research by da Silva *et al.* [16] a training session lasted 15 min in the first and 30 min in the second month of the project, Figueiredo *et al.* [15] subjected patients to 20-min sessions, and the time period was extended

Table 2. Characteristics of the included studies

Study	Participants	Intervention	Training effects			
Giendruczak da Silva *et al*., 2010 (Brazil)	N = 15 (8 ♂⚦7 ♀), HD Age 45 ±13.7 years HD 3 times a week BMI (kg/m²) 20.4 ±3.0 HD duration (months) 61.40 ±32.3	8 weeks, 3 x week 1 month 15 min., 2 months 30 min. Respiratory exercises (Threshold IMT); load 40% PI_{max}; 5 times/1 min interval	PI_{max} (cmH_2O) PI_{max} after inter* PE_{max} (cmH_2O) PE_{max} after inter* FVC (L) FVC after inter* 6MWT (m) 6MWT after inter*		69.7 ±30.3 119.8 ±114.7 p = 0.074 96.4 ±36.4 101 ±40.3 p = 0.320 4.0 ±0.9 4.0 ±1.2 p = 0.825 455.5 ±98.8 557.8 ±121.0 p = 0.003	
Rocha *et al*., 2010 (Brazil)	N = 13 (10 ♂, 3 ♀), HD Age 43.69 ±9.28 years HD 3 times a week BMI (kg/m²) 23.46 ±5.5 HD duration (months) 36.30 ±26.10	8 weeks, 3 x week 25 min during first 2 hours HD Grip strength 3 × 10/10-sec interval Exercise upper limb without fistula in the shoulder joint combined with breathing exercises and elbow joint with the use of 1-kg dumbbells Exercise the lower limbs in the knee and ankle joints 3 × 10/15-sec interval between series and 20 sec between exercises	MIP/PI_{max} (cmH_2O) MIP/PI_{max} after inter* MEP/PE_{max} (cmH_2O) MEP/PE_{max} after inter* PEF (L/min) PEF after inter* Dynamometr (kG) Dynamometr after inter*		97.69 ±28.32 98.46 ±23.39 p = 0.933 83.07 ±31.19 88.46 ±14.05 p = 0.470 375.38 ±75.23 416.15 ±57.37 p = 0.029 57.23 ±17.39 56.61 ±16.09 p = 0.865	
Figueiredo *et al*., 2012 (Brazil)	N = 34: G-1 (Threshold) (n = 16; 9 ♂, 7 ♀), HD G-2 (biofeedback) (n = 15; 9 ♂, 6 ♀), HD Control (n = 10; 6 ♂, 4 ♀), HD Age: G-1 40.46 ±2.79 G-2 41.20 ±3.40 Control 50 ±7.2 HD 3 times a week BMI (kg/m²): G-1 22.07 ±0.90 G-2 21.72 ±0.92 Control 23.8 ±5.4 HD duration (month): G-1 57.94 ±8.03 G-2 47.33 ±7.54 Control 64 ±19.6	6 weeks, 3 × week 20 min between 2 and 3 hours HD G1 respiratory exercises (Threshold IMT) load 40%, PI_{max}, 1 min breaths/ 1 min interval G2 respiratory exercises (biofeedback), load 40%, PI_{max}, 6–10 breaths/min		G-1	G-2	Control
			MIP (cmH_2O)	70.6 ±4.0	67.7 ±5.0	73.3 ±24.7 p = 0.84
			MIP after inter*	108.7 ±7.4	96.3 ±8.3	 p = 0.26
			MEP (cmH_2O)	73.1 ±5.1	67.7 ±5.4	75.0 ±25.0 p = 0.72
			MEP after inter*	82.5 ±6.7	76.0 ±4.3	 p = 0.56
			FVC(L)	2.4 ±0.2	2.3 ±0.2	2.5 ±0.8 p = 0.91
			FVC after inter*	2.8 ±0.2	2.5 ±0.2	 p = 0.18

Table 2. Cont.

Study	Participants	Intervention	Training effects			
				RMT	PMT	Control
Pellizzaro *et al.*, 2013 (Brazil)	*N* = 39: RMT (*n* = 11; 8 ♂, 3 ♀), HD PMT (*n* = 14; 7 ♂, 7 ♀), HD Control (*n* = 14; 8 ♂, 6 ♀), HD Age: RMT 43 PMT 48.9 Control 51.9 HD 3 × week BMI (kg/m²): RMT 22.2 PMT 23.1 Control 24.1 HD duration (month): RMT 60 PMT 54 Control 54	10 weeks, 3 × week During first 2 hours HD RMT respiratory exercises (Threshold IMT) load 50% PI_{max}, 3 × 15 breaths/1 min interval between series and after 30 days another evaluation 50% PI_{max} PMT exercises to straighten the knee joint load 50% 1MR, 3 × 15/1-min interval between series and after 30 days another evaluation 50% 1MR	PI_{max} (cmH_2O)	64.9	55.2	70.0 $p = 0.36$
			PI_{max} after inter*	87.4	65	64.6 $p < 0.001$
			PE_{max} (cmH_2O)	79.7	73.3	94.12 $p = 0.27$
			PE_{max} after inter*	91.4	79.7	75.3 $p = 0.02$
			FVC (L)	2.8	2.7	3.0 $p = 0.65$
			FVC after inter*	3.4	3.4	2.7 $p = 0.58$
			6MWT (m)	454.1	444.6	406.7 $p = 0.43$
			6MWT after inter*	519	457	407 $p < 0.001$

*Intervention

to 25 min in the study by Rocha *et al.* [17]. In a controlled study carried out by Pellizzaro *et al.* [18] patients were expected to perform 3 × 15 breaths and 3 × 15 knee extensions, with a one-minute break between the three sessions.

Intensity of the training

The intensity of training was calculated for every individual on the basis of the inhaling pressure measurement (PI_{max}), during initial phases of the research [15, 16, 18]. In research by da Silva *et al.* [16] the load was set to 40% PI_{max}, and exercises were performed in cycles of five with one-minute breaks. In Figueiredo's paper [15], patients who performed the respiratory muscle training with the use of the Threshold IMT device (G-1 group, Table 2) were breathing alternately, one minute of effort and one minute of break with the load of 40% of maximal inhaling pressure PI_{max}. The patients, who were exercising using the method of respiratory biofeedback (G-2 group, Table 2), were told to look at the screen of the biofeedback to control the efforts of the diaphragm, and to reach 30 cm H_2O PI_{max}, which corresponds to around 40% of maximal inhaling pressure. They were exercising with the frequency of 6–10 breaths/min. In the exercise program adopted by Pellizzaro *et al.* [18] the number of cycles and repetitions, the rest time between cycles, the load of one maximal repetition (1MR), and PI_{max} set for patients who performed the respiratory muscle training with the use of the Threshold IMT device (RMT group, Table 2), and in whom peripheral muscle training involving only the extension of a knee (PMT group, Table 2), fulfilled the requirements of the strength exercise [20]. Patients were training with the use of the Threshold IMT using 50% resistance PI_{max}, and after 30 days of training the maximum resistance was re-evaluated and changed again to 50% PI_{max}. Patients performed three series of 15 breaths, with a 60-second break between each series. The load of each patient from the PMT group was set in accordance to the 1MR test. The training load was set at 50% 1MR, and after 30 days of training it was changed according to another evaluation of 1MR. Patients performed a total of three series of 15 repetitions of knee extensions, with a 60-second break between each series. Patients in the research of Rocha *et al.* [17] used a small ball to strengthen the hand grip. Three series were performed with 10 repetitions and 10-second breaks between. Training of the upper limb without fistula was performed according to PNF method with the use of 1-kg dumbbells combined with respiratory muscle training (protruding, inspiration, and expiration) in three series of 10 repetitions and 15-second breaks between each series and 20 seconds between exercises. Bending and extending the knee was performed with 2-kg load on the distal part of the calf. It was done in three series of 10 repetitions, with 15-second breaks between series and 20-second breaks between exercises.

Effects of the training

An increase of respiratory muscle strength was observed as an effect of training programs. Most benefits were seen when training of respiratory muscles was performed with the use of the Threshold device.

In the research of Pellizzaro *et al.* [18] PI_{max} increased significantly in the RMT group using the Threshold IMT (Table 2). The increase was higher than in the PMT group and the control group C (Table 2). The improvement was also significantly higher in the PMT group in comparison to patients in the control group C, but the increase was lower. The percentage of patients who before training achieved the predicted values of PI_{max}, after adjustment for sex and age, was 60.6% (RMT), 55.1% (PMT), and 73.5% (C), respectively. At the beginning of the research only three patients, one in each group, reached the predicted value PI_{max}. After 10 weeks of training eight patients reached the predicted PI_{max} value, four of them from the RMT group, three from the PMT group, and one from the control group C. As to the post-training measurement, the RMT group reached 82.3% of the predicted value, while PMT and group C reached, respectively, 64.7% and 67.6%. However, these differences were not statistically significant, probably due to the small sample size.

In the training program devised by da Silva *et al.* [16] PI_{max} was increased from 69.7 ±30.3 to 119.8 ±114.7 (cmH_2O), p = 0.074 after using the Threshold IMT device. In the paper by Figueiredo *et al.* [15] the results obtained with the use of the respiratory biofeedback method were similar to those achieved with the use of the Threshold IMT. Both methods of respiratory muscle training increased the PI_{max} values. Values of PI_{max} for patients using the Threshold IMT (G-1, Table 2) increased from 70.63 ±4.03 cmH_2O to 108.75 ±7.41 cmH_2O (p < 0.0001), while for patients using biofeedback the method increased (G-2, Table 2) from 67.67 ±5.02 cmH_2O to 96.33 ±8.30 cmH_2O (p < 0.0001).

Rocha *et al.* [17] did not find any influence of exercise program on PI_{max}: 97.69 ±28.3 cmH_2O before and 98.46 ±23.39 cmH_2O after, p = 0.93. In training programmes that used 40% resistance PI_{max} in the Threshold IMT device, the differences in respiratory muscle strength were higher than in the programmes using 50% resistance PI_{max} (da Silva *et al.* [16] 50.1 cmH_2O; Figueiredo *et al.* [15] 38.12 cmH_2O; Pellizzaro *et al.* [18] 22.5 cmH_2O, respectively). This suggests that the intensity of training should be set on 30-40% PI_{max} (maximal inspiratory pressure in the oral cavity) [2].

In all four studies PE_{max} increased. At the beginning of the research the RMT group (Threshold IMT), the PMT group, and the control group reached, respectively, 67.5%, 69.4%, and 86.7% of the predicted value of PE_{max} (p = 0.10). Seven patients exceeded the predicted value at the beginning of the research and during the post intervention evaluation. In the research of Figueiredo *et al.* [15] values of PE_{max} in G-1 (Threshold IMT) ranged between 73.13 ±5.10 cmH_2O and 82.50 ±6.74 cmH_2O (p = 0.007) and G-2 (biofeedback) from 67.67 ±5.41 cmH_2O to 76.00 ±4.29 cmH_2O (p = 0.002). In the study by Rocha *et al.* [17] PE_{max} ranged from 83.07 ±31.19 cmH_2O to 88.46 ±14.0 cmH_2O (p = 0.46), and in the work carried out by da Silva *et al.* [16] PE_{max} (cmH_2O) amounted from 96.4 ±36.4 to 101 ±40.3 (p = 0.320). Spirometry results were not influenced by training [15–17].

In two of the cited studies, the evaluation of respiratory training effects by the 6MWT test was used. In the work of Pellizzaro *et al.* [18], before the beginning of training, patients from the RMT group, PMT group, and C group reached the distance of 454.1 m, 444.6 m, and 406.7 m, respectively. Distance values after the intervention with the Threshold IMT device were significantly longer at 519.0 m, 475.1 m, and 407.0 m, respectively. In research of da Silva *et al.* [16], the data acquired from 6MWT before and after the intervention, also showed a statistically significant improvement in the distance gained: from 455.5 ±98.8 to 557.8 ±121.0 m.

Correlations between the distance and PI_{max} were observed in both studies. da Silva *et al.* [16] showed a statistically significant correlation between the distance gained and PI_{max} before the training and two months after the intervention. Pellizzaro *et al.* [18] demonstrated a connection between respiratory muscle strength (PI_{max} and PE_{max}) and the distance gained by patients in 6MWT test. A significant correlation was also found between the distance gained by patients in 6MWT test and variables of both PI_{max} and PE_{max}.

Rocha *et al.* [17] evaluated also the strength of the hand grip, and they found it was lower when comparing the values from before and after the intervention, but the difference was not statistically significant: 57.23 ±17.39 kg before the intervention and 56.61 ±16.09 kg after the intervention. The results may have been caused by the short training time, as patients were exercising the strength of the arm grip in three series of 10 repetitions, and one cycle lasted 10 sec. In the aforementioned study quality of life was also evaluated using the SF-36 questionnaire. Some patients experienced a lower pain level in the legs, lower frequency of cramps, better mood, and less exhaustion during everyday chores. Pellizzaro *et al.* [18], on the other hand, used a KDQOL-SF™ questionnaire in order to evaluate the quality of life. They found a significant increase in the following domains: energy/tiredness, sleep, pain, and list of symptoms/problems.

Detrimental effects of physical training

No detrimental effects of physical training were reported. In the study by Rocha *et al.* [17] 11 patients were excluded from their study due to intercurrences in the dialysis treatment caused by haemodynamic instability. In the studies by Pellizzaro *et al.* [18] and Figueiredo *et al.* [15] some patients were excluded due to non-compliance.

It should be remembered that intradialytic exercise should be performed under careful surveillance because the HD session may induce myocardial stunning [22], and peritoneal dialysis (by causing increase in intraabdominal pressure) may induce/enhance cardiac repolarisation inhomogeneities [23].

Conclusions

Lower physical performance is one of the most commonly reported problems in haemodialysed patients, and it is caused most often by lower effort tolerance. It has a negative influence on everyday well-being and daily life chores. Reviewed research suggests that training of the respiratory muscles during haemodialysis increases the inspiratory muscle strength, which in turn improves effort tolerance and physical performance of patients suffering from chronic kidney disease. The significant increase of expiratory muscle strength seen in these patients could be due to the work of the abdomen during the interventions in expiratory muscle training [18]. A safe test to evaluate the exercise capacity of these patients is the 6MWT.

Respiratory muscle training performed during the haemodialysis procedure is a safe and effective therapy, not only providing an increased tolerance but also improving the quality of life of these patients. In groups subjected to training there is a lower occurrence of pain and lower limb cramping, fewer sleep disorders, mood improvement, and less exhaustion during the performance of everyday chores. There was also a significant increase in haemoglobin, haematocrit, and albumin levels and a decrease in CRP, potassium, and phosphate levels.

There were no reports on the influence of respiratory muscle training on their strength, functional parameters of the lungs, and physical capacity of patients with chronic kidney disease, peritoneally dialysed. These fields of interest require additional research.

Conflict of interest

The authors declare no conflict of interest.

References

1. Klinger M. Personal information 2017.
2. Moore GE, Brinker KR, Stray-Gundersen J, Mitchell JH. Determinants of VO_2peak in patients with end-stage renal disease: on and off dialysis. Med Sci Sports Exerc 1993; 25: 18-23.
3. Kouidi E, Albani M, Natsis K, Megalopoulos A, Gigis P, Guiba-Tziampiri O, Tourkantonis A, Deligiannis A. The effects of exercise training on muscle atrophy in haemodialysis patients. Nephrol Dial Transplant 1998; 13: 685-699.
4. Diesel W, Noakes TD, Swanepoel C, Lambert M. Isokinetic muscle strength predicts maximum exercise tolerance in renal patients on chronic hemodialysis. Am J Kidney Dis 1990; 16: 109-114.
5. Ulubay G, Akman B, Sezer S, Calik K, Eyuboglu Oner F, Ozdemir N, Haberal M. Factors affecting exercise capacity in renal transplantation candidates on continuous ambulatory peritoneal dialysis therapy. Transplant Proc 2006; 38: 401-405.
6. Sakkas GK, Ball D, Mercer TH, Sargeant AJ, Tolfrey K, Naish PF. Atrophy of non-locomotor muscle in patients with end-stage renal failure. Nephrol Dial Transplant 2003; 18: 2074-2081.
7. Olędzka R. Witamina D w świetle badań ostatnich lat. Bromatologia Chemia Toksykologiczna 2013; 46: 121-131.
8. Nascimento MM, Qureshi AR, Stenvinkel P, Pecoits-Filho R, Heimbürger O, Cederholm T, Lindholm B, Bárány P. Malnutrition and inflammation are associated with impaired pulmonary function in patients with chronic kidney disease. Nephrol Dial Transplant 2004; 19: 1823-1828.
9. Raj DS, Dominic EA, Pai A, Osman F, Morgan M, Pickett G, Shah VO, Ferrando A, Moseley P. Skeletal muscle, cytokines, and oxidative stress in end-stage renal disease. Kidney Int 2005; 68: 2338-2344.
10. Chojak-Fijałka K, Smoleński O, Miłkowski A, Piotrowski W. The effects of 6-month physical training conducted during hemodialysis in ESRD patients. Med Rehabil 2006; 10: 25-36.
11. Twardowski ZJ, Khanna R, Nolph KD, Scalamogna A, Metzler MH, Schneider TW, Prowant BF, Ryan LP. Intraabdominal pressures during natural activities in patients treated with continuous ambulatory peritoneal dialysis. Nephron 1986; 44: 129-135.
12. Dejardin A, Robert A, Goffin E. Intraperitoneal pressure in PD patients: relationship to intraperitoneal volume, body size and PD-related complications. Nephrol Dial Transplant 2007; 22: 1437-1444.
13. Karacan Ö, Tutal E, Çolak T, Sezer S, Eyüboğu FÖ, Haberal M. Pulmonary function in renal transplant recipients and end-stage renal disease patients undergoing maintenance dialysis. Transplant Proc 2006; 38: 396-400.
14. Wanic-Kossowska M, Koczocik-Przedpelska J. Mioneuropatia u chorych z przewlekłą niewydolnością nerek (PNN) leczonych hemodializą (HD) i dializą otrzewnową przerywaną (IPD). Część I. Ocena aktywności mioelektrycznej wybranych mieśni szkieletowych u chorych z PNN leczonych hemodializą i dializą otrzewnową. Pol Arch Med Wewn 1996; 95: 229-236.
15. Figueiredo RR, Castro AAM, Gonzaga Napoleone FMG, Faray L, de Paula Júnior AR, Osório RA. Respiratory biofeedback accuracy in chronic renal failure patients: a method comparison. Clin Rehabil 2012; 26: 724-732.
16. Giendruczak da Silva V, Amaral C, Borba Monteiro M, Nascimento DM, Boschetti JR. Effects of inspiratory muscle training in hemodialysis patients. J Bras Nefrol 2011; 33: 45-51.
17. Rocha ER, Magalhães SM, de Lima VP. Repercussion of physiotherapy intradialytic protocol for respiratory muscle function, grip strength and quality of life of pa-

tients with chronic renal diseases. J Bras Nefrol 2010; 32: 355-366.
18. Pellizzaro CO, Thomé FS, Veronese FV. Effect of peripheral and respiratory muscle training on the functional capacity of hemodialysis patients. Ren Fail 2013; 35: 189-197.
19. Moore GE, Painter PL, Brinker KR, Stray-Gundersen J, Mitchell JH. Cardiovascular response to submaximal stationary cycling during hemodialysis. Am J Kidney Dis 1998; 31: 631-637.
20. Shimano T, Kraemer WJ, Spiering BA, Volek JS, Hatfield DL, Silvestre R, Vingren JL, Fragala MS, Maresh CM, Fleck SJ, Newton RU, Spreuwenberg LP, Häkkinen K. Relationship between the number of repetitions and selected percentages of one repetition maximum in free weight exercises in trained and untrained men. J Strength Cond Res 2006; 20: 819-823.
21. Włoch T, Bromboszcz J. Rehabilitacja pulmonologiczna. Wytyczne AACVPR do programów rehabilitacji pulmonologicznej. Elipsa-Jaim, Kraków 2012.
22. Dorairajan S, Chockalingam A, Misra M. Myocardial stunning in hemodialysis: what is the overall message. Hemodial Int 2010; 14: 447-450.
23. Dabrowski W, Jaroszynski A, Jaroszynska A, Rzecki Z, Schlegel TT, Malbrain ML. Intra-abdominal hypertension increases spatial QRS-T angle and elevates ST-segment J-point in healthy women undergoing laparoscopic surgery. J Electrocardiol 2017; 50: 214-222.

Address for correspondence:

Grzegorz Kowal, MSc
Poradnia Rehabilitacji Ruchowej
2 Kryształowa St.
25-751 Kielce, Poland
Phone: +48 690 34 27 07
Email: grzegorz.kowal1@wp.pl