Original paper

Effects of respiratory muscle training in chronic kidney disease patients on peritoneal dialysis: a pilot study

Ocena efektu treningu mięśni oddechowych u chorych z przewlekłą chorobą nerek dializowanych otrzewnowo – badanie pilotażowe

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Słowa kluczowe: fizjoterapia, przewlekła choroba nerek, ćwiczenia oddechowe, trening mięśni oddechowych. dializa otrzewnowa.

Abstract

Introduction: The strength of inspiratory and expiratory muscles in patients treated with peritoneal dialysis is lower than in haemodialysis patients and in those after kidney transplantation. The dialysate in the abdominal cavity increases intraabdominal pressure and disturbs diaphragm contraction.
Aim of the research: To compare the effects of inspiratory muscle training (IMT) on respiratory and functional parameters in patients undergoing peritoneal dialysis.
Material and methods: A randomised, unblinded trial was conducted. Subjects were randomly assigned to perform 6 weeks of IMT at 40% of maximal inspiratory pressure. Measurements were taken at baseline and 6 weeks after the intervention. Primary outcomes included functional capacity (assessed by 6-minute walk test), maximum inspiratory pressure (PImax), maximum expiratory pressure (PEmax), and spirometry parameters.
Results: Initially, a cohort of 37 peritoneal dialysis patients, with an average age of 51.3 years (95% CI: 47.1–55.5), underwent randomisation. The control group consisted of 18 participants, whereas the study group comprised 19 subjects. Owing to attrition prior to the conclusion of the 6-week duration, the control group was subsequently reduced to 11, and the study group to 18. Patients who underwent respiratory muscle training (RMT) showed significant improvement in PImax ($p < 0.0001$), PEmax ($p = 0.048$), and 6MWT distance ($p = 0.01$). Increases in systolic blood pressure (SBP, $p = 0.036$) and heart rate (HR, $p = 0.045$) induced by the 6MWT were less marked in the respiratory training group.
Conclusions: Respiratory muscle training appears to enhance respiratory muscle strength, potentially improving exercise tolerance. Despite the attrition, our study provides valuable insights into the effects of IMT on respiratory and functional parameters in peritoneal dialysis patients.

Streszczenie

Wprowadzenie: Siła mięśni wdechowych i wydechowych u pacjentów leczonych dializą otrzewnową jest niższa niż u pacjentów hemodializowanych i w grupie po transplantacji nerek. Jedną z przyczyn tego stanu może być obecność w jamie brzusznej dializatu, który zwiększa ciśnienie śródbrzuszne i zaburza skurcz przepony.
Cel pracy: Ocena wpływu treningu mięśni wdechowych (IMT) na parametry oddechowe i funkcjonalne u pacjentów poddawanych dializie otrzewnowej.
Materiał i metody: Przeprowadzono randomizowane, niezaślepione badanie. Pacjenci zostali losowo przydzieleni do wykonywania 6-tygodniowego IMT przy 40% maksymalnego ciśnienia wdechowego. Pomiary przeprowadzono na początku badania i 6 tygodni po interwencji. Pierwszorzędowe wyniki obejmowały wydolność funkcjonalną (ocenianą za pomocą 6-minutowego testu marszu), maksymalne ciśnienie wdechowe (PImax), maksymalne ciśnienie wydechowe (PEmax) i parametry spirometryczne.
Wyniki: Początkowo randomizacji poddano kohortę 37 pacjentów dializowanych otrzewnowo, których średni wiek wynosił 51,3 roku (95% CI: 47,1–55,5). Grupę kontrolną stanowiło 18 osób, natomiast grupę badaną – 19 osób. Ze względu na

przypadki wypadnięcia pacjentów z badania przed zakończeniem 6-tygodniowego okresu, grupę kontrolną zmniejszono następnie do 11 osób, a grupę badaną do 18 osób. U pacjentów, którzy zostali poddani treningowi mięści oddechowych (RMT), stwierdzono znaczną poprawę PImax (p < 0,0001). Podobne korzyści zaobserwowano w zakresie PEmax (p = 0,048) i dystansu 6MWT (p = 0,01) w grupie IMT. Wzrost skurczowego ciśnienia krwi (SBP, p = 0,036) i częstości akcji serca (HR, p = 0,045) na skutek 6MWT był mniej wyraźny u pacjentów poddanych treningowi oddechowemu.
Wnioski: Trening mięśni oddechowych zwiększa siłę mięśni oddechowych oraz poprawia tolerancję wysiłku. Nasze badanie dostarcza cennych informacji na temat wpływu IMT na parametry oddechowe i funkcjonalne u pacjentów dializowanych otrzewnowo.

Introduction

Chronic kidney disease (CKD) is emerging as a growing global health concern, driven by its escalating prevalence. According to estimates, 9.1% of people worldwide suffer from CKD [1]. Peritoneal dialysis (PD) involves the introduction of dialysis fluid through a catheter into the peritoneal cavity. The dialysis fluid introduced into the peritoneal cavity increases the intra-abdominal pressure, which in turn may impede breathing [2]. In addition, it leads to a decrease in lung capacity and respiratory muscle strength [3]. This phenomenon, together with a decrease in respiratory muscle strength observed in patients with end-stage renal disease (ESRD), may lead to a more clinically significant decrease in respiratory function [4]. Respiratory muscle training (RMT) is a procedure that may improve the functioning of respiratory muscles in PD patients. A significant increase in respiratory muscle strength was observed after RMT in haemodialysis patients [5–8].

A recent literature review did not find any studies on the influence of respiratory training on respiratory strength and quality of life in PD patients [9].

Aim of the research

The aim of this study was to evaluate the effect of respiratory muscle training on respiratory function in patients with CKD who remain on PD.

Material and methods

Subjects

In presented research 37 patients (17 women and 20 men) with CKD treated with PD (31 CAPD and 6 APD) were recruited between 2015 and 2018. They were treated in 3 dialysis facilities. Patients were randomised into 2 groups: a respiratory muscle training group (RMT-G) consisting of 19 patients and the control group (CG) consisting of 18 patients.

The inclusion criteria for the study were as follows: CKD stage 5, chronic peritoneal dialysis treatment, and age 18–75 years. The exclusion criteria included the following: respiratory diseases affecting the mechanics of breathing (chronic obstructive pulmonary disease (COPD), asthma), contraindications to spirometry (e.g. thoracic or abdominal aortic aneurysm, pneumothorax, severe respiratory failure), contraindications to the 6 minute walk test (6MWT) (e.g. unstable coronary artery disease, myocardial infarction within the last 6 weeks, contraindications to physical training (e.g. poorly controlled hypertension, exercise-induced arrhythmias, congestive heart failure (≥ 2 according to NYHA), anaemia with Hb < 7.5 g/dl, severe peripheral vascular disease, skeletal-muscular deformities, and musculoskeletal changes that make the test difficult).

Study design

Respiratory muscle training was done using a Threshold IMT device (Philips, UK). Training included resistive airflow during inspiration and was conducted 5 days a week. Initially, patients completed one 15-minute session daily for 3 weeks, involving 5 breaths with a 1-minute break. This was escalated to two 15-minute sessions daily for the subsequent 3 weeks. Training intensity was individually set at 40% of PImax (maximal inspiratory pressure), based on pre-study measurements of PImax. The first session was supervised by a physician. Patients maintained a self-monitoring diary and received daily text reminders. Follow-up occurred at the 2-week mark via home visit or phone call.

Study participants were evaluated, and blood samples were drawn at baseline as well as at the 6-week follow-up, following the intervention period.

Outcome measures

Functional capacity was assessed using the 6MWT in a 30-metre hospital corridor, preceded by a 10-minute rest [10]. Time, distance, dyspnoea, and exertion (using the Borg scale) were recorded [11]. Blood pressure and heart rate were measured pre- and post-6MWT using a Beurer sphygmomanometer (Beurer, Germany). Maximum inspiratory (PImax) and expiratory (PEmax) pressures were measured with a MicroRPM device (Respiratory Pressure Meter, CereFusion UK).

The respiratory function tests were performed using a spirometer (Pneumo, abcMED, Poland; Lungtest 1000, MES, Poland; or EasyOne Diagnostic, NDD, Switzerland) according to the guidelines of the European Respiratory Society [12]. The examination was conducted with the patient in a seated position, back and neck straight, and feet resting on the floor. Three uninterrupted trials were performed, and the highest recorded values were accepted.

Statistical analysis

For each of the examined parameters, statistical testing of the parameter change over time was performed (before vs. after 6 weeks of respiratory muscle training). Testing was carried out both within the experimental groups (*t*-test for paired measurements) and for differences in measurements between experimental conditions, where the hypothesis about the influence of respiratory muscle training on the parameter under study was verified using the *t*-test for 2 independent samples. PImax and PEmax parameters measured in PD patients were compared to population norms [13] by a single-sample *t*-test. This analysis was conducted separately for men and women, considering age categories. In the process of statistical inference, a significance level of $\alpha = 0.05$ was adopted. All calculations and graphs were performed in the R environment (version 3.5.1; R Core Team [2018]. R: Language and environment for statistical calculations. R Foundation for Statistical Computing, Vienna, Austria. URL https://www. R- project.org/).

Results

Characteristics of the study group

The analysis included only measurements from subjects with complete data both before and after the respiratory training intervention. Initially, a cohort of 37 peritoneal dialysis patients, with an average age of 51.3 years (95% CI: 47.1–55.5), underwent randomisation. The control group consisted of 18 participants, whereas the study group comprised 19 subjects. Owing to attrition prior to the conclusion of the 6-week duration, the control group was subsequently reduced to 11 and the study group to 18. Dropouts were due to kidney transplants ($n = 3$), switching to haemodialysis (HD, $n = 3$), peritonitis ($n = 1$), and consent withdrawal ($n = 1$). Despite the dropouts, both groups remained demographically and clinically well matched; no statistical difference between groups was observed (Table 1).

The effect of respiratory muscle training on the tested parameters

Table 2 summarises the observed effects of respiratory muscle training on the study groups' tested parameters. If either pre- or post-intervention measurements were missing, both were excluded from the analysis. Patients who underwent RMT showed significant improvement in PImax ($p < 0.0001$). Similar gains were observed in PEmax ($p = 0.0475$) and 6MWT distance ($p = 0.0100$) within the RMT group. Increases in systolic blood pressure (SBP, $p = 0.0357$) and heart rate (HR, $p = 0.0446$) induced by the 6MWT were less marked in the respiratory training group.

Effect of age and time of peritoneal dialysis treatment on respiratory muscle strength (PImax, PEmax) and 6MWT

A significant inverse relationship existed between age and PImax, PEmax, and 6MWT distance, both pre- and post-RMT (Table 3). Peritoneal dialysis duration showed no correlation with PEmax or 6MWT distance before or after RMT (Table 4). Initially, PImax also lacked this correlation, but post-RMT, it inversely correlated with peritoneal dialysis duration ($p = 0.041$), suggesting greater benefit for patients who received earlier respiratory training.

Comparison of PImax and PEmax values in the examined group to normal values

In women over 55 and men aged 20–54 years, PImax was significantly lower than normal values. No such decrease was observed in women aged 20–54 or men aged 55–59 years (Table 5). PEmax declined relative to the norm in all age groups for both sexes (Table 5).

Table 1. Baseline demographic and clinical characteristics of the cohort

Parameter	Control G (*n* = 11)	RMT G (*n* = 18)	*P*-value
Gender F/M (n)	4/7	9/9	0.7021
Smoking:			
Yes/No	3/8	6/12	~1
%	37.5	50	
Age [years]	47.27	52.22	0.2665
Dialysis vintage [months]	18.36	19.50	0.8771
Abdominal fluid volume [l]	2.03	2.07	0.4573
BMI [kg/m²]	25.70	27.40	0.3369

Table 2. Results of statistical inference for respiratory and clinical variables before and after muscle training within each tested group (asterisks indicate a statistically significant difference for a given parameter before and after RMT in the respective group)

Parameter	Control group		Respiratory muscle training group	
	Mean ± SD	***n***	**Mean ± SD**	***n***
PImax [cm H_2O]:				
Before RMT[#]	77.55 ±30.36	11	67.56 ±34.70	18
After RMT	75.27 ±28.80	11	83.67 ±35.31****	18
PEmax [cmH_2O]:				
Before RMT	111.64 ±34.38	11	96.11 ±42.04	18
After RMT	113.36 ±32.79	11	106.56 ±39.61*	18
6MWT [m]:				
Before RMT	410.80 ±52.44	10	362.00 ±87.18	18
After RMT	417.00 ±62.42	10	386.28 ±95.60**	18
SBP [mm Hg] before RMT:				
Before 6MWT	126.50 ±17.55	10	142.89 ±24.58	18
After 6MWT	137.90 ±24.03	10	158.11 ±20.70	18
SBP [mm Hg] after RMT:				
Before 6MWT	134.30 ±20.68	10	147.33 ±25.27	18
After 6MWT	136.30 ±25.24	10	156.50 ±21.53*	18
DBP [mm Hg] before RMT:				
Before 6MWT	86.30 ±11.61	10	86.78 ±17.57	18
After 6MWT	86.80 ±10.97	10	90.39 ±19.50	18
DBP [mm Hg] after RMT:				
Before 6MWT	86.30 ±9.66	10	87.33 ±11.19	18
After 6MWT	84.90 ±10.63	10	88.67 ±12.30	18
Heart rate before RMT:				
Before 6MWT	79.30 ±19.25	10	69.11 ±10.98	18
After 6MWT	85.00 ±18.81	10	76.50 ±12.31	18
Heart rate after RMT:				
Before 6MWT	71.20 ±9.59	10	74.44 ±13.12	18
After 6MWT	77.80 ±10.95	10	79.94 ±13.78*	18
Urea [mg/dl]:				
Before RMT	105.00 ±43.31	11	112.80 ±27.63	18
After RMT	94.46 ±24.29	11	105.34 ±27.77*	18
Creatinine [mg/dl]:				
Before RMT	8.54 ±3.31	11	8.71 ±2.55	18
After RMT	8.19 ±2.98	11	8.38 ±2.61*	18
Haemoglobin [g/dl]:				
Before RMT	11.75 ±1.72	11	11.10 ±1.16	18
After RMT	11.91 ±2.07	11	11.27 ±1.32	17

Table 2. Cont.

Parameter	Control group		Respiratory muscle training group	
	Mean ± SD	***n***	**Mean ± SD**	***n***
Albumins [g/dl]:				
Before RMT	3.61 ±0.73	11	3.80 ±0.34	17
After RMT	3.61 ±0.61	8	3.86 ±0.41	12
FEV1 [l]:				
Before RMT	3.20 ±0.88	8	2.61 ±1.05	15
After RMT	3.40 ±0.57	8	2.70 ±1.04	16
FVC [l]:				
Before RMT	4.25 ±1.12	8	3.28 ±1.16	14
After RMT	4.48 ±0.92	8	3.37 ±1.18	15
FEV1/FVC [%]:				
Before RMT	74.81 ±5.10	8	75.80 ±7.35	14
After RMT	76.66 ±4.33	8	76.26 ±6.19	14
PEF [l/s]:				
Before RMT	7.05 ±2.71	8	5.75 ±2.36	15
After RMT	7.44 ±2.14	8	5.93 ±2.11	16
MEF 75 [l/s]:				
Before RMT	5.73 ±2.03	8	4.62 ±1.74	15
After RMT	6.35 ±1.61	8	5.10 ±1.82	16
MEF 50 [l/s]:				
Before RMT	3.50 ±1.09	8	2.99 ±1.61	15
After RMT	3.65 ±0.49	8	3.02 ±1.42	16
MEF 25 [l/s]:				
Before RMT	1.06 ±0.40	8	1.16 ±0.83	15
After RMT	1.32 ±0.28	8	1.06 ±0.52	16
MEF 25/MEF 75 [l/s]:				
Before RMT	2.86 ±0.86	8	2.50 ±1.34	15
After RMT	3.13 ±0.41	8	2.56 ±1.13	16
FET [s]:				
Before RMT	6.70 ±0.80	8	6.84 ±2.69	15
After RMT	7.39 ±1.89	8	7.32 ±2.01	16

*#For the control group, pre-RMT and post-RMT at the start and end of the observation, respectively. Meanings of symbols for comparison of values before and after RMT in the control and study group. *p < 0.05. **p < 0.01. ***p < 0.001. ****p < 0.0001.*

Comparison of tested parameters between the study and the control groups

PImax improved significantly in the RMT group post-intervention ($p < 0.0001$) and differed significantly from the control group ($p < 0.0001$). PEmax and 6MWT distance also increased in the RMT group ($p = 0.0475$, $p = 0.0100$). A significant decrease in heart rate difference pre- and post-6MWT was observed in the RMT group ($p = 0.0446$) compared to controls $p = 0.0390$) (Figures 1–4).

Biochemical parameters

Respiratory muscle training resulted in a statistically significant decrease in serum urea and creatinine

Table 3. Pearson correlation coefficients (*r*) and its *p*-values for the relationship between age and PImax, PEmax, and distance travelled during the 6MWT test regarding age

Age	PImax	PEmax	Distance
Before RMT:			
r	–0.6447	–0.5213	–0.6458
P-value	0.0001	0.0037	0.0002
After RMT:			
r	–0.6853	–0.5684	–0.7711
P-value	0.0017	0.0139	0.0001

Table 4. Pearson correlation coefficients (*r*) and its *p*-values for the relationship between dialysis vintage of the patients tested, and PImax, PEmax, and distance travelled during the 6MWT test

PD vintage	PImax	PEmax	Distance
Before RMT:			
r	–0.2862	–0.3096	–0.0475
P-value	0.1322	0.1021	0.8102
After RMT:			
r	–0.4856	–0.3931	–0.1805
P-value	0.0410	0.1065	0.4736

Table 5. Comparison of PImax and PEmax to population norm tables [25]

Parameter	Women			Men	
	[20–54]	[55–59]	[60–74]	[20–54]	[55–59]
PImax:					
Standard	87.0	77.0	65.0	124.0	103.0
PD patients	80.6	43.7	25.0	92.3	79.0
P-value	0.1550	0.0201	0.0050	0.0011	0.0546
n	5	3	5	11	5
PEmax:					
Standard	152.0	145.0	128.0	233.0	218.0
PD patients	95.0	74.7	53.0	132.5	107.2
P-value	0.0001	0.0167	< 0.0001	< 0.0001	0.0021
n	5	3	5	11	5

levels only in the respiratory muscle training group (Table 2), but no statistical significance was observed regarding the control group.

Discussion

To the best of our knowledge, this is the first study to evaluate the effects of respiratory muscle training on respiratory muscle strength, functional capacity, and exercise-related cardiac parameters in CKD patients treated with peritoneal dialysis. Both the control and the breathing training groups were matched in terms of basic demographic and clinical characteristics.

One of the main outcomes of this investigation is the significant increase in both inspiratory and expiratory muscle strength among PD patients who underwent respiratory muscle training. Similarly, favourable effects of respiratory muscle training were observed in chronically haemodialysed patients [5, 6, 8, 14–16]. This improvement in muscle strength is noteworthy given that CKD patients often experience a decline in muscle function. Diaphragm muscle weakness affects respiratory and peripheral muscles, leading to reduced cardiorespiratory efficiency, lower quality of life, and increased mortality [17, 18]. Systematic reviews confirm the benefits of inspiratory muscle training for CKD patients, enhancing respiratory muscle strength, functional capacity, lung function, and quality of life [19]. In stage 5 CKD, renal replacement therapy, such as haemodialysis or peritoneal dialysis, is essential but can impact breathing physiology, with peritoneal dialysis having a greater potential impact [5, 6, 8].

In our study of patients treated with PD, a decline in both inspiratory and expiratory respiratory muscle strength was observed, similar to findings in other studies in patients with end-stage kidney disease [20]. The underlying factors may include muscle fibre atrophy (type I and II), impaired oxygen transport, and muscle mass loss, particularly in advanced CKD stages, due to increased protein degradation and reduced synthesis, leading to protein-energy wasting (PEW) [21, 22].

Age significantly correlated with respiratory muscle strength, both before and after respiratory muscle training, consistent with previous research [23, 24].

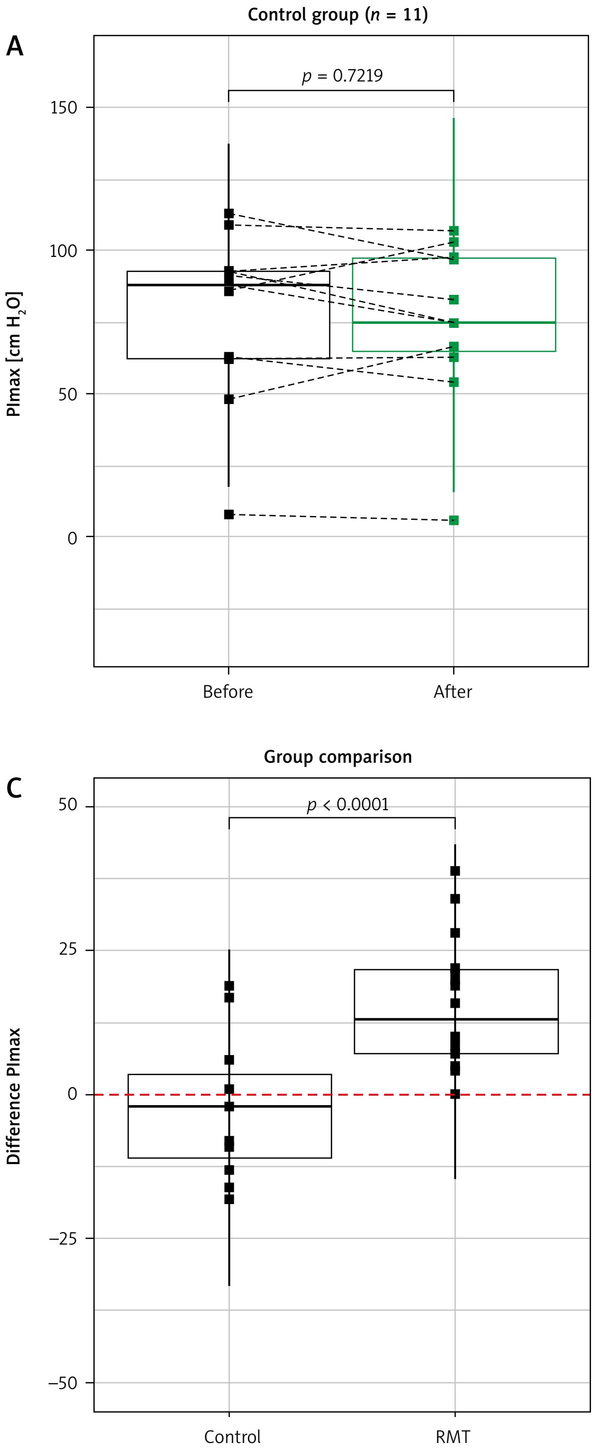

Figure 1. Effect of respiratory training on PImax in each of the experimental groups (**A, B**) and the difference (Δ) of the measurements (before and after) (**C**)

Similarly, HD patients were shown to have reduced muscle strength [25], and a high prevalence of sarcopenia influenced by older age, longer HD duration, low BMI, low prealbumin levels, and smaller arm and thigh circumferences. HD treatment temporarily had a negative impact on muscle strength, probably due to blood pressure and electrolyte changes [22].

Sarcopenia is highly prevalent among patients with end-stage renal disease undergoing dialysis. One of the key underlying mechanisms is the accelerated rate of protein catabolism, which is driven by both the pathological state of the disease and the catabolic effect of dialysis procedures. This is further exacerbated by insufficient energy and protein intake. Ex-

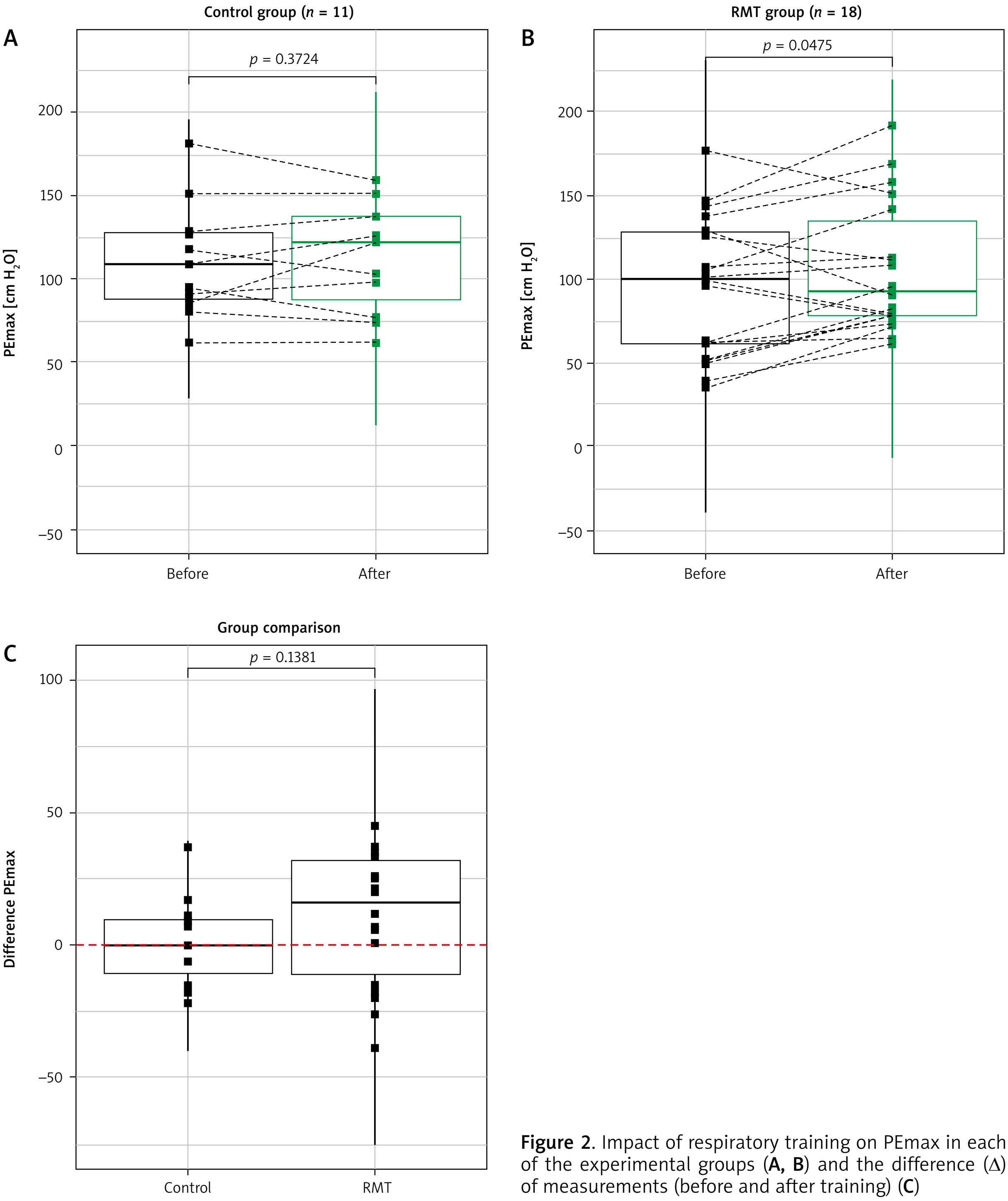

Figure 2. Impact of respiratory training on PEmax in each of the experimental groups (**A, B**) and the difference (Δ) of measurements (before and after training) (**C**)

isting literature also indicates that exercise interventions may mitigate the progression of sarcopenia [21]. The limited duration of our study precludes us from drawing any definitive conclusions in this regard. In the present investigation, the duration of peritoneal dialysis treatment was not found to influence the baseline strength of respiratory muscles prior to the initiation of the training regimen. In our cohort, the duration of PD treatment demonstrated a significant inverse correlation with PImax following targeted respiratory muscle training, while exerting no measurable impact on PEmax. Additionally, no correlation was observed between the duration of PD treatment and the distance covered in the 6MWT. These

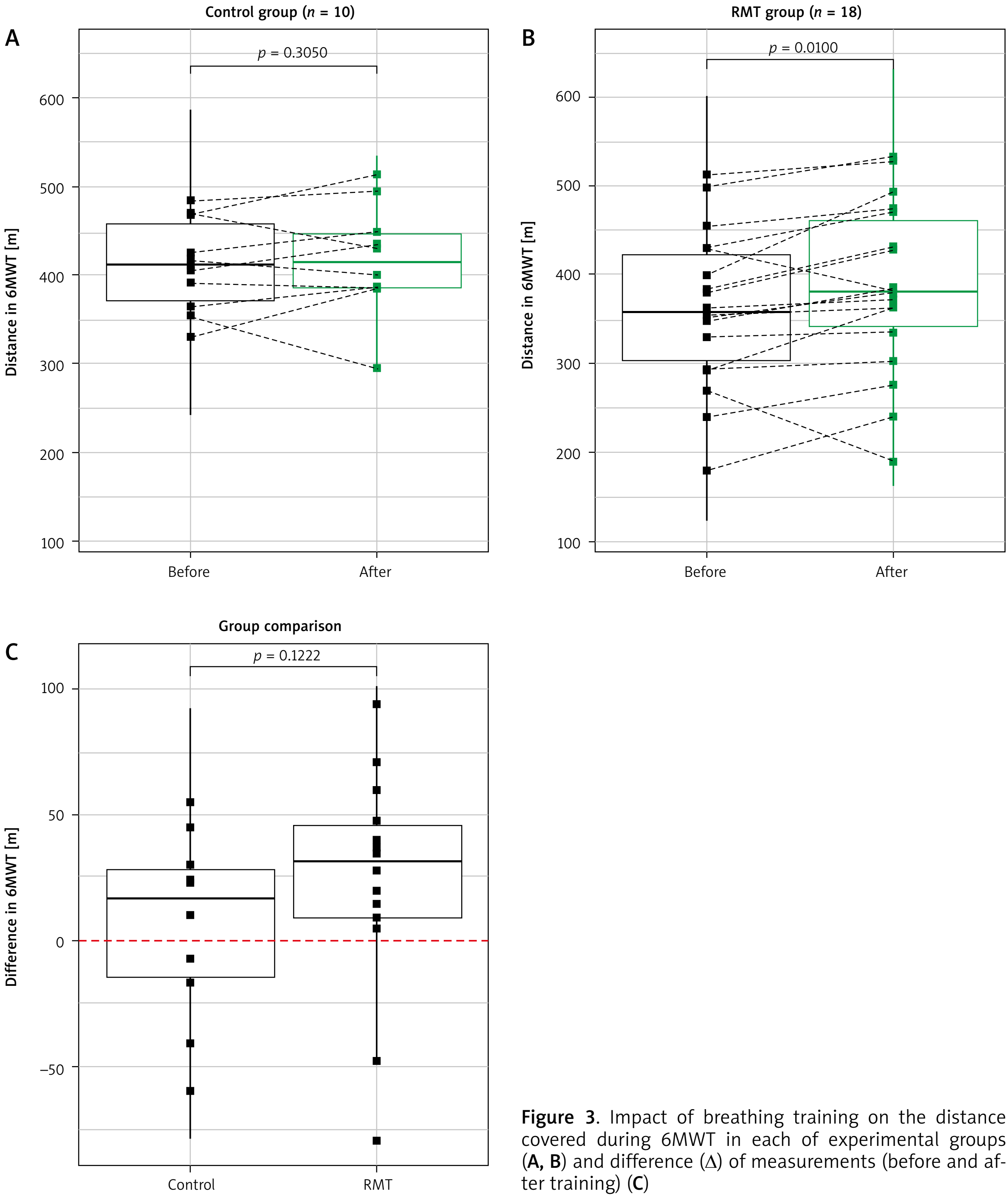

Figure 3. Impact of breathing training on the distance covered during 6MWT in each of experimental groups (**A, B**) and difference (Δ) of measurements (before and after training) (**C**)

observations imply that the impact of PD on respiratory muscle physiology is predominantly restricted to the impairment of inspiratory muscle strength, and this decrement becomes increasingly pronounced as the duration of dialysis therapy extends. However, as noted by Śliwiński *et al.*, inspiratory muscle fatigue may be a consequence of systemic fatigue, leading to diminished work efficiency of these muscles [26]. This is evidenced by a measurable reduction in PImax.

Karacan *et al.* found that inspiratory muscle strength in continuous ambulatory peritoneal dialysis patients is at 50% of normal values, lower than in haemodialysis (66%) and post-transplant patients (55%) [27]. Expiratory muscle strength in these patients is even lower, at

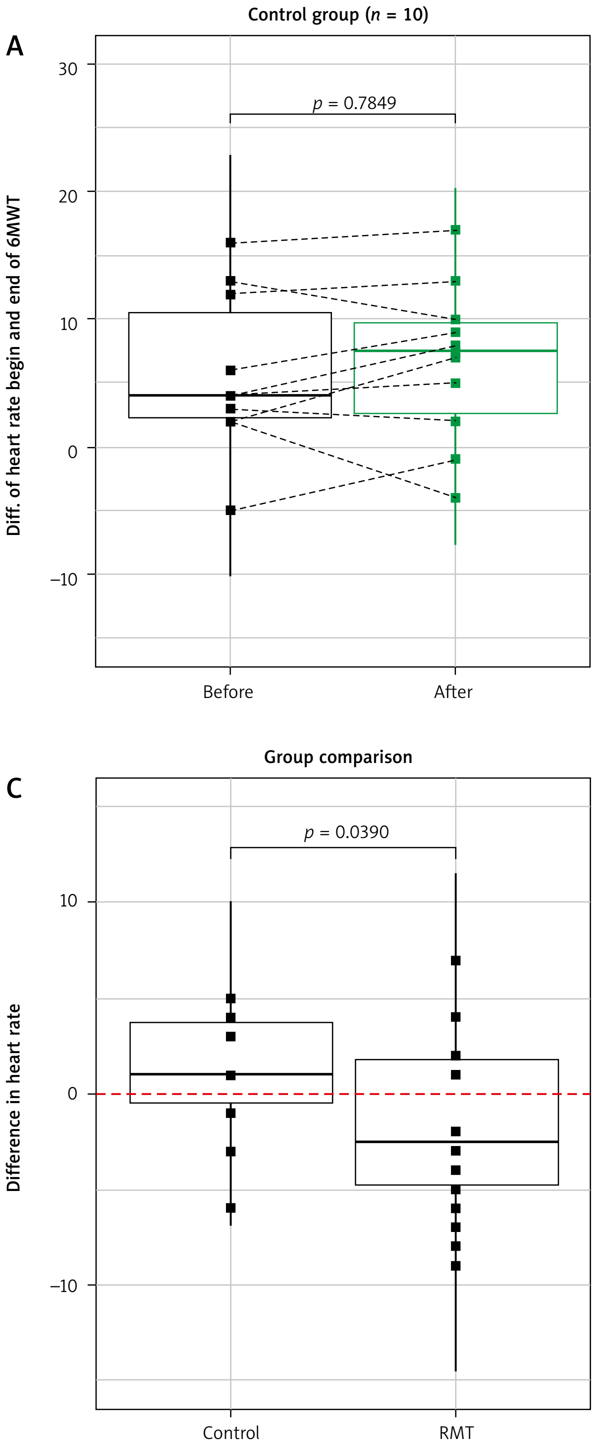

Figure 4. Effect of respiratory training on heart rate acceleration after 6MWT in each experimental group (**A, B**) and the difference (Δ) of measurements (before and after training) (**C**)

31% of normal. Our analysis benchmarked these values against those reported by Black and Hyatt [13].

The role of IMT in improving functional capacity is well-established in chronic heart failure patients [28]. However, its utility in CKD patients, particularly among those on PD, has been less thoroughly examined [9]. Some studies have employed threshold inspiratory muscle trainers (IMT) to administer RMT. For example, a 10-week program led to a 25% increase in inspiratory muscle strength [5]. Shorter interventions lasting less than 8 weeks have also shown improvements in inspiratory muscle strength [19]. Interestingly, a study by Dipp *et al.* reported that a 5-week, high-intensity program resulted in a significant 33.5%

improvement in PImax [16]. It should be noted that the resistance settings used in RMT programs have varied across studies. Da Silva *et al.* [6] and Figueiredo *et al.* [8] used a 40% PImax resistance in line with recommended guidelines, while Pellizzaro *et al.* [5] opted for 50% PImax. On the other hand, Dipp *et al.* [16] started with 50% resistance and increased it to 70%. All the studies mentioned above were conducted in HD patients.

In our own study, we utilised a Threshold IMT device and observed similar benefits. We employed a 6-week RMT program with an initial resistance setting of 40% PImax, which yielded significant gains in inspiratory muscle strength among PD patients.

One consistent observation across studies is that RMT primarily benefits the inspiratory muscles. This is probably because resisted inhalation requires increased diaphragmatic workload, while exhalation remains a largely passive process [29]. This differential effect may partly explain why training predominantly impacts inspiratory muscle strength. It is worth noting that during RMT with Threshold IMT devices, patients breathe through a mouthpiece against the individually adjusted inspiratory resistance, leaving exhalation minimally hindered, which further supports the focus on inspiratory muscle training in these regimens.

Research indicates that inspiratory muscle training (IMT) benefits CKD patients on haemodialysis by enhancing respiratory muscle strength, functional capacity, and exercise tolerance [30]. The 6MWT is a common tool for gauging exercise tolerance. With IMT, one study noted a 65 m improvement in distance5, while another observed a 78.5 m increase using a specific exhalation training device [31]. Figueiredo *et al.* reported a 96.7 m increment in the ISWT after an 8-week intervention [8]. Such training seems as effective as other exercise regimens. For instance, low-intensity activities over 6 months improved walking distances by 39 m in HD and PD patients [32]. Yet, the improvement in 6MWT walking distance that we observed fell short of previous findings, possibly due to shorter training or different equipment [5, 31]. Age also played an important role in our 6MWT outcomes. Lower scores in older populations often result from decreased physical ability, sedentary habits, or inadequate nutrition [33, 34]. Even though a statistically significant increase of 24 m in the distance covered during the 6MWT was observed after RMT, it is probably not clinically significant, because the difference needs to exceed 54 m for patients to perceive a change from feeling “about the same” [35].

During the 6MWT, HR and SBP usually increase, and the response of DBP can be variable (unchanged or insignificant decrease) [36]. We found that increases in SBP and HR induced by the 6MWT in PD patients were less pronounced in the group that underwent respiratory training, consistent with the findings of Campos *et al.* [31]. On the other hand, Cigarroa *et al.* observed a 5.7% drop in DBP in HD patients doing lower body exercises [37]. Shi *et al.* linked DBP with 6MWT distance. The reduction in 6MWT distance with age observed in this study aligns with findings by Shi *et al.* [38].

Respiratory muscle training had no significant impact on basic spirometric parameters such as FEV1, FVC, or FEV1/FVC. This diverges from findings in haemodialysis patients, where Pellizzaro *et al.* and El-Deen *et al.* observed improvements in FVC and FEV1 [5, 39]. Campos *et al.* also reported increases in these parameters, although their 8-week study focused on expiratory muscles [31]. Conversely, Medeiros *et al.* noted a PEF increase but no change in FVC or FEV1 [19]. These discrepancies may be attributed to longer intervention periods in haemodialysis studies, ranging from 8 to 12 weeks. No obstruction-type disorders were detected in our PD patient cohort.

In their study, Park *et al.* observed that the elevation of intra-abdominal pressure significantly impacts the position of the vertebral centre of rotation [40]. Considering the consequent alterations in the biomechanics of the upper body and lumbar segments, conducting a 3-dimensional computer analysis of the spinal morphology (DIERS study) in peritoneal dialysis patients appears warranted to accurately evaluate the effects of dialysate presence in the abdominal cavity [41].

In the current study, respiratory muscle training yielded very modest reductions in urea and creatinine concentrations, specifically a 6.6% decrease in urea levels and a 3.8% reduction in creatinine. The mechanism underlying these effects remains somewhat elusive but may involve a diminution of exercise-induced catabolism. Other investigated biochemical parameters exhibited no significant alterations. These findings diverge from the hypothesis posited in the literature that low phosphate levels could adversely affect respiratory muscle strength in peritoneal dialysis (PD) patients [42]. Our observations partially contrast with previous research indicating that respiratory muscle training could cause increases in haematocrit, haemoglobin, and albumin concentrations along with decreases in serum potassium and phosphorus [5]. Conversely, Figueiredo *et al.* did not observe any changes in haematocrit, haemoglobin, albumin, or serum urea [8].

The strengths of this study are its prospective design and randomisation. Limitations include a small sample size, although it is comparable to similar studies in chronic haemodialysis patients [5, 6, 8, 30]. Furthermore, the study encountered a high attrition rate, primarily attributed to transitions to haemodialysis or kidney transplantation, as well as the relatively short follow-up duration.

Conclusions

Respiratory muscle training appears to enhance respiratory muscle strength, potentially improving exercise tolerance. Despite the attrition, our study provides valuable insights into the effects of IMT on respiratory and functional parameters in peritoneal dialysis patients. Further research with larger sample sizes and longer intervention periods is warranted to better understand the implications of these findings for clinical practice and patient outcomes.

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Ethical approval

The study protocol was approved by the Bioethics Committee at the Świętokrzyska Chamber of Physicians in Kielce (Resolution No. 4/D/2014).

Conflict of interest

The authors declare no conflict of interest.

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