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Effect of low-frequency magnetic field (magnetic stimulation) and kinesitherapy on the level of selected blood parameters in haemodialysis patients

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ABSTRACT

Introduction: Abnormalities in the secretory and endocrine functions of the kidneys are often diagnosed in patients with chronic kidney disease and undergoing haemodialysis, leading to disturbances in body homeostasis. Frequent multimorbidity is an additional factor that negatively affects homeostasis. These factors contribute to a decrease in cardiopulmonary fitness, deterioration of the patient's psychophysical status, and, consequently, a decrease in quality of life. Due to several limitations of rehabilitation in this group of patients, solutions are constantly being sought to safely avoid or reduce the problems resulting from the above health burdens. Among the least invasive methods are magnetic stimulation and properly prepared and administered kinesitherapy.

Aim of the study: This study aimed to evaluate the effects of magnetic stimulation and kinesitherapy on selected blood parameters in haemodialysis patients.

Material and methods: The study covered 26 people. Six patients received magnetic stimulation and kinesitherapy, 10 received only kinesitherapy, and the others were in the control group. At baseline and after 6 and 12 weeks, blood tests were performed in all three groups to evaluate changes in the parameters studied (RBC, Hb, HCT, WBC, PLT, Na ions, K ions, Cl ions, urea, Pi, tCa, ALP and parathormone).

Results: There were no statistically significant differences in the blood parameters studied, except for urea. The urea level in the group where patients underwent magnetic stimulation and exercise increased in the second collection but decreased in the third, whereas in the exercise-only group, it showed an increasing trend in all 3 collections.

Conclusions: The levels of the assessed blood parameters do not show statistically significant changes (except for urea). However, one can observe certain non-statistically significant changes in the assessed blood parameters that are more noticeable in the study groups than in the control group. Therefore, it can be suspected that both treatments involving magnetic stimulation in combination with exercise and exercise alone have an impact on the human body. However, further research in this area is necessary.

Keywords: magnetic stimulation, kinesitherapy, haemodialysis

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Introduction

Magnetic stimulation using the Viofor JPS System device is one of the non-invasive therapeutic methods based on the pulsed low-frequency magnetic field. The fundamental frequency for the systemic applicator in the form of a mat ranges from 180 Hz to 195 Hz, while pulse packet frequencies range from 12.5 to 29 Hz, packet groups from 2.8 to 7.6 Hz, and series from 0.08 to 0.3 Hz. Average induction is lower than for magnetotherapy, reaching values ranging from 11.5 μT to 276 μT. Both the indicated frequencies and induction values have a specific effect on the body. In the case of frequency, it is an action that produces biophysical, magneto-mechanical, and electrodynamic effects. In contrast, bioelectrical, biochemical, and bioenergetic effects are observed for induction. A significant advantage of the procedure is the relatively small number of contraindications compared to the extensive list of indications [1–4].

Abnormalities in the secretory and endocrine functions of the kidneys are often diagnosed in patients with chronic kidney disease and undergoing haemodialysis. This leads to disturbances in body homeostasis [5]. An additional factor that disrupts homeostasis is the frequently occurring multimorbidity, also age-related, particularly cardiovascular diseases, the most common being congestive heart failure, coronary disease, peripheral artery disease, and diabetes with organ complications [6–8]. These disorders and the need for regular haemodialysis, with most patients dialyzed 3 times a week for 4 hours, result in a significant reduction in their physical activity [6, 9].

Patients on repeated haemodialysis are concerned about taking up physical activity because of the risk of complications of inappropriate exercise such as deterioration or damage to the vascular access for dialysis termed arteriovenous fistula [10]. Centres that perform dialysis rarely include kinesitherapy or even a sample exercise program to be performed at home as part of their standards [8, 11, 12]. Consequently, in haemodialysis patients, a significant reduction in activity leads not only to decreased quality of life but also increases the risk of deterioration of health, thus translating into a higher incidence of deaths among these patients [7, 8, 13].

Given those concerns and insufficient opportunities to educate haemodialysis patients on how to safely undertake physical activity, solutions that are as non-invasive and readily available as possible are needed to improve their overall health status and thus quality of life [8, 12, 14, 15]. For this reason, it was decided to evaluate the effect of magnetic stimulation to support the functioning of the body in this group of patients. Scientific studies using this treatment have demonstrated its beneficial effects on numerous systems by activating oxido-reduction and cellular regeneration processes and improving blood circulation, thus promoting the maintenance of homeostasis [2, 4]. It was decided to also evaluate the effect of simple physical exercises, for the sake of the participant's mental comfort, not involving the upper limbs.

Aim of the study

The present study aimed to evaluate the effect of low-frequency magnetic field (magnetic stimulation) and kinesitherapy on the levels of selected blood parameters in haemodialysis patients.

Material and methods

The study included 26 patients receiving chronic haemodialysis treatment at the Dialysis Station of the Department of Nephrology, Hypertension, and Family at the Military Medical Academy Memorial Teaching Hospital of the Medical University of Lodz — Central Veterans' Hospital (USK im. WAM — CSW in Łódź). The first group of participants, who received magnetic stimulation treatments and kinesitherapy, consisted of 6 individuals (3 women and 3 men). The second group, which received the same kinesitherapy as the first group, consisted of 10 individuals (3 women and 7 men). The third group, consisting of 10 individuals (4 women and 6 men), was the control group. The inclusion criterion for the study was obtaining informed consent from the haemodialysis station patient during the study. Allocation to specific groups depended on the presence of contraindications for magnetic stimulation and the patient's consent to regularly perform the specified exercises. Patients in the group where magnetic stimulation was performed could not have contraindications for this procedure, such as active cancer, electronic implants, acute coronary failure or severe bacterial, viral, and fungal infections [16]. They also had to commit to systematically performing the prescribed exercises for 12 weeks, similar to patients in the exercise-only group. Patients in the control group agreed only to the required blood collection. The exclusion criteria included a patient's refusal to participate in the study, a patient's refusal to continue a study that had already begun, a patient's refusal to continue participation due to a deterioration in the patient's well-being or overall condition, lack of consistent participation in the required research procedures. Due to exclusions, the initial group of 35 patients concluded with 26 patients in the study. The largest number of patients (4 patients) dropped out from the group where magnetic stimulation was applied, and exercise was recommended, hence the small sample size. The patients included in the study had coexisting conditions typical for haemodialysis patients, especially coronary artery disease, peripheral vascular diseases, and diabetes with organ complications, but these conditions did not serve as the basis for complete exclusion from participation in the study [6]. The characteristics of the studied groups are presented in Table 1. Each patient gave informed consent to participate in the study before the treatments (Tab. 1).

A Viofor JPS System device was used to perform magnetic stimulation, and patients from Group "Exercise and LF-EMF" received a systemic treatment

Table 1. The characteristics of the studied patient groups - means and standard deviations (SD) of age, body mass, body height and BMI

Group	Gender	Number of patients	Age	Body mass (kg)	Body height (cm)	BMI
			Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Exercise and LF-EMF	Women	3	70.3 ± 5.79	75.6 ± 3.68	163.3 ± 0.47	28.4 ± 1.38
	Men	3	64.7 ± 4.64	73.6 ± 6.65	177 ± 3.74	23.5 ± 2.22
	All	6	67.5 ± 5.96	74.7 ± 5.47	170.2 ± 7.33	25.9 ± 3.04
Exercise	Women	3	69,3 ± 9.46	60.8 ± 21.97	156 ± 7.79	24.3 ± 6.37
	Men	7	67.7 ± 6.84	71.9 ± 9.54	171.4 ± 5.55	24.5 ± 3.41
	All	10	68.3 ± 7.76	68.6 ± 15.3	166.8 ± 9.47	24.4 ± 9.47
Control	Women	4	66.5 ± 7.3	68 ± 8.89	165.7 ± 4.81	24.5 ± 2.23
	Men	6	66.7 ± 14.37	81.2 ± 6.79	171.5 ± 6.79	27.8 ± 4.08
	All	10	66 ± 12.06	75.9 ± 10.07	169.2 ± 8.3	26.5 ± 3.81

BMI — body mass index; LF-EMF — low-frequency–electromagnetic fields; SD — standard deviation

using a mat applicator. The parameters used were M1P2 1-6, with the intensity increased gradually from a value of 1 on the first day of treatment until it reached a value of 6. The magnetic field was emitted at a constant frequency of 181.8 Hz (M1 — application with constant intensity throughout the procedure, P2-JPS system with 2 types of pulses at a frequency of 180–195 Hz) and with a peak induction not exceeding 1.2 mT. The duration of the procedure was automatically set after entering the required parameters for the study stage and did not exceed 12 minutes. The treatments were performed three times a week for 12 weeks. At the same time, patients in both groups were advised to exercise while on haemodialysis and at home on days when they did not receive haemodialysis.

On days when patients were not undergoing haemodialysis, they exercised at home, whereas on haemodialysis days, they exercised under the supervision of a physiotherapist. In total, the exercises took place 7 times a week. Exercises, due to the arteriovenous fistula, did not involve the upper limbs. Patients were asked to perform 4 series of 10 repetitions of triple flexion (an exercise involving the hip, knee, and ankle joints) of each lower limb each time, as well as 4 sets of 10 repetitions of isometric contraction of the quadriceps. No interventions related to the conducted study were undertaken in the control group. Patients from each of the groups underwent haemodialysis 3 times a week.

In all three groups, blood was drawn 3 times for biochemical tests. The first blood collection was performed at baseline (on the day the project began), the second after 6 weeks, and the third after 12 weeks. At each stage of the study, blood samples were collected before the commencement of haemodialysis. Blood samples were obtained by the staff of the Dialysis Station of the Department of Nephrology, Hypertension, and Family Medicine at USK im. WAM – CSW in a volume matching the test tubes indicated and provided by the Laboratory of the USK im. WAM – CSW in Lodz, where the analysis was conducted. The blood drawn was used only for the project, and the data obtained were used to evaluate the effects of magnetic stimulation and kinesitherapy on their levels at various points in the project. Measured were the levels of red blood cells (RBCs), haemoglobin (Hb), haematocrit (HCT), white blood cells (WBCs), platelets (PLTs), sodium ions (Na ions), potassium ions (K ions), chloride ions (Cl ions), urea, inorganic phosphate (Pi), total calcium (tCa), alkaline phosphatase (ALP), and parathormone (PTH).

Statistical analysis

Statistical analysis and data visualization were performed using Statistica 13.1 software. The Shapiro-Wilk test was used to examine the distribution of the variables. A one-way ANOVA analysis of variance was performed to examine differences between the study variables. The Tukey test was used to determine homogeneous groups. Principal component analysis (PCA) was used to visualize the data and detect correlations between variables. The significance level was set at $\alpha = 0.05$.

Results

The collected data were grouped into three tables, divided into morphology components, markers of calcium-phosphate metabolism and parathyroid function, and

Table 2. Means and standard deviations (SD) for blood morphological parameters

Group	Week	RBC Norm 3.8–5.4 × 10^6/μL		Hb Norm 12.0–16.0 g/dL		HCT Norm 36.0–48.0%		WBC Norm 4.0–11.0 × × 10^3/μL		PLT Norm 150.0–400.0 × × 10^3/μL	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Exercise and LF-EMF	0	3.7	0.34	11.02	1.28	34.47	3.50	5.54	1.05	174.17	23.17
	6	3.52	0.34	10.18	1.12	32.02	3.34	6.15	1.76	184.83	58.03
	12	3.36	0.49	10.15	1.19	31.83	3.34	5.6	1.29	179.83	48.33
Exercise	0	3.92	1.01	10.75	1.29	34.02	3.98	7.4	2.61	258.6	86.54
	6	3.49	0.62	10.35	1.81	32.69	4.74	7.32	1.98	258.2	128.87
	12	3.51	0.50	10.43	1.56	33.41	4.15	6.57	2.22	229.9	69.81
Control	0	3.5	0.24	10.17	0.49	30.41	1.71	5.94	1.54	206.4	51.52
	6	3.48	0.31	10.23	0.74	31.21	2.26	6.57	1.74	214.6	49.90
	12	3.57	0.28	10.46	0.75	31.91	2.17	6.18	1.60	212.8	47.69

Hb — haemoglobin; HCT — haematocrit; LF-EMF — low-frequency–electromagnetic fields; PLT — platelets; RBC — red blood cells; WBC — white blood cells

Table 3. Means and standard deviations (SD) for selected ions and urea

Group	Week	Na ions Norm 136.0–146.0 mmol/L		K ions Norm 3.5–5.1 mmol/L		Cl ions Norm 101.0–109.0 mmol/L		Urea Norm 2.8–7.2 mmol/L	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Exercise and LF-EMF	0	139.72	2.44	4.35	0.25	105.02	2.28	13.41^{b}	4.16
	6	138.05	1.51	5.22	0.76	104.2	2.53	25.47^{a}	8.46
	12	139.4	1.59	5.08	0.65	104.63	2.33	18.18^{ab}	3.20
Exercise	0	138.29	1.84	4.6	0.53	105.2	1.70	16.9^{ab}	5.45
	6	137.97	2.77	4.69	0.72	104.27	4.67	21.05^{ab}	7.52
	12	137.69	3.14	4.91	0.55	104.23	3.67	23.46^{a}	6.64
Control	0	137.87	1.62	4.92	0.70	104.64	2.75	21.15^{ab}	3.58
	6	139.74	3.00	5.36	0.64	94.01	28.87	19.76^{ab}	7.24
	12	136.94	2.12	5.01	0.49	103.38	3.71	17.62^{ab}	1.99

^{a,b} — different letters in the column indicate the presence of significant differences between the means within the analysed parameter. Cl — chlorine; Na — sodium; K —potassium; LF-EMF — low-frequency–electromagnetic fields; SD — standard deviation

other data. In each case, the mean and standard deviation at each stage of the project between individual blood collections in all study groups were presented (Tab. 2).

Analysis of RBCs, Hb, HCT, WBCs, and PLTs did not show statistically significant differences between consecutive collections (Tab. 3).

Analysis of the results for Na, K, and Cl ion levels also showed no statistically significant differences between successive collections. Statistically significant differences were observed only for urea, both in the group that received magnetic stimulation treatment and exercise and in the group that only exercised. There were no statistically significant changes in the control group. In the group undergoing magnetic stimulation and exercise, the urea level initially increased, then decreased, whereas in the exercise-only group, it showed an increasing trend throughout the entire study period (Tab. 4).

Similar to the analysis of blood morphology components, the analysis of markers of calcium-phosphate metabolism and parathyroid function showed no statistically significant differences between consecutive collections (Fig. 1).

Two main elements were identified based on the correlation matrix. They explained 43.27% of the total variation (PC 1 — 23.68% of the variation, PC2 — 14.8% of the variation). The graph shows the results of principal component analysis (PCA) based on correlations

Table 4. Means and standard deviations (SD) for selected markers of calcium-phosphate metabolism and parathyroid function

Group	Week	Pi Norm 0.81–1.45 mmol/L		tCa Norm 2.2–2.65 mmol/L		ALP Norm 30.0–120.0 U/l		PTH Norm 1.6–6.9 pmol/L	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Exercise and LF-EMF	0	1.25	0.40	2.27	0.24	149.65	151.69	29.65	30.42
	6	2.07	0.78	2.2	0.11	140.45	144.09	88.31	136.09
	12	1.65	0.55	2.23	0.14	161.2	168.54	74.23	119.14
Exercise	0	1.44	0.47	2.28	0.19	119.3	60.92	28.57	25.35
	6	1.75	0.72	2.18	0.23	121.36	60.60	39.51	24.38
	12	2.12	0.65	2.08	0.19	135.79	73.89	50.09	34.54
Control	0	2.28	1.26	2.18	0.33	97.37	43.41	45.47	24.22
	6	2.25	1.16	2.1	0.30	98.23	35.22	58.55	43.77
	12	2	0.82	2.13	0.30	110.07	50.95	45.72	36.70

ALP — alkaline phosphatase; LF-EMF — low-frequency–electromagnetic fields; Pi — inorganic phosphate; PTH — parathormone; tCa — total calcium

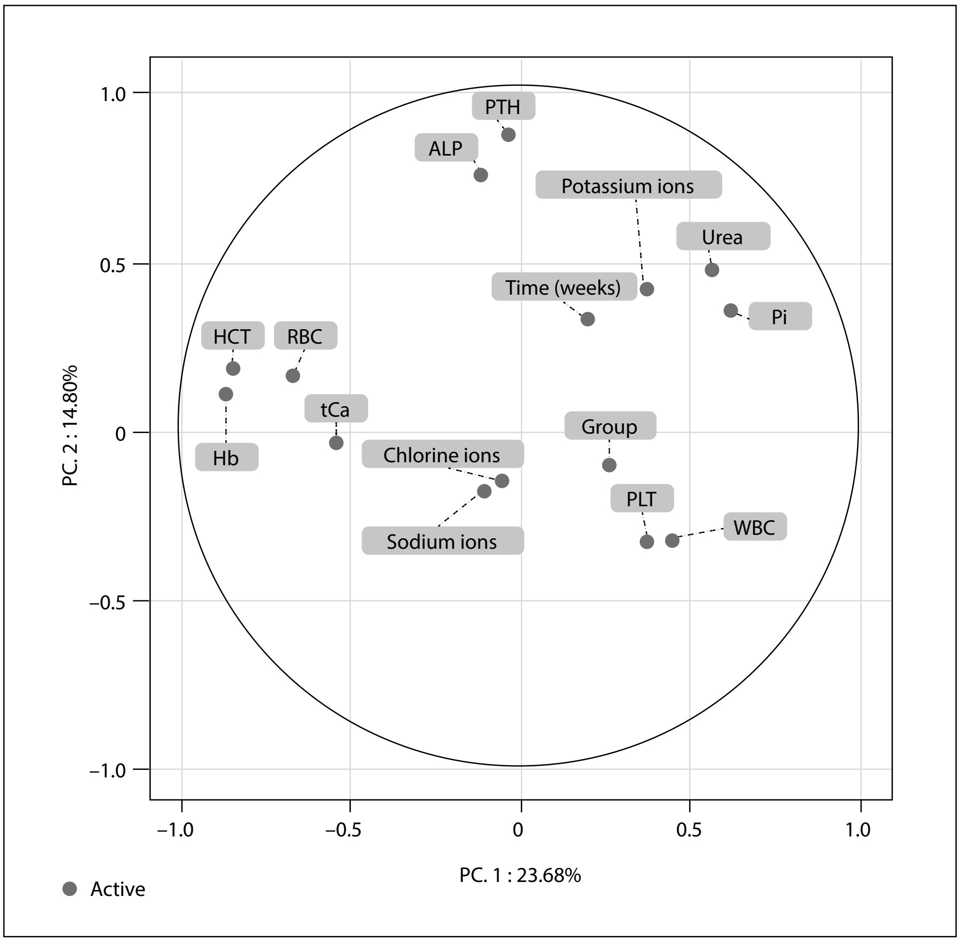

Figure 1. Changes in the value of selected parameters vs. the type of group and time (n = 78). ALP — alkaline phosphatase; Hb — haemoglobin; HCT — haematocrit; Pi — inorganic phosphate; PLT — platelets; PTH — parathormone; RBC — red blood cells; tCa — total calcium; WBC — white blood cells

for the three groups of participants (exercise and LF-EMF group — 1; exercise group — 2; control group — 3) who were measured for individual parameters for 12 weeks. All results were used for the PCA analysis: RBCs, Hb, HCT, PLTs, WBCs, Na ions, K ions, Cl ions, urea, ALP, tCa, Pi, and PTH.

HCT, RBC, tCa, and Hb formed separate clusters, thus indicating a negative correlation with group type. This means that the highest values of these parameters were observed in the exercise and LF-EMF groups. Cl ions and Na ions also formed separate clusters but their negative correlation with group type was weaker. Furthermore, K ions, urea, and Pi showed a positive correlation with storage time.

Discussion

Scientific studies have shown a clear beneficial effect of kinesitherapy and magnetic stimulation on virtually all systems of the human body [4, 16–26]. In the case of haemodialysis patients, this is an important issue, as they are usually older adults. In the study sample, the average age of all patients was 67.7 years. These data are in line with those published by Fresenius NephroCare Polska, where the mean age of nearly 6,000 patients from 71 centres performing dialysis was 66 years [6]. Combined with renal failure, the age factor in many cases determines multimorbidity, which further negatively affects the functioning of haemodialysis patients.

Both kinesiotherapy and low-frequency magnetic field treatments are widely used and are a regular part of the rehabilitation program for most neurological, orthopaedic, or other conditions [16, 17, 19, 21, 23–26]. For haemodialysis patients, however, standards for improvement management are still lacking [12]. This is a very unfavourable phenomenon, as the numerous limitations resulting from renal failure, chronic haemodialysis therapy, and comorbidities significantly reduce patient's functional capacity and quality of life. These include restrictions on physical activity, which contribute to a decline in cardiorespiratory fitness. A properly selected exercise program is completely safe and often feasible to implement at home and has a very beneficial effect not only on the physical but also mental health of the dialysis patient. It also represents the prevention of depressive states and promotes the treatment of depression [10, 27]. In a study by Yamamoto, it was observed that moderate-intensity exercise, as used in the present study, did not have a statistically significant effect on blood parameters but beneficial changes were noted in BMI and respiratory capacity [28]. Furthermore, Nowicki, who performed a 3-month observation of haemodialysis patients who took an average of 3,500 steps per day showed an increase in haemoglobin, a decrease in triglycerides, and preserved serum albumin parameters [29]. Similar observations regarding the relationship between the number of steps per day and haemoglobin levels were published in a study by Zamojska et al. This author also observed an increase in haematocrit and serum albumin levels [30]. In the present study, haemoglobin and haematocrit levels were also assessed, but no significant changes in these parameters were observed. The tendency for an overall improvement in blood parameters was also observed by Zhang et al., who demonstrated a positive correlation between increased physical activity on reduced mortality in haemodialysis patients [15]. Yamamoto et al. [31] and Martins et al. [14] also reported similar relationships in their analyses.

The rationale for including physical activity in the standard management of haemodialysis patients is recognized so clearly that research is now being conducted into the use of physical activity in virtual reality. Such a solution would not only promote physical fitness but also improve the sense of security during exercise. It has also been found that this form of activity is so beneficial to the mental status of the participants that it can be used in the prevention and support of treatment of depressive conditions [32]. It is noteworthy that haemodialysis patients are willing to engage in physical activity but they need professional instruction beforehand to have a sense of security and knowledge of how to protect themselves from its side effects. At the same time, they are no less interested in attractive solutions that would allow them to enjoy physical activity [33].

The second aspect to be evaluated in the project was the use of magnetic stimulation to improve the function of people undergoing haemodialysis. This procedure is technically easy to perform, and studies conducted so far have shown its beneficial effects on stimulating recovery, delaying ageing processes, and improving immune function, among other things. There are no studies in the available databases that have evaluated the effects of magnetic stimulation on the blood parameters of haemodialysis patients. However, analysis of the data on other disease entities suggests that one can expect a beneficial effect of this method on the patient's body [2, 34–36].

The analysis of the results of the conducted research allows us to conclude the existence of the strongest relationship in the studied groups concerning the levels of K ions, urea, and Pi, and the weakest relationship in terms of blood morphological parameters and tCa. However, in the analysed literature, it was not possible to find an answer to the reasons for the observed characteristics of these parameters. It was also not possible to find an answer to why statistically significant changes in urea levels occurred in the studied patient groups while there were no statistically significant changes in the levels of other assessed blood parameters. The lack of data for comparison may be related to the limited prevalence of rehabilitation procedures among haemodialysis patients, particularly the use of magnetic stimulation. This issue requires further analysis on a larger group of haemodialysis patients and longer-term observations, exceeding the 12-week period.

Conclusion

In summary, the research presented in this study showed that neither kinesitherapy nor magnetic stimulation treatments are indifferent to the human body. Despite the small number of patients included in the study, the collected data suggest that further research on a larger scale is needed. This would allow for collecting more meaningful results and incorporating the evaluated treatments into the standards of management of haemodialysis patients at dialysis stations.

Limitations of the study

The main limitations of the study are:

- the limited number of patients Dialysis Station of the Department of Nephrology, Hypertension, and Family at the Military Medical Academy Memorial Teaching Hospital of the Medical University of Lodz – Central Veterans' Hospital that participated in the project and the relatively short time allocated for task implementation;
- contraindications for magnetic stimulation treatments in some patients undergoing haemodialysis.

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Ethics statement: *Ethical clearance was obtained from the Bioethical Commission of Medical University in Lodz. Also, informed written consent was obtained from all participants after explaining the purpose of the study, the importance of their contribution as well as the right to refuse participation. All the information gathered was kept confidential.*

Conflicts of interest: *The authors declare no conflict of interest.*

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