

Electrotherapy Treatments Performed in the Area of the Throat and Larynx and the Level of TSH, FT₃ and FT₄ Hormones: A Randomized Controlled Trial

Jolanta Zwolińska (✉ jolantazwolinska@op.pl)

University of Rzeszow

Barbara Augustyn

University of Rzeszow

Katarzyna Baj

University of Rzeszow

Jadwiga Krukowska

University of Rzeszow

Research Article

Keywords: Electrotherapy, potassium iodide iontophoresis, electrotherapy

Posted Date: April 23rd, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-362424/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at Scientific Reports on August 2nd, 2021. See the published version at <https://doi.org/10.1038/s41598-021-95145-w>.

Abstract

No current studies are available on application and side effects of potassium iodide iontophoresis. This study assessed the potassium iodide iontophoresis effect in the throat and larynx area on TSH, FT3 and FT4 hormone levels. Double-blinded randomized controlled trial with 1:1 parallel-group was conducted at the University of Rzeszow, Poland. A total of 50 healthy volunteers with normal TSH, FT3, FT4 levels without focal changes in the thyroid ultrasonography were subjected to 10 electrotherapy treatments (galvanization and iontophoresis groups). TSH, FT3, FT4 levels were determined before 10 treatments (test 1), 2 weeks after their completion (test 2) and after 6 months (test 3). In tests 2 and 3, both groups had normal levels of TSH, FT3, and FT4. No statistically significant differences between the galvanization and iontophoresis groups were found in terms of change of TSH, FT3, FT4 levels between tests 1 vs. 2 and 1 vs. 3. Both groups had lower levels of all measured parameters in test 3. Potassium iodide iontophoresis does not affect thyroid hormone levels in the short and long term. It is advisable to continue the follow-up study with larger groups to confirm the safety of electrotherapy procedures in the pharynx and larynx area.

Introduction

Iodine is essential for the production of thyroid hormones: triiodothyronine (T_3) and thyroxine (T_4), which are essential for the proper functioning of the body. These hormones play an important role in metabolism, growth and maturation of various organs and systems, especially the nervous system [1,2]. According to the recommendations of WHO and IOM (The United States Institute of Medicine), the daily intake of iodine for adults should be 150 μg [2-4]. Both low and high iodine intake are associated with an increased risk of thyroid disease, and optimized iodine intake is an important to prevent thyroid diseases [3,5,6].

In order to assess the thyroid functioning, it is recommended to measure the level of thyroid-stimulating hormone (TSH) secreted by the pituitary gland and the free triiodothyronine (FT_3) and free thyroxine (FT_4) in the blood [7-10].

Medical reference books enumerate various indications for the use of physiotherapeutic procedures in the throat and larynx conditions [11-14]. However, these recommendations are not appropriately grounded in scientific studies and literature available in the databases. The most common throat and larynx conditions in which physical therapy is ordered include paralysis of the vocal cords of the larynx, chronic pharyngitis and laryngitis, dysphonia, vocal cord nodules. Patients are most often referred for physical therapy treatments in the area of the pharynx and larynx by medical specialists in the field of otolaryngology and phoniatics [15]. Potassium iodide (KI) iontophoresis is used in the therapy of throat and larynx conditions, arthritis, arthrosis, scar contractures and hypertrophic scars [15-18].

The application of KI iontophoresis allows to reduce antibiotic therapy, which is of great importance in the case of its excessive use [19-21]. There are no reports in the literature on the possible side effects of KI

iontophoresis in the pharynx and larynx area.

The aim of the study was to assess the impact of KI iontophoresis procedures performed in the pharynx and larynx area on the level of TSH, FT₃ and FT₄ hormones.

Results

Flow of participants

At baseline, the randomization process yielded no major differences between the groups G and I regarding age (P = 0.6234), gender (P = 0.3818), body mass index (P = 0.2724).

Short-term effects of electrotherapy (n = 50)

One person from group G demonstrated a significant decrease in TSH level (0.101 µIU / ml) in test 2 while a significant increase in this value (11.6 µIU / ml) in test 3 was observed. This person was excluded from further analysis. For the remaining participants from both groups, TSH, FT₃ and FT₄ levels were within the normal range. There were no statistically significant differences between groups G and I in TSH level in test 1 and test 2, as well as changes in TSH levels recorded in the period (1–2) (Table 1).

Table 1
Changes in TSH levels in the study groups over the period (1–2)

TSH [µIU/ml]	Type of therapy						
	galvanization			iontophoresis			
	Mean (95% c.i.)	Me	s	Mean (95% c.i.)	Me	s	P
Before electrotherapy	2.26 (1.84; 2.68)	2.03	1.01	2.28 (1.99; 2.57)	2.22	0.71	0.9493
After electrotherapy	1.96 (1.59; 2.32)	1.88	0.89	1.93 (1.61; 2.24)	1.75	0.77	0.8968
Therapy effect	-0.31 (0.61;0.00)	-0.22	0.74	-0.35 (-0.66;-0.04)	-0.40	0.75	0.8278

P – test probability value calculated using the independent samples t-test.

Decrease in TSH levels (group G: P = 0.0513, group I: P = 0.0281) was observed in individual groups.

FT₃ level before electrotherapy was slightly higher in group G. There were no statistically significant differences between groups G and I in terms of changes in this parameter in the period (1–2) (Table 2).

Table 2
Changes in FT₃ levels in the studied groups in the period (1–2)

FT ₃ [pg/ml]	Type of therapy							<i>P</i>
	Galvanization			Iontophoresis				
	Mean (95% c.i.)	Me	<i>s</i>	Mean (95% c.i.)	Me	<i>s</i>		
Before electrotherapy	3.43 (3.28; 3.59)	3.42	0.37	3.23 (3.03; 3.42)	3.36	0.47	0.0910	
After electrotherapy	3.42 (3.20; 3.63)	3.38	0.52	3.37 (3.13; 3.60)	3.34	0.57	0.7611	
Therapy effect	-0.02 (-0.18;0.14)	-0.06	0.39	0.14 (-0.06; 0.34)	0.11	0.48	0.2051	
<i>P</i> – test probability value calculated using the independent samples <i>t</i> -test.								

No statistically significant changes were found in the FT₃ parameter in individual groups (group G: *P* = 0.8311, group I: *P* = 0.1521).

No statistically significant differences were observed between groups G and I in terms of changes in FT₄ in the period (1–2) (Table 3).

Table 3
Changes in FT₄ in the studied groups in the period (1–2)

FT ₄ [ng/dl]	Type of therapy						<i>P</i>
	Galvanization			Iontophoresis			
	Mean (95% c.i.)	Me	<i>s</i>	Mean (95% c.i.)	Me	<i>s</i>	
Before electrotherapy	1.31 (1.25; 1.38)	1.31	0.16	1.29 (1.24; 1.33)	1.26	0.12	0.5124
After electrotherapy	1.31 (1.22; 1.39)	1.25	0.21	1.26 (1.21; 1.32)	1.29	0.14	0.3822
Therapy effect	-0.01 (-0.07; 0.06)	-0.03	0.16	-0.02 (-0.07; 0.02)	0.00	0.11	0.6473
<i>P</i> – test probability value calculated using the independent samples <i>t</i> -test.							

No statistically significant changes were found in the FT₄ parameter in the studied groups in period (1–2) (group G: *P* = 0.8710, group I: *P* = 0.3209).

The direction of changes of the measured parameters was analyzed in individual cases in groups G and I (Table 4)

Table 4

The number and percentage of people for whom the given parameter increased and decreased in the period (1–2)

Grouped features	Type of therapy								
	Galvanization				Iontophoresis				<i>P</i>
	Decrease		Increase		Decrease		Increase		
	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	
TSH [μ IU/ml] (change)	15	60%	10	40%	18	72%	7	28%	
FT ₃ [pg/ml] (change)	14	56%	11	44%	10	40%	15	60%	0.2575
FT ₄ [ng/dl] (change)	14	56%	11	44%	12	48%	13	52%	0.5713

P – test probability value calculated using the chi-square test of independence.

In group G, TSH decreased in 60% of people, and in group I in 72%. There were no statistically significant differences between G group and I group in terms of the effects of electrotherapy. The share of people with decreased TSH level was similar in both groups, which corresponded to the previous conclusion, with a similar level of changes expressed in the numerical form. Similar conclusions can be drawn for the parameters FT₃ and FT₄.

Long-term effects of electrotherapy (n = 36)

In both groups, the TSH levels in test 3 were within the normal range. There were no statistically significant differences between groups G and I in TSH levels in three subsequent tests, as well as changes in TSH levels recorded in the periods: (1–2), (2–3) and (1–3) (Table 5).

Table 5
Changes in TSH levels in the study groups in the period (1–2), (2–3) and (1–3)

TSH [μ IU/ml]	Type of therapy						
	Galvanization (n = 21)			Iontophoresis (n = 15)			
	Mean (95% c.i.)	Me	s	Mean (95% c.i.)	Me	s	P
Before electrotherapy (1)	2.18 (1.72; 2.64)	1.79	1.01	2.42 (1.99; 2,86)	2,31	0,79	0.4515
After electrotherapy (2)	2.01 (1.65; 2.37)	1.91	0.79	1.95 (1.57; 2.33)	1.91	0.68	0.8238
6 months later (3)	1.64 (1.36; 1.92)	1.88	0.61	1.91 (1.46; 2.37)	1.79	0.82	0.2640
(1–2)	-0.17 (-0.52; 0.18)	0.01	0.76	-0.47(-0.94;0.00)	-0.54	0.85	0.2819
(2–3)	-0.37 (-0.61; -0.12)	-0.33	0.54	-0.04(-0.59;0.51)	-0.33	0.99	0.2108
(1–3)	-0.54 (-0.97; -0.12)	-0.39	0.93	-0.51(-1.02;0.00)	-0.31	0.92	0.9185
<i>P</i> – test probability value calculated using the independent samples <i>t</i> -test.							

In both groups in test 3 there was a significant decrease in TSH levels compared to the two previous measurements. In period (1–3), there was a significant change in group G ($P = 0.0151$), while in group I there was a decrease at the verge of statistical significance ($P = 0.0502$).

Similar changes were found in the parameters FT_3 and FT_4 . There were no significant differences between groups G and I regarding changes in FT_3 (Table 6).

Table 6
Changes in FT₃ levels in the study groups in the period (1–2), (2–3) and (1–3)

FT ₃ [pg/ml]	Type of therapy							
	Galvanization (n = 21)				Iontophoresis (n = 15)			
	Mean (95% c.i.)	Me	s	Mean (95% c.i.)	Me	s	P	
Before electrotherapy (1)	3.42 (3.25; 3.59)	3.42	0.37	3.29 (3.08; 3.51)	3.36	0.39	0.3306	
After electrotherapy (2)	3.43 (3.19; 3.67)	3.38	0.53	3.40 (3.08; 3.72)	3.37	0.57	0.8675	
6 months later (3)	3.14 (2.95; 3.33)	3.14	0.42	3.00 (2.80; 3.19)	3.03	0.35	0.2865	
(1–2)	0.01 (-0.17; 0.20)	-0.03	0.40	0.11 (-0.15; 0.37)	0.01	0.47	0.5220	
(2–3)	-0.29 (-0.56; -0.03)	-0.23	0.58	-0.40 (-0.69; -0.12)	-0.27	0.52	0.5562	
(1–3)	-0.28 (-0.45; -0.11)	-0.27	0.37	-0.30 (-0.50; -0.09)	-0.14	0.37	0.8891	
<i>P</i> – test probability value calculated using the independent samples <i>t</i> -test.								

In both groups there were significant differences between the results of test 3 and two previous tests. There was a significant decrease in FT₃ value in period (2–3) (group G: *P* = 0.0325, group I: *P* = 0.0095) and in period 1–3 (group G: *P* = 0.0024, group I: *P* = 0.0074). There were also no significant differences between groups G and I with regard to FT₄ parameter change (Table 7).

Table 7
Changes in FT₄ levels in the study groups in the period (1–2), (2–3) and (1–3)

FT ₄ [ng/dl]	Type of therapy							
	Galvanization (n = 21)				Iontophoresis (n = 15)			
	Mean (95% c.i.)	Me	s		Mean (95% c.i.)	Me	s	P
Before electrotherapy (1)	1.31 (1.24; 1.39)	1.31	0.16		1.28 (1.24; 1.33)	1.26	0.09	0.5584
After electrotherapy (2)	1.31 (1.21; 1.41)	1.25	0.22		1.26 (1.19; 1.33)	1.25	0.12	0.4002
6 months later (3)	1.22 (1.15; 1.28)	1.20	0.14		1.16 (1.10; 1.23)	1.15	0.12	0.2136
(1–2)	0.00 (-0.08; 0.08)	-0.03	0.17		-0.03 (-0.10; 0.04)	-0.04	0.12	0.6279
(2–3)	-0.09 (-0.20; 0.01)	-0.06	0.23		-0.10 (-0.19; 0.00)	-0.08	0.18	0.9616
(1–3)	-0.09 (-0.16; -0.02)	-0.07	0.16		-0.12 (-0.19; -0.05)	-0.13	0.12	0.5553

P – test probability value calculated using the independent samples t-test.

In period 1–3 there was a significant decrease in FT₄ values in the G group ($P = 0.0123$) and in I group ($P = 0.0016$).

Discussion

The bibliographic databases contain a few original works on application and possible side effects of galvanization or potassium iodide iontophoresis on the pharynx and larynx area.

This study was designed to evaluate the effect of transdermal iodine application on the levels of TSH, FT₃, FT₄. The amount of iodine that should penetrate the tissues during iontophoresis was calculated on the basis of Faraday's first law of electrolysis, assuming that the entire current is made up of only the ions of the drug substance [22]. If numerous competing ions, including parasitic ones, are present in the pads used for the treatment during the iontophoresis, the amount of the basic drug substance penetrating the tissues is reduced.

Puttemans et al. (1982) confirmed the penetration of KI into the tissue using galvanic current. The authors estimate that about 10% of the KI used for iontophoresis has penetrated deep into the tissues in the transdermal administration. After a series of 10 iontophoresis treatments with KI, the mean concentration of iodine in the thyroid gland increased by about 30% [23].

The acceptable upper level of the daily iodine supply is 1100 µg, although the higher intake is usually well tolerated [2]. Ingestion of KI provides a safe protection against irradiation of the thyroid gland after exposure to radioactive iodine [24, 25]. Verger et al. review shows that the daily consumption of a dose of 15 mg KI effectively protects the thyroid gland at the level of over 90% [24]. According to Zanzonico & Becker, the blockage of the thyroid gland by oral KI in a dose of 50–100 mg may effectively reduce the thyroid radiation [25]. In the study by Bacher et al., 100 mg of KI daily was used to prevent radiation of the thyroid gland [26].

In our study, 200 mg of KI was used for a single iontophoresis treatment. From Faraday's law I of electrolysis, it results that during one iontophoresis treatment less than 6.1927461 mg of KI was introduced into the tissues. Our calculation is based on the assumption that it is impossible to eliminate all competing ions in the electric field created between the treatment electrodes. The changes in hormone levels observed by us may indicate that the iodine dose used had no effect on the levels of TSH, FT₃ and FT₄ hormones.

During iontophoresis, the thyroid gland is also influenced by direct, galvanic current. The biological effect of electric fields is still the subject of much research. The flow of current can affect all tissues and organs [27]. Living cells can be induced to migrate by applying a small dose of direct current (galvanotaxis) [28]. The human body as an element of an electrical circuit has the character of an anisotropic conductor. During the flow of current, thermal energy is released and the tissues are hyperemic [18, 29]. According to the Joule-Lenz's law, the amount of heat released is directly proportional to the square of the current intensity, its flow time and tissue resistance [29]. The electric current causes depolarization of the cell membrane of excitable cells [27]. It also influences the pH of the tissues. The electrochemical changes around the negative electrode (the alkaline environment produced by OH⁻ ions) are more severe compared to the changes around the positive electrode (the acidic environment produced by H⁺ ions) [30]. In our study, the heat generated and electrochemical changes were minor and did not pose a threat to the study participants subjected to the experiment. We used a current of 2 mA, which corresponds to the perception threshold for direct current. This value is about 1.5 mA for women and about 2.5 mA for men [27, 29].

Gierlotka (2006) emphasizes that direct current flowing through tissues long enough can cause pathological changes even if its intensity does not exceed the perception threshold [29]. According to Dechent et al. (2020), the negative effects of current flow through tissues may show up immediately, but may also be delayed by several months or even years [27]. The reduction in the values of all three parameters, which we noted in test 3 in both groups, suggests that the assessment of possible side effects of electrotherapy treatments in the throat and larynx area should be the subject of future studies in physiotherapy involving larger groups of subjects.

A certain limitation of our study are few deviations from the adopted research protocol. In group G, one person used a lower dose of current (1.5 mA) due to the intense feeling of current vibrations. On the penultimate day of treatment, one patient from group G underwent two galvanization treatments (in the

morning and evening). One person from group G had a second blood test one week later (3 weeks after the end of electrotherapy).

Conclusion

In summary, potassium iodide iontophoresis treatments do not affect the levels of TSH, FT₃ and FT₄ in the short and long term. The high frequency of focal lesions in the thyroid gland ultrasonography examination in the study group is an argument for carrying out such an examination in patients referred for electrotherapy in the pharynx and larynx area. The evaluation of possible side effects of electrotherapy in the area of the pharynx and larynx requires the continuation of follow-up studies including larger groups of subjects.

Material And Methods

Design

Participants who agreed to participate in the study and had no contraindications to electrotherapy in the neck area were selected or excluded from participation in the study through a computer-generated randomization list. Qualified participants were subjected to ultrasonography of the thyroid gland and had hormone levels (TSH, FT₃ and FT₄) determined. Thereafter, two study groups assigned to two different interventions (galvanization – group G /iontophoresis – group I) were formed by subsequent randomization. The participants of the study were not informed to which group they were assigned to. A double-blinded, 1:1 parallel-group, randomized controlled trial was conducted.

Participants

The students of the third, fourth and fifth year of physiotherapy were invited to participate in the study. They were given written information about the purpose and course of the study and the possibility of withdrawing from participation at every stage of the study.

Inclusion criteria were:

- informed written consent of the patient to participate in the study;
- no contraindications to electrotherapy in the area of the throat and larynx;
- normal results of ultrasonography of the thyroid and hormone levels (TSH, FT₃, FT₄);
- no neoplastic diseases and thyroid diseases in the examined person and in the immediate family.

Exclusion criteria were:

- poor tolerance of electrotherapy treatments;

- breaks between consecutive treatments longer than 3 days;
- failure to complete a series of iontophoresis / galvanization treatments;
- use of any stimulants during the observation period.

The members of Scientific Circle of Physical Energy Used in Physiotherapy were therapists.

The study was conducted in Centre for Innovative Research in Medical and Natural Sciences, University of Rzeszow.

Intervention

Participants were subjected to a series of 10 electrotherapy treatments (galvanization or iontophoresis) according to the result of randomization.

Methodology of cathodic galvanization treatment:

- distilled water (placebo) was used for the treatment
- current 2 mA
- treatment time 30 min

Methodology of cathodic iontophoresis treatment:

- 10 ml of 2% KI solution (200 mg of KI) was used
- current 2 mA
- treatment time 30 min

After each treatment, the condition of the skin in the treatment area was assessed in order to exclude any symptoms of iodine allergy.

During the iontophoresis procedure, 6.1927461 mg of potassium iodide, including 4.73409324 mg of iodine was introduced into the tissues (Appendix A).

The following were used for electrotherapy:

- a 4 cm x 5 cm active electrode placed in the throat area (current density was 0.1 mA / cm²)
- a 5 cm x 6 cm passive electrode placed in the nape (current density was 0.066 mA / cm²)

Outcome measures:

Before the study, all students had an ultrasonography examination of the thyroid gland performed by a radiologist.

The outcomes were the levels of TSH, FT₃, FT₄ hormones (Appendix B). Hormone levels were tested before a series of 10 electrotherapy treatments (test 1), two weeks after the end of the electrotherapy series (test 2), and after 6 months (test 3) (Fig. 1). All hormone tests were performed in the same laboratory.

Data analysis

In the first stage of the analysis, the data obtained from the 50 participants who participated in test 1 and test 2 were analyzed. The level of TSH, FT₃ and FT₄ was compared before electrotherapy (test 1), after electrotherapy (test 2), as well as the effect of electrotherapy between group G (galvanization) and group I (iontophoresis). The statistical significance of the electrotherapy effect was also assessed in each group separately.

In the next stage, the data obtained from 36 participants who took part in three subsequent tests were analyzed. The significance of changes in individual parameters was assessed in the period between the first and second tests (1-2), between the second and third tests (2-3), and between the first and third tests (1-3) (electrotherapy effects) - separately for group G and group I. The level of individual parameters was compared between groups I and G for each study, as well as for the observed changes (effects of different electrotherapy treatments).

As the distributions of the studied values did not differ significantly from normality, parametric tests were used:

- t-test for independent samples to evaluate differences between groups;
- t-test for paired samples to assess the significance of changes in parameters between studies within groups.

The chi-square test of independence was used to assess the differences in the frequency of decreases or increases in the values of individual parameters in both groups.

The sample size was determined for one of the laboratory parameters, namely TSH. On the basis of the preliminary examination (for 10 people), the mean TSH value was determined at the level of 2.6 $\mu\text{IU} / \text{ml}$ with the standard deviation amounting to about 1.2 $\mu\text{IU} / \text{ml}$. It was assumed that the sample size should detect a change between tests at 50% of the variation in the first test (i.e. 0.6 $\mu\text{IU} / \text{mL}$) at a significance level of 0.05 and 80% of test power. Such assumptions for the t-test for dependent samples give a minimum sample size of 21. Some assumptions taken into account might seem debatable therefore groups of 25 were included in the analysis.

In the analysis and interpretation of results, statistical significance was determined at $p \leq 0.05$ (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$). *STATISTICA* software was used for all calculations.

Declarations

Acknowledgements

We thank the participants for giving their time and energy to take part in this study. The authors would like to acknowledge the contribution to the implementation of the study to the members of Scientific Circle of Physical Energy Used in Physiotherapy.

Authors Contribution

J.Z.:

- Conceptualization,
- Methodology,
- Validation,
- Investigation,
- Data Curation,
- Writing - Original Draft,
- Preparation,
- Supervision,
- Project administration

A.B.:

- Methodology,
- Validation,
- Investigation,
- Data Curation,
- Writing - Review & Editing,
- Visualization,
- Funding acquisition

B.K.:

- Methodology,
- Validation,
- Investigation,

- Data Curation,
- Writing - Review & Editing,
- Visualization,
- Funding acquisition

J.K.:

- Investigation

Funding

This work was supported by University of Rzeszow, Medical College DN5121/18/2019,

DNP-SKN/8/2020

Competing interests

The authors declare no competing interests.

Ethics approval

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of University of Rzeszow (resolution No. 2018/05/04). Participants gave written informed consent before data collection began.

Trial registration

ClinicalTrials.gov (NCT04013308; URL: www.clinicaltrials.gov).

Day of first registration 09/07/2019

References

1. Spitzweg, C., Heufelder, A.E., Morris, J.C. Thyroid iodine transport. **10**(4), 321-330, DOI:10.1089/thy.2000.10.321 (2000).
2. Leung, A.M., Braverman, L.E. Iodine-induced thyroid dysfunction. *Curr Opin Endocrinol Diabetes Obes.* **19**(5), 414-419, DOI:10.1097/MED.0b013e3283565bb2 (2012).
3. Zimmermann, M.B., Boelaert, K. Iodine deficiency and thyroid disorders. *Lancet Diabetes Endocrinol.* **3**(4), 286-295, DOI: 10.1016/S2213-8587(14)70225-6 (2015).
4. Gietka-Czernel, M. Iodine prophylaxis. *Post Nauk Med.* **28**(12), 839-845 (2015). (in Polish)
5. Laurberg, P. *et al.* Iodine intake as a determinant of thyroid disorders in populations. *Best Pract Res Clin Endocrinol Metab.* **24**(1), 13-27, DOI: 10.1016/j.beem.2009.08.013 (2010).

6. Yuqian, L. *et al.* Iodine excess as an environmental risk factor for autoimmune thyroid disease. *Int J Mol Sci.* **15**(7), 12895-12912, DOI:3390/ijms150712895 (2014).
7. Karpińska, J., Kryszalowicz, B., Błachowicz, A., Franek, E. Primary, secondary and iatrogenic thyroid dysfunction. *Chor Serca Naczyń.* **4**(1), 48–53 (2007). (in Polish)
8. Kluesner, J.K. *et al.* Analysis of current thyroid function test ordering practices. *J Eval Clin Pract.* **24**, 347–352, DOI:1111/jep.12846 (2018).
9. Barhanovic, N.G., Antunovic, T., Kavaric, S., Djogo, A., Kalimanovska, V. Age and assay related changes of laboratory thyroid function tests in the reference female population. *J Med Biochem.* **38**, 22–32, DOI:2478/jomb-2018-0020 (2019).
10. Shui-Boon, S., Tar-Choon A. Laboratory testing in thyroid conditions-pitfalls and clinical. *Utility Ann Lab Med.* **39**(1), 3-14, DOI:3343/alm.2019.39.1.3 (2019).
11. Śliwiński, Z., Sieroń, A. Great physiotherapy (Elselvier Urban & Partner, 2014). (in Polish)
12. Mika, T., Kasprzak, W. Physical therapy (PZWL Wydawnictwo Lekarskie, 2019). (in Polish)
13. Mikołajewska, E. Elements of physiotherapy physical therapy for practitioners (PZWL Wydawnictwo Lekarskie, 2011). (in Polish)
14. Cameron, M.H. *Physical agents in rehabilitation: from research to practice* (Saunders, 2013).
15. Zimmer-Nowicka, J., Zasada, M., Kaczmarczyk, D., Morawiec-Sztandera, A. Analysis of indications and evaluation of the frequency of physiotherapeutic procedures of the larynx and pharynx in selected rehabilitation offices. *Otorynolaryngologia.* **9**(3), 127-133 (2010). (in Polish)
16. Straburzyńska-Lupa, A., Straburzyński G. Physiotherapy (PZWL Wydawnictwo Lekarskie, 2007). (in Polish)
17. Jaśkiewicz, J., Bromboszcz, J., Włoch, T., Piekarz, A., Blachura L. Iontophoresis and phonophoresis. Theoretical basis and practical application. *Reh Med.* **4**, 29-45 (2000). (in Polish)
18. Drygalski, M., Bożek, M., Bielecki, T., Gaździk, T.S. The use of electrostimulation in the treatment of soft tissue and bone damage. *Ortho & Trauma.* **3**(3), 35-46 (2016). (in Polish)
19. Chajęcka-Wierzchowska, W., Zadernowska, A., Łaniewska-Trokenheim, Ł. Resistance to antibiotics of food-borne enterococcus bacteria **66**(1), 67-79 (2017). (in Polish)
20. Senderowska, J., Muszyńska, A. Rational antibiotic therapy in primary care. *Fam Med Primary Care Rev.* **15**(3), 389-390 (2013). (in Polish)
21. Dziekiewicz, M., Albrecht, P. Rational antibiotic therapy according to the National Antibiotic Protection Program - selected issues. *Lekarz POZ.* **4**, 323-327 (2016). (in Polish)
22. Mnich, Z.S., Kostrzewska, A., Czyżewska, E. *Podstawy fizyczne i biofizyczne elektroterapii* [Physical and biophysical basics of electrotherapy]. In: Kwolek A, editor. *Rehabilitacja medyczna [Medical rehabilitation]* 111-146 (Urban & Partner, 2003).
23. Puttemans, F.J., Massart, D.L., Gilles, F., Lievens, P.C., Jonckeer, M.H. Iontophoresis: mechanism of action studied by potentiometry and x-ray fluorescence. *Arch Phys Med Rehabil.* **63**(4), 176-180 (1982).

24. Verger, P., Aurengo, A., Geoffroy, B., Le Guen, B. Iodine kinetics and effectiveness of stable iodine prophylaxis after intake of radioactive iodine: a review. *Thyroid*, **11**(4), 353-360, DOI:[1089/10507250152039082](https://doi.org/10.1089/10507250152039082) (2001).
25. Zanzonico, P.B., Becker V. Effects of time of administration and dietary iodine levels on potassium iodide (ki) blockade of thyroid irradiation by ¹³¹i from radioactive fallout. *Health Phys: The Radiation Safety Journal*. **78**(6), 660-667, DOI:[10.1097/00004032-200006000-00008](https://doi.org/10.1097/00004032-200006000-00008) (2007).
26. Bacher, K. *al.* Thyroid uptake and radiation dose after ¹³¹I-lipiodol treatment: is thyroid blocking by potassium iodide necessary? *Eur J Nucl Med Mol Imaging*. **29**(10), 1311-1316, DOI:[10.1007/s00259-002-0917-z](https://doi.org/10.1007/s00259-002-0917-z) (2002).
27. Dechent, D. *et al.* Direct current electrical injuries: A systematic review of case reports and case series. **46**(2), 267-278, DOI: [10.1016/j.burns.2018.11.020](https://doi.org/10.1016/j.burns.2018.11.020) (2020).
28. Song, B. *et al.* Application of direct current electric fields to cells and tissues in vitro and modulation of wound electric field in vivo. *Nat Protoc*. **2**(6), 1479-1489, DOI:[1038/nprot.2007.205](https://doi.org/10.1038/nprot.2007.205) (2007).
29. Gierlotka, S. Effects of electric shock. *Bezp Pr Nauk Prakt*.**9**, 30-32 (2006). (in Polish)
30. Geddes, L.A., Roeder, R.A. Direct-current injury: Electrochemical aspects. *J Clin Monit*. **18**, 157–161, DOI:[1023/B:JOCM.0000042923.00392.a8](https://doi.org/10.1023/B:JOCM.0000042923.00392.a8) (2004).

Figures

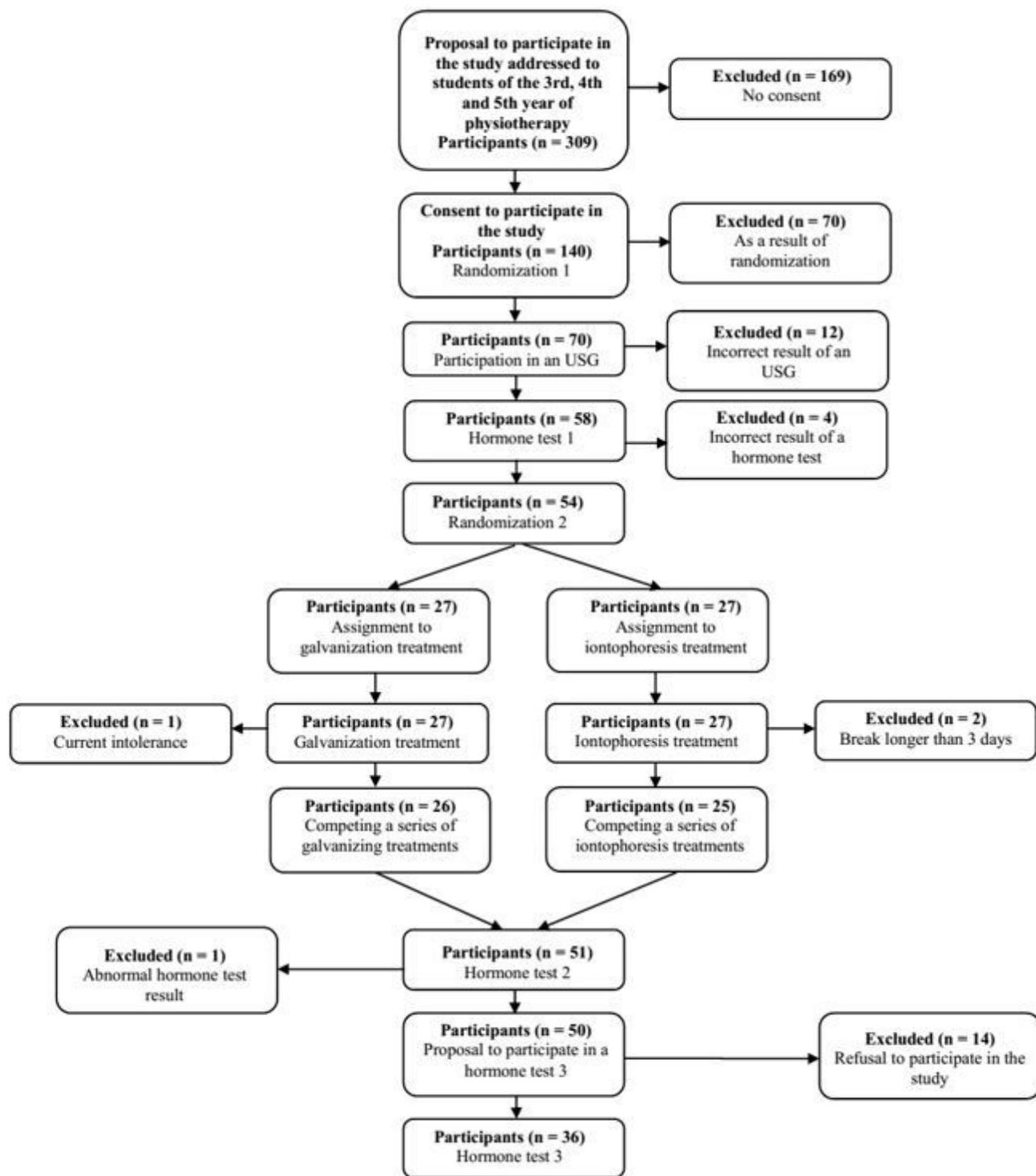


Figure 1

Design and flow of participants through the trail

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Appendix.docx](#)