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SHORT AND LONG-TERM EFFECTS OF PULSED WAVE AND CONTINUOUS WAVE ULTRASOUND FOR THE TREATMENT OF CARPAL TUNNEL SYNDROME: A RANDOMIZED CLINICAL TRIAL

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ABSTRACT

Background: Sonotherapy is used in carpal tunnel syndrome (CTS) treatment; continuous or pulsed ultrasound waves are commonly used. The aim was to assess the short and long-term effects of CTS treatment using continuous and pulsed ultrasound waves.

Methods: This study was a randomized clinical trial. Forty-eight patients with mild and moderate CTS (20 unilateral and 28 bilateral) were subjected to complex physiotherapy. Complex physiotherapy included whirlpool massage, neuromobilization, and sonotherapy (continuous wave and pulsed wave ultrasound). The patients were randomly placed in two treatment groups and were subjected to sonotherapy with continuous or pulsed ultrasound waves. Seventy-six hands were assessed before, immediately after, and one year after treatment. Outcome measures included the Boston Carpal Tunnel Questionnaire (CTS SSS & FSS), computer-measured global handgrip force, provocative and functional tests, assessments of vegetative disorders, and sensation disorders.

Results: Significant improvements in symptoms and parameters were observed after sonotherapy in both groups immediately after and one year after treatment.

Long-term effects of CTS SSS & FSS for pulsed-wave amounted to $p=0.0018$, $p=0.0001$ while $p=0.0003$, $p=0.0021$ for continuous wave, respectively. Between the groups, a statistically significant difference was found in the change of muscle strength ($p=0.0374$) and Luthy's sign result ($p=0.0262$) between examination one and examination 3.

Conclusions: Short and long-term effects of continuous and pulsed ultrasound wave in CTS treatment is comparable. Effects are influenced by energy density transmitted to tissues. Pulsed wave appears more effective in the long-term in improving the condition of hand muscles.

Keywords: carpal tunnel syndrome, ultrasound therapy, pulsed wave, continuous wave, ultrasound waves.

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INTRODUCTION

Carpal tunnel syndrome (CTS) becomes a frequent peripheral neuropathy provoked by enhanced pressure in the carpal tunnel causing median nerve compression [1,2]. Numerous internal and external factors can cause CTS, resulting in nerve ischemia, edema, and/or trophic disorders [3]. The worldwide CTS incidence ranges from 0.1–11.7%, demonstrating numerous and varied diagnostic criteria, including electromyography parameters and ultrasonography [4-7].

CTS symptoms, including median nerve paresthesia, can dramatically decrease a patient's physical activity and quality of life, resulting in a significant medical and financial burden to the healthcare system [8].

Conservative treatments such as immobilization and physiotherapy are applied in mild and moderate CTS forms, and patients with contraindications to surgery [9-13]. Sonotherapy is frequently used as a component of physiotherapy [9,14,15]. Ultrasound wave has different effects in different tissues, and some consider its selective application important in CTS therapy [16]. Parameters of the ultrasound wave, energy doses, and coupling agents may affect tissue transmission; therefore, evidence supporting the effectiveness of sonotherapy is inconsistent [17-20].

According to numerous authors, to fully benefit from the therapeutic potential of ultrasound, it is necessary to continue randomized blind studies of high methodological quality focusing on long-term sonotherapy effects. The results of such studies are required to determine optimal energy dose and frequency for ultrasound wave administration in clinical settings [9,15,18,21,22].

While mechanisms governing ultrasound's biological action are unclear, it can be quantitatively described using the thermal and mechanical index [22]. The thermal index is the energy required to raise tissue temperature, determined by the amplitude of pressure changes and variation in wave frequency [16]. The mechanical index refers to pressure changes on the ultrasound wave path resulting from squeezing and stretching forces. In clinical practice, continuous wave ultrasound is reported to reduce pain and increase tissue flexibility, whereas pulsed wave ultrasound reduces swelling and inflammation [19,23]. It was based only on mechanisms of ultrasonic wave transmission, the author postulate continuous wave ultrasound effectiveness to be related to thermal effects, and pulsed wave ultrasound to significant mechanical tissue stimulation. This study was designed to test this hypothesis. The overall aim of this study was to evaluate the influence of ultrasonic wave character and density of energy transferred on short- and long-term effects of CTS treatment.

METHODS

The Bioethics Committee of the University of Rzeszow, Poland (Resolution No. 5/02/2011) approved this study, and it was realized in St. Hedvig Provincial Clinical

Hospital No 2, Rzeszow, Poland, from September 2011 to December 2016.

The initial sample consisted of 74 people. Inclusion criteria were mild and moderate CTS and neurologist referral to physiotherapy (covering: whirlpool massage, sonotherapy, and median nerve neuro mobilization). Exclusion criteria were hand trauma and a history of cancer. Sixty-nine people who gave informed consent underwent physiotherapy according to the study protocol. Ultimately, 48 people participated in the study from beginning to end (20 people with unilateral CTS and 28 people with bilateral CTS) (Figure1). The analysis included 76 hands: 44 right hands and 32 left hands.

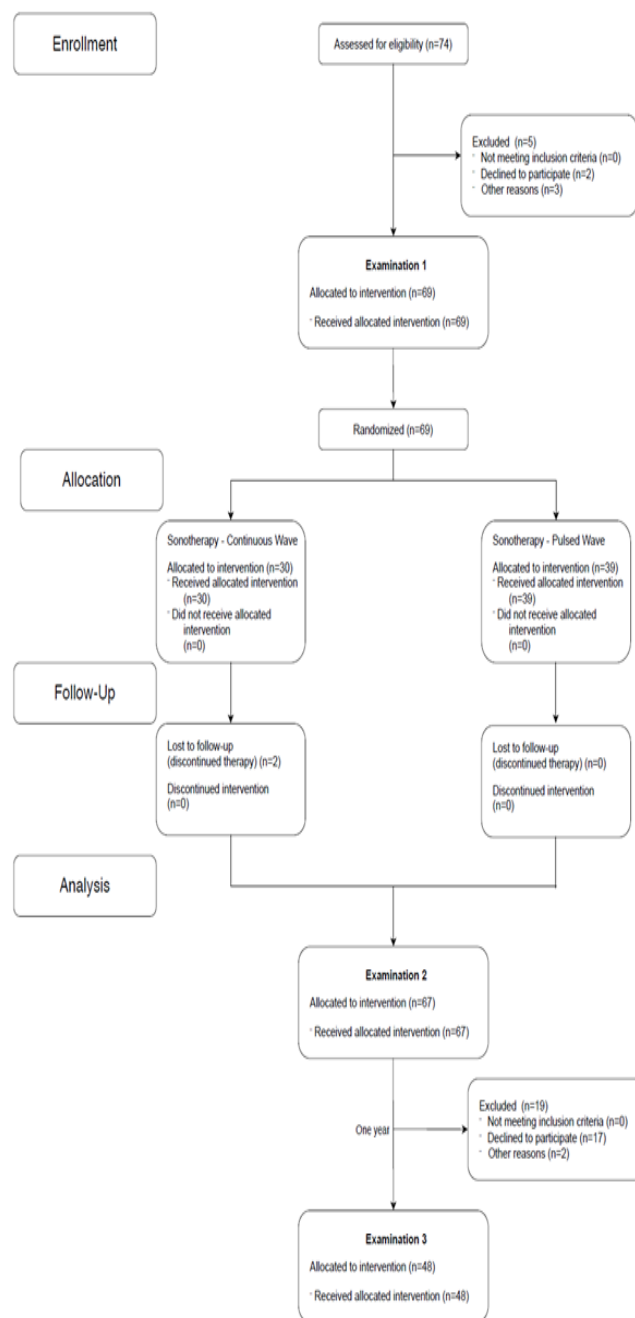


Figure 1. Flowchart of the study participants.

The study was carried out based on the ethical standards stipulated in the Declaration of Helsinki.

The patients were subjected to electroneurography to assess median nerve sensory and motor conductivity and to

determine the CTS stage based on Padua et al. classification [24]. Electroneurography was performed using EMG Dantec Keypoint [Medtronic, Skovlunde, Denmark].

Subjective clinical signs were evaluated with the Boston Carpal Tunnel Questionnaire (BCTQ). BCTQ includes two subscales. The symptoms severity scale (SSS) assesses signs regarding severity, frequency, time, and type. The functional status scale (FSS) estimates how the impact of the symptoms on everyday life [25-27]. Computer-measured global handgrip force was used to assess hand muscle strength. The sensors' precision in computer measurement amounted to $\pm 0.1\%$ [Electronic Hand Assessment Set designed by Rzeszow University of Technology, Rzeszow Poland]. Provocative tests included: Phalen's test, reversed Phalen's test, tourniquet test. Objective clinical symptoms (Luthy's sign, vegetative disorders, and sensation disorders) were tested [28]. The sensation disorders were determined with Touch-Test Two-Point Discriminator [North Coast Medical, Gilroy, CA., USA].

All hands were tested before (examination 1), immediately after (examination 2) and one year after (examination 3) treatment completion.

The physiotherapy regimen included whirlpool massage of a hand, sonotherapy, and automobilization of the median nerve (10 treatment sessions over two weeks). Sonotherapy and whirlpool massage were used to prepare patients for kinesiotherapeutic techniques [9,11,12,29].

Random placement in one of two groups was used; each received different types of the applied ultrasonic wave as discussed below.

Apart from ultrasound wave character (pulsed vs. continuous), sonotherapy parameters were identical. The transducer had an ERA (*effective radiation area*) of 5 cm² and water served as the coupling agent. The oscillation frequency of the ultrasound wave was 1 MHz. Wave intensity amounted to 0.6 W/cm², and treatment energy was 1080 J. Energy density was 108 J/cm² for the treatment area (~10 cm²). The treatments were performed by means of Sonicator 730 [Mettler Electronics corp., Anaheim, CA., USA]

In the pulsed wave treatment group (PW group), the "duty cycle" value was 20% (impulse: 2 ms; break: 8 ms), SATA (space-averaged time-averaged) intensity was 0.12 W/cm², and the treatment time was 30 min. In the continuous wave treatment group (CW group), "duty cycle" was 100%, SATA intensity was equal to wave intensity (0.6 W/cm²), and treatment time was 6 min.

The principal investigator assessing the condition of the hands had no not aware of the patient's assignment to CW or PW group. Randomization (flipping a coin) and physiotherapeutic procedures were carried out by the investigator's assistants. Participants did not know their assignment to the CW or PW group.

Statistical analysis was used to assess differences between the examinations (1-2), (2-3), (1-3) ("treatment effects") and between groups: (effects of different types of ultrasonic

waves). Corresponding nonparametric tests were also used. The significance of the effects of treatment was investigated with a Wilcoxon test. Differences between groups in treatment effects were studied with Mann-Whitney U tests. The incidence of symptoms and the positive results of provocation tests in the groups were compared using chi-square tests of independence. Similarly, the incidence of relief in adverse symptoms in both groups was compared; however, these cases were only considered when symptoms were reported in the first examination. The results were considered statistically significant at $p \leq 0.05$ (* $p < 0.05$ ** $p < 0.01$; *** $p < 0.001$). STATISTICA v. 12 by Statsoft was used for all calculations.

RESULTS

The PW and CW groups were comparable regarding demographics and work character (Table 1).

Table 1. Patient demographics

Variable	Pulsed wave	Continuous-wave	p-value
Number of patients/hands	27/40	21/36	
Patients age (years) mean \pm SD	52.7 \pm 12.6	57.3 \pm 10.2	0.1198 ^{a)}
Work character physical/mental (patients)	13/14	11/10	0.7711 ^{b)}
Number of mild/moderate cases (hands)	3/35 ^{c)}	7/29	0.1463 ^{b)}

a) Mann-Whitney test b) chi-square test of independence

c) normal electroneurography results were found in two hands, but they were referred for treatment due to the presence of clinical signs or symptoms.

Subjects from the CW group were ~5 years older than the PW group; the difference, however, turned out to be not statistically significant (Table 1).

Table 2 presents changes in hand condition in both groups over three periods: between the first and second examination (1-2); between the second and third examination (2-3); and, between the first and third examination (1-3).

Table 2. Effects of therapy: mean change in hand condition of analyzed parameters over study period

Analyzed parameters	Wave Type					
	Pulsed wave			Continuous wave		
	(1-2)	(2-3)	(1-3)	(1-2)	(2-3)	(1-3)
CTS SSS [pts]	-0.78 (0.0001***)	0.15 (0.4593)	-0.63 (0.0018**)	-0.56 (0.0014**)	-0.31 (0.1300)	-0.86 (0.0003***)
CTS FSS [pts]	-0.83 (0.0000***)	-0.15 (0.4155)	-0.98 (0.0001***)	-0.94 (0.0001***)	0.03 (0.9723)	-0.92 (0.0021**)
Muscle strength [kPa]	4.5 (0.0000***)	3.3 (0.0275*)	7.8 (0.0000***)	2.3 (0.0009***)	0.9 (0.2580)	3.2 (0.0021**)
Phalen's test [s]	-6.1 (0.0040**)	-1.7 (0.4995)	-7.7 (0.0410*)	-4.9 (0.1251)	0.3 (0.8754)	-4.6 (0.1650)
Reversed Phalen's test [s]	3.5 (0.1742)	-4.7 (0.3044)	-1.2 (0.8130)	0.3 (0.5481)	3.8 (0.1648)	4.0 (0.3869)

In parentheses: the statistical significance of treatment effects (*p*-value calculated using Wilcoxon test)

* denotes $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

In examination 2 a significantly lower level of complaints (CTS SSS) was found in the PW group. However, a lack of significant differences between CW and PW groups

was found in terms of changes in the level of complaints (SSS) in all study periods (1-2), (2-3), and (1-3) (Table 3). A comparable change in the results of the CTS FSS scale was found in both groups in all study periods (1-2), (2-3), and (1-3) (Table 3).

Table 3. Comparison of pulsed wave and continuous wave ultrasound treatment effects

Analyzed variables	Wave Type						p
	Pulsed wave			Continuous wave			
	Mean (95% c.i.)	Me	Std. dev.	Mean (95% c.i.)	Me	Std. dev.	
CTS SSS [pts]							
Results in individual examinations							
examination 1	3.05 (2.76; 3.34)	3	0.90	3.31 (3.05; 3.56)	3	0.75	0.2651
examination 2	2.28 (2.03; 2.52)	2	0.75	2.75 (2.44; 3.06)	3	0.91	0.0346*
examination 3	2.43 (2.13; 2.72)	3	0.93	2.44 (2.05; 2.84)	2	1.16	0.9629
Change between examinations							
examination 2 vs 1	-0.78 (-1.08;-0.47)	-1	0.95	-0.56 (-0.82;-0.29)	-1	0.77	0.5728
examination 3 vs 2	0.15 (-0.22; 0.52)	0	1.14	-0.31 (-0.68; 0.07)	0	1.12	0.1083
examination 3 vs 1	-0.63 (-0.96;-0.29)	-1	1.05	-0.86 (-1.23;-0.49)	-1	1.10	0.3703
CTS FSS [pts]							
Results in individual examinations							
examination 1	2.85 (2.51; 3.19)	3	1.08	3.17 (2.81; 3.52)	3	1.06	0.1254
examination 2	2.03 (1.75; 2.30)	2	0.86	2.22 (1.92; 2.53)	2	0.90	0.3379
examination 3	1.88 (1.57; 2.18)	2	0.94	2.25 (1.85; 2.65)	2	1.18	0.2190
Change between examinations							
examination 2 vs 1	-0.83 (-1.12;-0.53)	-1	0.93	-0.94 (-1.30;-0.59)	-1	1.04	0.4783
examination 3 vs 2	-0.15 (-0.48; 0.18)	0	1.03	0.03 (-0.40; 0.46)	0	1.28	0.4467
examination 3 vs 1	-0.98 (-1.39;-0.56)	-1	1.29	-0.92 (-1.41;-0.42)	-1	1.46	0.9217
Muscle strength [kPa]							
Results in individual examinations							
examination 1	26.1 (22.8; 29.4)	25.9	10.3	24.3 (21.5; 27.1)	23.5	8.2	0.5110
examination 2	30.6 (26.9; 34.2)	28.9	11.5	26.6 (23.4; 29.7)	27.3	9.2	0.2038
examination 3	33.8 (29.7; 37.9)	29.7	12.8	27.5 (24.4; 30.5)	26.9	9.1	0.0237*
Change between examinations							
examination 2 vs 1	4.5 (2.6; 6.3)	3.7	5.8	2.3 (0.9; 3.6)	2.2	3.9	0.2392
examination 3 vs 2	3.3 (0.5; 6.1)	1.4	8.6	0.9 (-1.2; 3.1)	0.8	6.4	0.3124
examination 3 vs 1	7.8 (4.9; 10.7)	6.2	9.1	3.2 (1.0; 5.4)	3.2	6.5	0.0374*

p – probability, calculated using Mann–Whitney U test; * stands for $p < 0.05$

In period (1–2), muscle strength increased significantly in both groups (Table 2). In period (2–3), muscle strength further increased in the PW group; consequently, changes in period (1–3) turned out to be significantly greater in this group than in the CW group (Table 3).

For both Phalen's tests, results above 60 were standardized

to this value. If symptoms in this test occur after 60 sec or more, the result is assumed to be normal. A significant decrease in Phalen's test values was recorded in the PW group in periods (1-2) ($p = 0.0040$) and (1-3) ($p = 0.0040$). The results of the reversed Phalen's tests failed to indicate any significant differences between consecutive tests in both groups (Table 2). No differences were observed between groups regarding the Phalen's and reversed Phalen's test results and detected changes.

In the period (1-2), the number of positive tourniquet test results decreased in the PW group; this value did not change significantly in period (2-3). In the CW group, the number of positive results in the period (1-2) did not decrease but did so in period (2-3). In examination 3, the proportion of positive results was similar in both groups (~50%) (Table 4).

In the next stage, the analysis was limited to 57 hands with the positive result of the tourniquet test in examination 1. In examination 2, almost half of the hands in the PW group obtained a favorable change in the tourniquet test result. In contrast, about one in four hands in the CW group were reported to have a favorable outcome (that is negative tourniquet test result). In test 3, the percentage of hands with negative (favorable) test results was similar for both groups (Table 4).

Table 4. Number and percentage of hands with positive test results and vegetative disorders

Functional tests and disorders	Wave Type				p
	Pulsed wave		Continuous wave		
	N	%	N	%	
Tourniquet test					
Positive test results					
examination 1	31	77.5%	26	72.2%	0.5957
examination 2	19	47.5%	26	72.2%	0.0285*
examination 3	22	55.0%	19	52.8%	0.8461
Negative test results (effectiveness of therapy)					
examination 2 vs 1 ^{#)}	15/31	48.4%	7/26	26.9%	0.0973
examination 3 vs 1 ^{#)}	14/31	45.2%	12/26	46.2%	0.9403
Luthy's sign					
Positive test results					
examination 1	26	65.0%	20	55.6%	0.4003
examination 2	12	30.0%	11	30.6%	0.9580
examination 3	6	15.0%	14	38.9%	0.0182*
Negative test results (effectiveness of therapy)					
examination 2 vs 1 ^{#)}	14/26	53.8%	10/20	50.0%	0.7957
examination 3 vs 1 ^{#)}	20/26	76.9%	9/20	45.0%	0.0262*
Vegetative disorders					
Hands with positive test results					
examination 1	15	37.5%	17	47.2%	0.3914
examination 2	8	20.0%	7	19.4%	0.9516
examination 3	7	17.5%	16	44.4%	0.0107*
Negative test results (effectiveness of therapy)					
examination 2 vs 1 ^{#)}	11/15	73.3%	12/17	70.6%	0.8632
examination 3 vs 1 ^{#)}	8/15	60.0%	6/17	35.3%	0.1622

p-value calculated using a chi-square test of independence (* denotes $p < 0.05$)

^{#)} number and percentage of hands with a negative test

result and without vegetative disorders in examination 2/3 out of hands with the positive test result and with vegetative disorders in examination 1

In the period (1-2), a reduction in the number of hands positive for Luthy's sign was reported for both groups. In the period (2-3), this number was further reduced in the PW group (15%); in the CW group, the number of hands positive for Luthy's sign rose to ~40% (Table 4).

Analysis of the impact of wave type on the effectiveness of treatment was limited to the 46 hands positive for Luthy's sign in examination 1. In examination 2, the number of hands with a negative result of Luthy's sign was ~50% of the original number for both groups. In examination 3, the level of improvement was 77% in the PW group and ~45% in the CW group; the difference turned out to be statistically significant ($p=0.0262^*$) (Table 4).

In examination 1, vegetative disorders affected 32 hands in both groups in total. In examination 2, the frequency of vegetative disorders decreased to ~20.0% in both groups. In examination 3, the frequency of vegetative disorders was still low in the PW group (~20%); in the CW group, a regression and a return to baseline were observed (<40%) (Table 4). Analysis of the effectiveness of treatment was limited to 32 hands identified to have vegetative disorders in examination 1. Incidence of improvement in periods (1-2) and (1-3) was compared in the groups studied; however, the differences between the groups were not statistically significant (Table 4).

Statistically significant improvement of sensation in the period (1-2) was found in both groups. In the PW group, the result of the Wilcoxon test was $p=0.0040$, and in the CW group, $p=0.0007$. The changes observed during the period (2-3) were not significant. The differences between the groups regarding sensation level in examinations 1, 2, and 3 were not statistically significant (Table 5).

Table 5. Changes in two-point sensation (number and percentage of hands)

Sensation	Wave Type								P
	Pulsed wave				Continuous wave				
	normal	good	im-paired	pro-protective	normal	good	im-paired	pro-protective	
examination 1	20	10	9	1	12	11	6	7	0.0994
	50.0%	25.0%	22.5%	2.5%	33.3%	30.6%	16.7%	19.4%	
examination 2	30	8	2	0	24	6	2	4	0.3987
	75.0%	20.0%	5.0%	0.0%	66.7%	16.7%	5.6%	11.1%	
examination 3	28	8	2	2	25	7	1	3	0.9382
	70.0%	20.0%	5.0%	5.0%	69.4%	19.4%	2.8%	8.3%	

p-value calculated using the Mann–Whitney U test

DISCUSSION

Ultrasound wave demonstrated positive effect within various tissues has led to its application in medicine. Ultrasound waves improve blood flow and tissue metabolism; it also has an anti-inflammatory effect stimulating nerve conductivity and tissue regeneration [9,30]. Presently, sonotherapy use in clinical practice is limited by our comprehension of the mechanisms in charge of its safe and effective application.

The nature of the ultrasonic wave, its frequency, intensity, duty cycle, and application time determine the overall effects of sonotherapy, as does tissue type and environment [16,31].

Sonotherapy and whirlpool massage are reported to increase flexibility and decrease the tone of soft tissues; therefore, in the present study, they were applied before neuromobilization. The low wave intensity and a restricted amount of applied energy during treatment protected the median nerve from overheating. No side effects were observed in any participant after therapy.

Wilson & Sevier (2003) and Ebenbichler et al. (1998) showed the sound effects of CTS treatment after the application of ultrasounds with an intensity range from 0.1 to 2.0 W/cm² [30,32]. Viera (2003) demonstrated that sonotherapy at ≥ 1 W/cm² could exacerbate CTS symptoms [33]. According to Haar (2007), low-dose ultrasound results in reversible and beneficial effects within tissues, whereas extremely high doses can cause necrosis. This author has also established that ultrasound's biological effects are dependent upon treatment energy (wave intensity x impact time) [22]. According to Huisstede et al. (2010) and Page et al. (2013), the evidence for the influence of wave intensity and frequency on outcomes post-treatment is insufficient [9,18].

To critically evaluate sonotherapy treatment methods in future studies, the ERA and size of the sonicated surface should be considered, as this data allows for the calculation of total treatment energy and energy density [34]. Alexander et al. (2010) concluded that subjecting the shoulder to low-intensity ultrasound does not affect soft tissue pathology. They determined the minimal total energy required to achieve a positive outcome as 2250 J [34]. However, they did not analyze applied energy density, and this parameter is not usually taken into account in clinical trials. It is important to compare total energy emitted during treatment and energy density to evaluate sonotherapy effectiveness. According to the generally adopted sonotherapy method, in one treatment session, the sonicated area should not exceed twice the ERA [23].

In the study included in the Robertson & Baker review (2001), CTS sonotherapy was administered using a transducer with a frequency of 1 MHz; the energy density was 60 and 120 J/cm² [19].

In the present study, energy density was identical in both groups and amounted to 108 J/cm². The applied frequency of 1 MHz provided wave penetration in the area in which CTS was observed, and eliminated the risk of the median nerve overheating (absorption coefficient for neural tissue was three times lower compared with a frequency of 3 MHz) [35].

Yildiz et al. (2011) demonstrated that sonotherapy effects are determined by the use of a drug as a coupling agent [21]. In the present study, sonotherapy treatments were applied in a water bath to provide maximum transmission of ultrasonic waves. The applied surface of the ERA

transducer (5 cm²) aligned with the recommendations of other published studies, i.e., the sonicated area did not exceed twice the surface area of the ERA [19,23,36].

In clinical studies included in the review of the literature by Robertson and Baker (2001), SATA values were within the range of 0.02 to 2.6 W/cm² [19]. Wong et al. (2007) demonstrated the range used by physiotherapists to be 0.02 to 3.3 W/cm² [23]. In the present study, SATA values were 0.12 W/cm² and 0.6 W/cm² for pulsed wave and continuous wave ultrasound, respectively.

In the present study, the therapy protocol provided satisfactory short-term and long-term effects using both pulsed wave and continuous wave ultrasound. For most of the evaluated parameters and symptoms, the observed treatment effects were independent of the ultrasonic wave type.

The BCTQ is a standard tool to evaluate the severity of symptoms in clinical practice and research. It is a reliable, responsive, and acceptable instrument, enabling the assessment of treatment outcomes of treatment from the patient's perspective [25,37,38].

In periods (1-2) and (1-3) in both PW and CW groups, a statistically significant improvement in CTS SSS and FSS scales has been obtained. There were no significant differences between PW and CW groups with regard to changes noted in individual research periods, which indicates that the type of wave had no influence.

Meirelles et al. (2006) observed better results in patients after carpal tunnel release (CTR); the mean result in CTS SSS was (averages 1.41) and FSS (averages 1.59), respectively [27].

Noteworthy, the physiotherapeutic program of the present study was planned for people who cannot or do not want to subject to CTR in fear of various complications or relapse.

In De Kleermaeker et al. (2019) study CTS SSS and CTS FSS for patients before and eight months after CTR, the improvement in CTS SSS was 1.34, and in CTS FSS 0.68 [39]. However, in the present study worse result in CTS SSS was found both in CW (0.87) and PW group (0.62), while better result in CTS FSS; both in CW (0.92) and PW (0.97). It may be concluded that the comprehensive physiotherapeutic program provides the desired improvement of the hand function.

Pulsed wave ultrasound provided a more significant reduction in the incidence of positive tourniquet test results immediately after treatment and improved muscle strength and hand function in a long-term perspective.

In general, the results suggest that a continuous and pulsed wave provided similar treatment effects for most of the subjective symptoms. Still, it should be noted that pulsed wave ultrasound can effectively improve hand function long-term. The results of the present study confirmed the optimum selection of wave intensity and energy density.

Limitation

In the present study, sonotherapy effects could have been

masked by simultaneous application of whirlpool hand massage and median nerve automobilization. Due to ethical considerations, it was an impossible comparison of sonotherapy effects to sham treatment and the elimination of physiotherapeutic methods used parallelly. My study group consisted of professionally active individuals who reported refractory nocturnal ailments and who expected good effects of treatment. According to other authors, such effects can be achieved after the implementation of complex physiotherapy [9,15,30].

The advantages of the present study include the high participation rate in the 1-year follow-up (71.6% of the whole group). Additional strengths of the study are precisely determined sonotherapy parameters and methodology and double-blinding in the study, which allowed to achieve the assumed goal of the study.

CONCLUSION

In summary, sonotherapy combined with whirlpool massage and kinesiotherapy is a risk-free and effective method of conservative treatment of mild and moderate CTS. Continuous wave and pulsed wave ultrasound are both effective in CTS treatment, and treatment results are comparable regarding short- and long-term effects. The effects of sonotherapy are influenced by the energy density transmitted to tissues during treatment. Application of the pulsed wave is more time-consuming but worth consideration in case of muscle weakness and dysfunction.

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