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The Influence of Whole-Body Vibration on Cardiovascular Parameters and Changes in the Perception of an External Stimulus Among Postmenopausal Women

Wpływ zabiegu wibroterapii ogólnoustrojowej na podstawowe parametry kardiologiczne oraz zmiany odczuwania bodźca zewnętrznego u kobiet w wieku pomenopauzalnym

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Key words
whole-body vibration, women, postmenopausal women, blood pressure, sensory threshold, body composition

Abstract
Introduction: Medical science is constantly looking for effective methods to prevent involutional changes. Whole-body vibration training is a promising form of whole-body rehabilitation.
Aim: The aim of the study was to assess the effect of whole-body vibration on basic cardiovascular parameters (heart rate and blood pressure) and changes in the perception of an external stimulus among postmenopausal women with varying body composition.
Material and methods: This was a pilot study and involved 20 women. Before the procedure, body composition analysis was performed using the Tanita analyser. All participants underwent a series of vibration massage treatments lasting 30 minutes. Blood pressure, heart rate and sensory threshold levels were measured before and after the vibrotherapy.
Results: Diastolic blood pressure before vs. after (median; 74.20 vs.71.45 mm Hg; $p=0.047$), and heart rate before vs. after (median; 67.40 vs. 66.00 bpm; $p<0.001$) were analysed. Higher water content positively correlated with a decrease in diastolic blood pressure ($R=0.51$; $p<0.05$). The older the women were, the less the heart rate decreased ($R=-0.45$; $p<0.05$). After vibrotherapy, the sensory threshold values in the non-dominant hand decreased slightly ($p=0.076$). The greater the visceral fat content ($R=-0.48$; $p<0.05$) and body mass ($R=-0.56$; $p<0.05$), the smaller the improvement in threshold.
Conclusions: After whole-body vibration, the values of diastolic blood pressure and heart rate in the examined women were lower than those recorded prior to the procedure. It has been shown that the higher water content in the female body was associated with a greater reduction in diastolic blood pressure. However, the older the women, the less the decrease in heart rate. After the whole-body vibrotherapy, only a slight decrease in the sensory threshold was noted. However, it was found that in the studied women that the greater the content of visceral fat tissue and body mass, the smaller the change in sensory sensitivity.

Słowa kluczowe
wibroterapia ogólnoustrojowa, kobiety, wiek pomanopauzalny, ciśnienie krwi, próg czucia, skład ciała

Streszczenie
Wstęp: W naukach medycznych nieustannie poszukuje się skutecznych metod profilaktyki zmian inwolucyjnych. Obiecującą formą rehabilitacji ogólnoustrojowej jest trening wibracyjny całego ciała.
Cel pracy: Celem pracy była ocena wpływu wibroterapii ogólnoustrojowej na podstawowe parametry kardiologiczne (tętno i ciśnienie krwi) oraz zmiany odczuwania bodźca zewnętrznego u kobiet w wieku pomenopauzalnym charakteryzujących się różnym składem ciała.

The individual division of this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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Materiał i metody: Badania miały charakter pilotażowy. Objęto nimi 20 kobiet. Przed zabiegiem zmierzono skład ciała analizatorem Tanita. U wszystkich badanych wykonano serię zabiegów masażu wibracyjnego trwających 30 minut. Przed i po wibroterapii zmierzono ciśnienie krwi, tętno oraz poziom progu sensorycznego.
Wyniki: Ciśnienie rozkurczowe przed vs po (mediana; 74,20 vs 71,45 mmHg; $p=0,047$), tętno przed vs po (mediana; 67,40 vs 66,00 uderzeń/min; $p<0,001$). Wyższa zawartość wody korelowała dodatnio z obniżeniem ciśnienia rozkurczowego krwi ($R=0,51$; $p<0,05$). Im kobieta była starsza, tym mniej obniżała się wartość tętna ($R=-0,45$; $p<0,05$). Po wibroterapii nieznacznie obniżyła się wartości progu sensorycznego w ręce nie dominującej ($p=0,076$). Im większa była zawartość tkanki tłuszczowej wisceralnej ($R=-0,48$; $p<0,05$) i masa ciała ($R=-0,56$; $p<0,05$), tym mniejsza była poprawa progu.
Wnioski: Po wibracji ogólnoustrojowej uzyskano niższe wartości ciśnienia rozkurczowego krwi oraz tętna u badanych kobiet, niż te odnotowane przed zabiegiem. Wykazano, że wyższa zawartość wody w organizmie kobiet powiązana była z większym stopniem obniżenia ciśnienia rozkurczowego krwi. Jednak, im kobieta była starsza, tym zaobserwowano predyspozycję do niższego obniżenia wartości tętna. Po zabiegu wibroterapii ogólnoustrojowej odnotowano tylko nieznaczne obniżenie wartości poziomu progu sensorycznego. Stwierdzono, jednak, że im większa była zawartość tkanki tłuszczowej wisceralnej i masa ciała badanych kobiet, tym mniejsza była zmiana wrażliwości czuciowej.

INTRODUCTION

Lifestyle and pro-health attitudes manifested in the daily choices made by people have significant impact on the general health and quality of human life. The development of technology and computerisation, promoting and simply forcing a sedentary lifestyle, has infamously contributed to an increase in the number of people suffering from civilisation diseases. A sedentary lifestyle undoubtedly has adverse impact on most systems and functions of the body, contributing to a number of negative changes that disrupt independence in everyday life. Hypokinesia impairs the functioning of the circulatory and respiratory systems, leads to a decrease in muscle strength and endurance (sarcopenia), promotes the development of osteoporosis and degenerative changes, which are usually accompanied by chronic pain, and this also leads to unfavourable consequences related to the human psyche[1].

In many cases, good health depends on modifiable factors, such as the use of a healthy and balanced diet, undertaking moderate physical activity, or avoiding stimulants. The guidelines presented by the World Health Organization (WHO) recommend, among others, healthy people over 65 undertake moderate physical activity at the level of 150 minutes a week, or 75 minutes per week in the case of activities requiring higher energy expenditure[2]. Physical activity is therefore one of the most important preventive factors contributing to the mitigation of involutional changes related to the aging process of the human body.

However, seniors do not always have the ability or willingness to undertake physical activity at the level proposed by the WHO. Effective methods of preventing involutional changes are constantly being sought, which are non-pharmacological and non-invasive, and available to the majority of the population. One such method is whole-body vibration training (WBV)[3,4], which may prove to be an effective method in supporting physical activity, while being a less burdensome form of rehabilitation, its implementation with virtually minimal cooperation on the part of the patient. The involvement of the patient usually includes only lying quietly on a couch equipped with vibration modules and resting, often accompanied by soothing and relaxing music.

Mechanical vibrations are not a new phenomenon, they accompany humans in their everyday functioning. For example, the human body vibrates when on train, cycling or skiing. The possibility of using vibration as a therapeutic tool was first described by the French neurologist Jean Marie Charcot in the 19th century, who hypothesized that the vibration stimulus positively affects the symptoms of Parkinson's patients[5]. In practice, 2 main types of WBV are used: sinusoidal (constant vibration frequency) (sinusoidal whole-body vibration, S – WBV) and stochastic (random vibration frequencies) (stochastic resonance whole body vibration, SR – WBV)[6].

A person subjected to vibration perceives sensory impressions based on the ability of the human body to perceive external stimuli and to evaluate them subjectively. The patient feels mechanical vibrations that stimulate both superficial and deeply located receptors[7]. From the point of view of physiology, feeling is a sensation conditioned by receptor stimulation, e.g. in the skin (touch, vibration, temperature) – superficial (exteroceptive) sensation, or in the musculoskeletal system (joints, ligaments, periosteum) – deep feeling (proprioception). Following the theory of Wall and Melzack[8], the influence of sensory experiences, including vibrations conducted by thick and quickly conducting Aβ fibres, is analysed on the inhibition of the slower conducting Aδ and C pain fibres at the level of the posterior horns of the spinal cord. This is carried out by obtaining the effect of a long-lasting increase in the pain threshold by "omitting" a less expressed impulse on the way to the central nervous system, which reduces the patient's pain sensations.

In connection with the presented facts, it seems that whole body vibration training may be an interesting subject of further scientific research, and its usefulness and effectiveness should be verified with both objective methods and subjective feelings reported by studied groups. Mechanical vibrations on the human body can also have a harmful effect and negative impact on its functioning[9]. Mechanical vibrations are a strong physical stimulus that can affect many tissues and organs, therefore, in occupational medicine, there is a concept of vibration disease that can affect workers exposed to daily vibrating stimuli.

Long-term vibrations of constant high frequencies may lead to the development of so-called vibration syndrome[10]. The impact of vibrations on the human body may cause a resonance phenomenon, inducing excitation of tissues or all organs, and thus, resulting in non-specific systemic disorders. For example, there may be changes at the neuronal level, including modulating the direction of response to a stimulus from hypoalgesia (inhibition) to hyperalgesia (excitation)[7,11]. Symptoms may include: sensory disturbances, weakness, increased reaction time, dizziness or changes in perception[12,13]. The side-effects were also described by Hartman-Petrycka et al.[6], who reported that vibrations from stochastic resonance contributed to the probable occurrence of side-effects, which usually manifested in the evening of the day on which the vibration training took place. These effects were: pain in the spine and knee joints, intensification of pain in a person with degenerative changes in the joints of the spine, nausea and vomiting, as well as symptoms of hyperthyroidism. The above presented authors indicate that information on the given side-effects was collected on the basis of the tested women's statements. These women discontinued therapy after the occurrence of the above-mentioned incidents and were not supported by any other objective measurement method. It was noted that the combination of the circumstances concerning the procedure performed on the vibration platform and the occurrence of certain negative effects could be a coincidence, but an interesting hypothesis was also put forward regarding the thyroid gland, stating that perhaps SR-WBV training increased blood flow through this organ and thus, increased its activity. Bogaerts et al.[14] reported an exacerbation of pain in several patients undergoing vibration treatment. On the other hand, Issurin et al.[15] found that high-frequency vibrations, i.e. 100-170 hertz (Hz), are absorbed by the soft tissues, which leads to an increase in the excitability of the central nervous system, an increase in blood pressure as well as rapid stimulation and increase in muscle tone.

In connection with the information presented above, special attention should be paid to the parameters of the vibrational stimulus used for the procedure, which should continue to be carefully examined and controlled in order to provide patients with optimal and safe treatment conditions. Furthermore, patients should immediately inform researchers about any side-effects of the vibration therapy.

AIM

The aim of the study was to assess the impact of whole-body vibrotherapy on basic cardiological parameters (heart rate and blood pressure) and changes in the perception of an external stimulus among postmenopausal women with varying body composition, including answering the following research questions:

1. How does whole-body vibrotherapy affect diastolic blood pressure and heart rate in postmenopausal women?
2. What is the effect of water content in the body of postmenopausal women on diastolic blood pressure and heart rate?
3. What is the value of the sensory threshold in the tested women under the influence of whole-body vibrotherapy and what are the effects of visceral adipose tissue content and body mass on this parameter?

MATERIAL AND METHODS

The research was a pilot study and involved 20 female students of the Kraków Senior Academy, Andrzej Frycz Modrzewski Krakow University. The mean age of the subjects was 70.55 years, standard deviation ± 4.70, body height 165.30 ± 7.36 cm, body mass 74.97 ± 10.45 kg. The full characteristics of the studied women are presented in Table 1 in the 'Results' section. Before beginning the study, in accordance with the requirements of the 1964 Declaration of Helsinki, the volunteers were informed about the purpose and nature of the research project, and provided their written informed consent to participate in the study.

The criterion for inclusion in the study were: obtained informed consent of the participants and the lack of contraindications to whole-body vibrotherapy. The exclusion criteria were: advanced blood vessel lesions (e.g. aneurysms, thrombosis, atherosclerosis), recent myocardial infarction and strokes and/or implanted cardiac pacemaker. The procedure was not performed after the following events: arthroplasty of the large joints, implantation of various implant types, following reconstruction or other surgical procedures until the surgical wound was fully healed, in people with acute inflammation caused by pathogenic microorganisms (bacteria, viruses, fungi), including inflammatory lesions of the skin. In addition to the whole-body vibrotherapy, contraindications were: abscesses, unregulated arterial hypertension, acute multiple sclerosis, epilepsy, diseases with dizziness, lack of sufficient mental performance, syringomyelia, unhealed fractures until they fully heal and rebuild, damage traumatic tendons, ligaments and muscles until they are fully regenerated, advanced kidney and urinary tract and gallbladder stones, haemorrhages, active neoplastic process, increased body temperature/fever, traumatic skin injuries (wounds) or disruption of its continuity with varying morphology.

Before implementing the vibration massage treatment, the patients rested for 15 minutes, after which each of them had their heart rate and blood pressure measured. Measurements both before and after the vibration massage were made in a sitting position. Subsequently, the threshold of superficial sensation was tested. As a sensory stimulus, an electric current impulse with growing amplitude increased until the sensory threshold (minimal perceptible tingling) was reached. For this purpose, a device for electrotherapeutic procedures (BTL5818SLM) was used. This allows reading of the current intensity to the nearest 0.1 milliampere (mA), TENS stimulation with the parameters of

Table 1

Characteristics of the examined postmenopausal women and parameters of their body composition before the application of vibration

	Mean	Median	*SD*	Min	Max
Age [years]	70.55	69.50	4.70	63	82
Body height [cm]	165.30	165.00	7.36	155	185
Body mass [kg]	74.97	72.85	10.45	62	97
Percentage of body fat in total body mass [%]	34.82	35.90	7.27	15.1	48.3
Body fat mass [kg]	28.01	27.35	7.53	15.0	51.7
Lean body mass [kg]	49.89	47.80	9.34	39.4	73.1
Muscle mass [kg]	47.38	45.40	8.89	37.4	69.5
Total water content [kg]	33.78	30.75	6.51	28.0	50.9
Total body fluid content [%]	44.13	42.45	5.08	37.6	58.9
Bone mass [kg]	2.51	2.40	0.45	2	4
Visceral adipose tissue	11.20	10.00	3.29	8	19
BMI [kg/m^2]	28.06	26.65	3.91	22.3	37.9

SD – standard deviation; Min – minimum; Max – maximum

100 Hz and 100 μs and a biphasic current waveform. The electrodes were placed on the inside of the examined person's forearm. Measurements were carried out on both the dominant and non-dominant upper limbs. The sensory threshold test was also repeated immediately following the procedure.

An additional element of the research was the use of the Tanita Body Composition Analyzer, which made it possible to evaluate such parameters of the body as: body mass, Body Mass Index (BMI), water content in the body of the studied women, their muscle mass and percentage of adipose tissue. These parameters were used to assess the impact of vibration on people with varying body composition. The DC-430 S MA model was used for the study. The body composition was tested before a series of treatments, and the measurements were performed in a standing position.

After the above measurements were made, the patients underwent a 30-minute vibration massage treatment (vibrotherapy) using the RAM Vitberg + apparatus. For the research, the Rehabilitation Massage Apparatus module was implemented, which simultaneously applies general and local vibrotherapy, using active therapeutic modules. This product has been registered as a class IIa medical device, certified according to EN ISO 13485: 2012. RAM Vitberg +, as a therapeutic stimulus, applies non-invasive, mechanical, specialised vibrational-cycloidal vibrations directed in 3 directions, with a small stimulus amplitude (0.01-0.19 mm), low or medium stimulus frequency (10.10-52.20 Hz) and a variable sequence of impulses. A series of 10 vibrational massage treatments was conducted with the use of the Basic module, the [G] Relax program, characterised by a calm, soothing course of vibrations during the entire treatment. The treatments were performed in supine position via the Basic module.

The research was approved by the Bioethics Committee of Andrzej Frycz Modrzewski University in Krakow, No. KBKA/3/O/2020.

Methods of statistical analysis

The test results were accumulated in Excel and then processed in SPSS21. After analysing normality of the distribution using the Shapiro-Wilk test, comparisons of the obtained results before and after the application of vibration were made using the Wilcoxon test.

In order to evaluate the influence of various factors on the effects of vibrations, first changes in the given parameters of the circulatory system and in the sensory threshold were calculated by subtracting the results obtained after the vibration massage from the baseline results. Spearman's rho correlation coefficients were calculated from the thus calculated changes in the parameters of the circulatory system and sensory thresholds, as well as the parameters of body composition for the studied women. The results at the level of $p<0.05$ were considered statistically significant.

RESULTS

The value of diastolic pressure measured after the vibration massage was significantly lower than before its implementation (Table 2) (Figure 1). The pulse value measured post treatment was also significantly lower than the values obtained before the treatment with vibrotherapy. The sensory threshold level did not change statistically, but a slight decrease in its value could be observed, especially in the case of the non-dominant limb ($p=0.076$) (Figure 2).

After calculating the changes in the parameters of the circulatory system and the sensory threshold by subtracting the measurement results obtained following the vibration massage from the measurement results obtained before the vibration, analysis of the correlation of changes in these parameters with the body pa-

rameters was performed (Table 3). The size of changes in diastolic blood pressure was positively correlated with the total water content in the organisms of the studied women. The size of the changes in heart rate was negatively correlated with age. The size of the change in the sensitivity threshold in the dominant hand was negatively correlated with body mass, and negatively with the visceral adipose tissue of the subjects.

DISCUSSION

Vibration (mechanical vibration) is a physical phenomenon based on the propagation of low-frequency sounds oscillating in solid media[4,5]. Vibration massage is a complex form of therapy that consecutively affects many structures of the human body. The vibration stimulus may be a therapeutic factor, which depends on the selected parameters, including low-amplitude and frequency vibrations, particularly recommended in the literature[4-7]. Mechanical vibrations may affect the human body through direct contact with a vibrating platform or modules. Treatments can be performed in a standing position, such as during vibration on the SR-WBV, or in a lying position using, for example, the RAM Vitberg + device. The effects of the vibration primarily include an increase in neuromuscular excitability and thus, stimulation of the muscle spindles which contributes to an increase in their activity, activation of alpha motor neurons and feedback changes in muscle tension (contraction). The-above allows to indicate the possibility of using mechanical vibrations to improve neuromuscular control, the effect of which may be used in the prevention of sarcopenia[16-19].

Brumagne et al.[20] demonstrated positive effects of vibration on improvement in function and sensitivity of proprioreceptors, in the control of the tension regarding muscles stabilising the spine, and the efficiency of spinal reflexes as well as body stability[21]. Collins et al.[22], on the other hand, indicated the positive influence of vibration therapy on the reception of stimuli via mechanoreceptors located on the skin (surface) by increasing their sensitivity, as well as to the receptors of deep sensation, which are sensitive to vibration stimulation[7,12]. Receptors highly sensitive to mechanical vibrations also include Vater-Pacini lamellar bodies and the annular-spiral ends of muscle spindles[7,19]. Torvinen et al.[23] reported an increase in muscle strength and improvement in motor function as well as balance after using SR-WBV in people over 60 years of age. Rogan et al.[24] performed a meta-analysis of current scientific reports covering all types of WBV to determine their impact on balance, especially in seniors. The results of the literature review led to the conclusion that WBV can

Table 2

Pulse, blood pressure and sensory threshold values in postmenopausal women

	Moment of measurement	Mean	Median	*SD*	Min	Max	Z	*p*
Systolic pressure [mmHg]	Before	132.08	132.00	10.58	116	152	-0.90	0.370
	After	130.56	131.35	12.11	105	150		
Diastolic pressure [mmHg]	Before	74.72	74.20	8.00	62	89	-1.99	0.047
	After	72.33	71.45	8.00	62	88		
Heartbeat [beats/min]	Before	71.08	67.40	7.64	61	87	-3.57	<0.001
	After	67.58	66.00	6.73	60	80		
Sensory threshold, forearm, dominant side [mA]	Before	20.67	20.28	9.28	10.3	55.4	-1.62	0.104
	After	19.31	16.20	9.94	9	57		
Sensory threshold, forearm, non-dominant side [mA]	Before	19.56	17.25	9.43	11	55	-1.78	0.076
		18.81	16.00	10.06	9.4	54.4		

Before – measurement before applying vibration; After – measurement after the application of vibration; *SD* – standard deviation; Min – minimum; Max – maximum; Z – value of the Wilcoxon test statistic; p – level of statistical significance

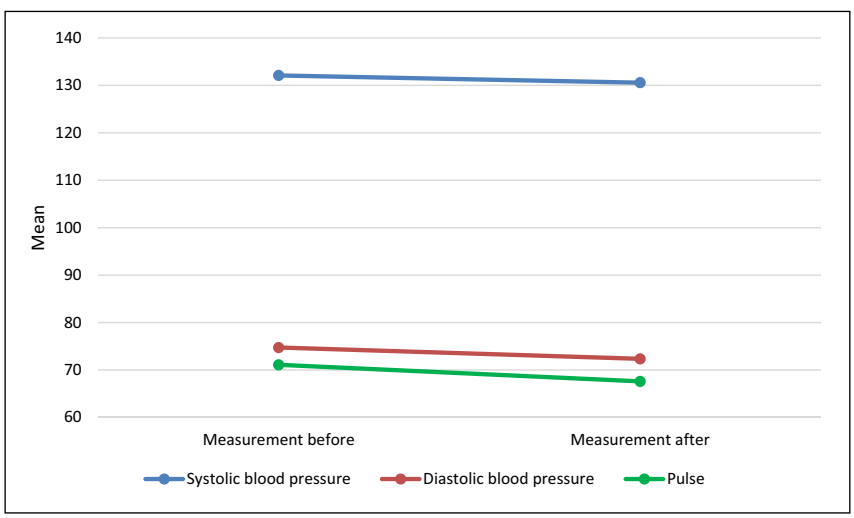

Figure 1

Pressure [beats/min] and systolic as well as diastolic blood pressure [mmHg] before and after applying whole-body vibration

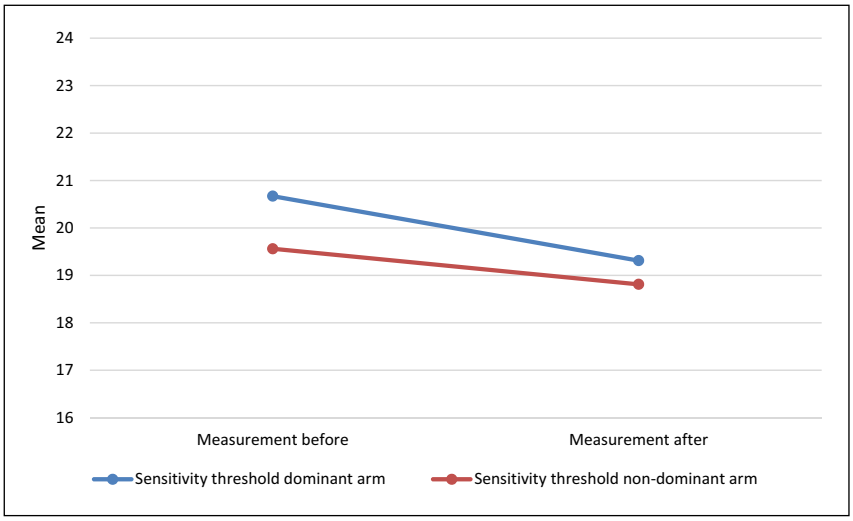

Figure 2

Sensory threshold values [mA] measured on the forearm of the dominant and non-dominant arms before and after applying whole-body vibration

be used to improve static balance in older individuals, and may positively affect dynamic balance in these people. Zhang et al.[25] studied the effects of WBV on motor function, balance and general health in elderly and weakened people. The examined persons underwent procedures with the use of vibrations 3-5 times a week, at a frequency of 6-26 Hz and an amplitude of 1-3 mm. After the series of treatments, improvement in postural stability, in overall health and an increase in the strength of the knee extensors were noted. No side-effects were observed during training and it was concluded that vibration exercises are a safe and effective method to improve the health of older people. Szumski[11] presented a study in which he stated that SR-WBV vibration training may be an alternative to exercises that stimulate proprioreceptors and prevent falls resulting from postural instability. In addition, he showed that vibrations can significantly affect the human musculoskeletal system and emphasized the possibility of using stochastic vibrations in stimulating selected motor skills, including muscle strength, as an alternative to dynamic effort.[11]

During exposure of the body to mechanical vibrations, kinetic energy is converted into thermal energy by activating the frictional forces, thus, an increase in the temperature of the tissues can be noted[26]. Therefore, vibration massage acting on the human body contributes to the expansion of blood vessels and improvement of their elasticity, and as a result, proper oxygenation and nourishment of tissues, improvement of blood flow in microcirculation and increased basic metabolism[27]. Moreover, during the procedures, collagen fibres of the skin and fascia are tightened, and the bone trabeculae are micro-stressed. The latter phenomena help in the prevention of osteoporosis by increasing the mineral density of bone tissue[17,28,29]. Lauper et al.[30], Borello-France et al.[31] and Luginbuehl et al.[32] showed the positive effects of vibration massage in the treatment of urinary incontinence through an observed increase in the tone of the fundus muscles. In research on vibration, the lipolytic effect of vibration and a reduction in the amount of subcutaneous fat and lymph redistribution were also observed[33].

Table 3

Analyses of the correlation between body parameters and the size of changes (before-after) in the parameters of the circulatory system and the threshold of sensation

	Change in systolic blood pressure	Change in diastolic blood pressure	Heart rate change	Change in sensory threshold, dominant side of the forearm	Change of the sensory threshold, non-dominant side of the forearm
Age [years]	-0.17	-0.18	-0.45*	0.21	0.11
Body height [cm]	0.36	0.26	-0.24	-0.43	-0.26
Body mass [kg]	0.28	0.11	-0.12	-0.56*	-0.29
Percentage of body fat in total body mass [%]	-0.21	-0.23	0.29	0.03	0.20
Body fat mass [kg]	0.11	-0.07	-0.13	-0.28	-0.26
Lean body mass [kg]	0.44	0.15	-0.38	-0.40	-0.29
Muscle mass [kg]	0.44	0.15	-0.38	-0.40	-0.29
Total water content [kg]	0.38	0.33	-0.38	-0.40	-0.42
Total body fluid content [%]	0.19	0.51*	-0.39	0.10	-0.02
Bone mass [kg]	0.44	0.15	-0.36	-0.38	-0.34
Visceral adipose tissue	0.13	0.17	-0.35	-0.48*	-0.37
BMI [kg/m^2]	0.12	0.02	-0.23	-0.41	-0.27

*$p<0.05$

Mechanical vibrations used during the whole-body vibration treatment seem to be a safe way of influencing the human body. What is more, they do not burden the circulatory system. In the research presented in the current study, it was indicated that the value of diastolic pressure, measured after the performed vibration massage, was significantly lower than prior to the treatment. The size of changes in diastolic blood pressure was positively correlated with the total water content in the bodies of the studied women, which means that the more water was accumulated in the woman's body, the more her diastolic blood pressure decreased after the vibration massage was applied. The heart rate value measured after vibration was also significantly lower than the value obtained before the intervention. The size of the heart rate change was negatively correlated with age, which means that the older the tested person was, the less the heart rate decreased after the vibration treatment. It is known that along with age, the ability of the body to adapt decreases, and that is a possible reason for the lower heart rate decrease in the elderly subjects. However, this is an indication that future research focused on optimising the parameters of vibration massage should take into account the age of people undergoing such treatments in the methodology. In the research by Kerschan-Schindl et al.[34], there were no significant changes in heart rate or blood pressure. Nonetheless, an increase in blood flow in the popliteal artery was noted. Vibration training was found to have a relaxing effect on the cardiovascular system, either through the action of the parasympathetic system or peripheral pressure receptors and muscle congestion. Vibration massage can also be used in the treatment of peripheral circulatory disorders, including the treatment of oedema, further contributing to normalisation regarding the work of the entire circulatory system[13].

Under the influence of vibrations, blood vessels expand, blood circulation and oxygen uptake increase. It has been shown that, for example, a 3-minute application of vibrations at a frequency of 26 Hz and a vibration amplitude of 6 mm increases oxygen uptake by an average of 4.5 ml/kg/min[34]. The use of vibrotherapy in cardiac rehabilitation provides satisfactory and positive results and can complement not always well-tolerated resistance training[13].

Feeling is a sensory impression based on subjective assessment of a stimulus acting on the human body, and therefore, it is individually differentiated. Sensory threshold, on the other hand, is always the first human-recognised effect of, e.g. electric currents during electrotherapeutic treatments. In the authors' own research, it was found that the sensory threshold did not change statistically significantly after the whole-body vibration massage treatment. However, a slight decrease in the level of the sensory threshold could be observed, i.e. an increase in sensory sensitivity to an electrical stimulus, especially on the non-dominant side of the body ($p=0.076$). Perhaps after increasing the size of the group, the observed tendency to increase the sensory sensitivity would reach statistical significance. Following the theory of the "pain gate"[8], it can be assumed that the stimulus affecting Aβ sensory fibres would also lead to an increase in the threshold of pain sensation by "blocking" the transmission of pain impulses with free Aδ and C fibres at the spinal cord level. For ethical reasons, in this study, changes in sensitivity to pain stimuli were not examined, but it can be assumed that the sensitivity to pain in the examined persons became lower, the excitability of pain receptors could have reduced, i.e. as a consequence, the pain threshold increased while the degree of its perception decreased[7].

It is believed that a special role in relieving pain during the application of vibration massage is played by vibrations at a frequency of approximately 40 Hz, which are transmitted through the Meissner body, or at a frequency of about 100 Hz transmitted by the Vater-Pacini body[7],[19]. Referring to the available literature data, it is believed that the positive effects of vibration on pain relief have repeatedly been observed in various trials, e.g. reduction of chronic pain in the spine[20]. Beinert et al.[35], using vibration massage of the neck muscles, noted both analgesic effects and improvement of sensorimotor function. Yang et al.[36] found that whole-body vibration can be used and is recommended in patients with chronic low back pain, as the results of studies have showed significant differences in pain relief between the study and control groups. Similarly, Chochowska et al.[37] found that after a series of 10 classic and 10 vibration massages, there was a statistically significant in the level of pain among patients with chronic lumbosacral spine pain. Elfering et al.[38] demonstrated a positive effect of whole-body vibration using stochastic resonance in reducing musculoskeletal pain in young people.

The sensations that accompany a person during his/her life, especially superficial (sensory) sensations and those defined as pain, are associated with various factors that may affect their interpretation, modification and degree of feeling. Perception is the result of experiences arising on the basis of mental interpretation of the phenomena that occur, which may be modified, e.g. by previous experiences and the psychosomatic conditions of a person. The level of receiving electrical stimuli from the environment may depend on many factors, including, for instance, the level of skin hydration, its moisture, the degree of warming or cooling, but also genetic, sociological and cultural conditions, those related to age or race, and finally, to the activity of endogenous opioids, or even current mental state of the patient. In the authors' own research, they checked the level of changes in the sensory threshold compared with the basic parameters of body composition. It was noticed that in the case of the dominant hand, the level of sensory threshold was negatively correlated with body mass and the content of visceral adipose tissue, which means that the greater the content of visceral fat and body mass in the studied women, the smaller the observed improvement in sensory sensitivity. Such a result may indicate that

women with higher body fat content may experience less pain-relieving effects of vibration.

It is also known that a high level of visceral adipose tissue leads to many negative health consequences, such as insulin resistance, metabolic syndrome, diabetes, microneuropathies, and hindered regeneration processes. Therefore, it can be hypothesised that obesity and metabolic problems affect the level of perceived external stimuli, including that electrical, commonly used in primary care during physiotherapeutic procedures. Thus, it is more difficult for obese people to obtain the same good results of pain inhibition through ascending analgesic mechanisms as in slim people and this probably also applies to the vibration massage treatment. Studies by Donocik et al.[39] have shown that the better effects of stochastic vibration treatments, applied twice a week for 15 minutes, during 6 weeks were influenced by lower BMI and higher height of the participants. For these people, greater improvement was noted in balance, reducing the risk of falls. Overall, this type of vibration was shown to be more effective in younger, taller and thinner women.

The above-data from the literature show that the procedures with the use of vibrations, after taking all contraindications to their use into account, which may turn out to be a useful and convenient form of prohealth prophylaxis. The effects of vibrations can certainly be positive and noticeable for the patient, however, appropriate stimulation parameters should be selected, with a specific number of treatments and frequency of the vibrations used. This therapy may be particularly useful and interesting for elderly people who, due to their age and accompanying involutional changes, do not always want or may take advantage of targeted physical activity, such as gymnastics or fitness classes for seniors.

The presented research has some limitations. Certainly, the small group of women was a disadvantage of the study. Moreover, women at various stages of older age (pre-old age, early old age and late old age) and with different body composition parameters participated in the trial. However, taking into account the obtained positive changes in the circulatory system and certain tendencies to increase the sensitivity to sensory stimuli, the obtained results of our own research indicate that further detailed studies in this subject area, involving a larger group of women would be justified.

CONCLUSIONS

The results of the research carried out authorise the formulation of the following conclusions:

1. Whole-body vibrotherapy in postmenopausal women has a positive effect on diastolic blood pressure and heart rate by lowering them.
2. After the use of whole-body vibrotherapy in postmenopausal women, it has been shown that the water content in their bodies had significant impact on the values of diastolic blood pressure and heart rate - the higher the water content among the studied women, the greater the reduction in diastolic blood pressure, and in older women – the more the heart rate decreases.
3. The use of whole-body vibrotherapy among the women included in the study caused a slight decrease in the value of the sensory threshold, and the change in sensory sensitivity was related to the content of their visceral adipose tissue and body mass.

Conflict of interest
The authors declare no conflicts of interest.

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