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The Impact of Oscillatory Vibrations on Lymphoedema of the Lower Limbs

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Abstract

Introduction: *According to WHO studies, over 300 million people worldwide suffer from oedema [1]. It is estimated that in Poland the number of patients with lymphoedema is about 300,000 [2]. In the majority of the cases the lymphoedema turns into chronic incurable disease which requires constant control and treatment. In the case of lower limbs, the oedema is often associated with other chronic diseases, e.g. diabetes, severe obesity or chronic venous insufficiency. In such cases, it is very important for the patient to understand the cause of the oedema, the irreversibility of the changes, and the fact that the therapy will be necessary for the rest of their life. Unfortunately, the lack of proper and comprehensive treatment results not only from insufficient awareness and patient's knowledge, but also from the limited possibilities of public health care.*

Objectives: *The aim of the study was to determine the impact of oscillatory-cycloid vibrations (OCV) on the 1st and 2nd degree oedema of the lower limbs.*

Material and methods: *The study involved 47 patients who developed first- and second-degree oedema. Patients underwent 10 oscillatory-cycloid vibrations treatments for 5 consecutive days. Their G1 and G2 circumferences were measured before and after therapy and filled in a questionnaire.*

Results: *Measurements of lower limb circumferences at the ankle and calf have decreased: average circumference of the left ankle from 27.04 cm to 25.3 cm and average circumference of the right ankle from 26.81 cm to 25.36 cm, while the average circumference of the left calf from 41.36 cm to 39.15 cm and average right calf circumference from 40.89 cm to 39.11. 78.7% of patients experienced a reduction in oedema, 42.6% noticed smaller cramps in their limbs, and 38.3% of patients declared feeling lighter in their legs.*

Conclusions: *1. Oscillating-cycloid vibration treatment can be an effective method of reducing the first- and second-degree oedema. 2. Vibration therapy*

can be used as a method supporting the treatment of oedema in patients with peripheral circulatory insufficiency or can be used as secondary prevention to maintain the effects after the phase of maximum oedema reduction. 3. The subjective feelings of patients confirm the effectiveness of the performed procedures.

Key words: *lymphoedema, venous insufficiency of the lower limbs, oscillatory--cycloid vibrations.*

Introduction

Although there is no definite definition of lymphoedema that would be consistent with international consensus, based on existing literature, oedema can be defined as pathological, excessive fluid accumulation in lymphatic vessels and in the extracellular space [1,2]. The problem with congestive lymphatic insufficiency and hence lymphoedema is rarely the result of congenital vascular malformations that usually manifest themselves from early childhood [3].

Most often, oedema occurs due to [4,5]:

1. neoplastic diseases involving lymph nodes and radiation therapy,
2. chronic venous insufficiency (30% of cases of oedema are due to deep vein thrombosis),
3. surgical procedures and injuries,
4. viral, bacterial and parasitic infections.

Chronic venous disease is one of the most common vascular diseases. Among the European population, 40-60% of women and 15-30% of men suffer from this disease, while in the Polish population 47% of women and 37% of men showed signs of venous disease. Incidence increases significantly with age [6,7].

The main cause of venous insufficiency is the reduction of venous wall tone and impairment of venous valve function in both deep and superficial vessels.

It causes:

1. development of venous hypertension, which is responsible for the development of pathological changes in the veins and tissues around the vessel,
2. slower venous outflow from the lower limbs,
3. the formation of reflux in the superficial and deep veins, which is further intensified by standing position, warmth, obesity and pregnancy,
4. development of varicose veins and venous ulceration.

Congestive processes in microcirculation and venous hypertension lead to adhesion, migration and activation of leukocytes, which, as a result, damages microcirculation, resulting in excessive capillary permeability. This, in turn, causes swelling of the limbs and impaired tissue nutrition (trophic changes appear in the form of discolouration, inflammation of the subcutaneous tissue and ulceration) [7]. All this consequently leads to functional failure of lymphatic vessels and affects the degeneration of the walls of lymphatic vessels and the overgrowth of their light with protein-cellular material [8].

It is estimated that venous insufficiency is the cause of lymphoedema in about 300 million people worldwide [9].

To diagnose the cause of oedema, a thorough interview, clinical examination along with limb volume measurement and in some cases imaging tests (lymphoscintigraphy, Doppler ultrasound of the venous system) are important [10]. To correctly determine the degree of lymphoedema of the lower limbs, Brunner's classification can be used [11,12]:

1. 1st degree – a slight swelling that covers the foot and lower leg, most often visible at the end of the day and disappearing automatically after the elevation of the limb;
2. 2nd degree – swelling occurs throughout the day and disappears after a night. Stemmer's symptom appears, i.e. thickening of the subcutaneous tissue and skin, which prevents the pinching of the skin fold above the second toe;
3. 3rd degree – permanent oedema, but without deformity of the limb;
4. 4th degree – permanent oedema causing deformities of the limb, skin lesions may appear in the form of: eczema, erysipelas, lymphatic fistulas;
5. 5th degree – called "elephantiasis", is characterised by large swelling, which significantly distorts the lower limb. It is accompanied by thickening of the skin, muscle changes and impaired limb function.

Current medical knowledge and scientific research confirm that the key role in the treatment of lymphoedema is physiotherapy, which should start with the patient's education. Unfortunately, most patients or people at risk of lymphoedema do not have sufficient awareness and knowledge about the disease itself and the risks of not receiving treatment. For this reason, particular attention should be paid to introducing patients with oedema to lymphatic educational and preventive measures to the rehabilitation program. Early treatment prevents the appearance of complications and allows complete reduction of oedema.

One of the basic forms of prevention in cardiovascular failure should be physical activity. Analysing statistical data, it can be said that physical activity after the age of 40 is inversely proportional to the frequency of incidence. Cardiovascular insufficiency increases with age, while physical activity decreases at higher age ranges [13]. Reduced physical activity in the elderly may be due to many factors, including co-morbidities characterised by high intensity of pain, which can effectively discourage motor activities. Lack of movement, in turn, intensifies the congestive processes of the lymph and venous systems.

Given the effect of vibration on the circulatory and lymphatic systems in the form of:

- elimination of congestive symptoms,
- reduction of oedema,
- better venous outflow,
- lower blood resistance in the arteries, which facilitates the work of the heart,
- widening of blood vessels and an increase in the speed of blood circulation,
- increased oxygen and nutrient supply to organs,

it can be assumed that oscillatory-cycloid vibrations (OCV) may complement the daily motor activity of patients and may support preventive actions in the field of reducing lymphoedema in people with congestive heart insufficiency.

The aim of this study was to determine whether and to what extent oscillatory-cycloid vibrations (OCV) will affect the reduction of lower limb circumferences in patients with oedema and whether it can be a method used to support primary and secondary oedema prevention in chronic peripheral circulatory insufficiency in the lower limbs.

Material and methods

47 people took part in the study, the vast majority of whom were women (89.4%).

Among the surveyed population, the decisive number of respondents was in the age range of 61-80 years (80.9%). Other age groups were respectively: 18-40 years – 2.1%, 41-60 years – 12.8% and over 80 years – 4.3%.

Prior to the study patients were interviewed to be included or excluded. During the interview, patients were asked about cardiovascular diseases and co-morbidities, as well as co-morbidities, as noted in the survey.

Based on the interview, the study group excluded:

1. patients during treatment and after a history of cancer,
2. people whose oedema was the result of surgery or mechanical injury and the tissues did not fully heal,
3. people who are diagnosed with the acute phase inflammation.

The study included people who had a history of oedema and ailments related to lower limb circulatory system insufficiency. The most common problems that patients declared were: oedema (100%), varicose veins (74.5%), telangiectasias (74.5%), hypertension (55.3%) and cramps (55.3%). Oedema reported by patients was classified as first and second-degree oedema.

Co-morbidities that may affect cardiovascular insufficiency of the lower limbs were diagnosed in the following percentage of respondents: obesity – 25.5%; diabetes – 23.4%.

Patients participating in the study had measurements of lower limb circumferences at levels:

1. G1 – 1st shin, circumference of the lower leg in the thickest place (the results are described as calf measurement)
2. G2 – 2nd shin, measurement just above the ankle (measurement of the ankle joint, but for simplicity the results are described as ankle measurement).

Measurements were made on the first day before starting the therapy and on the last day of therapy after the end of the treatment.

Each patient underwent 10 oscillatory-cycloid vibration treatments on a Vitberg + medical apparatus with an attached specialised module for lower limb massage, which was carried out over the next 5 days. Each treatment lasted 29 minutes and 10 seconds and 2 treatments were performed without a break between them on one day. The operation characteristics of the apparatus in terms of frequency, amplitude and acceleration are presented in Table 1.

The vibration treatment was performed with A program, the characteristics of which are presented in Figure 1 in A1 in accordance with the instructions for use (Figure 2).

Table 1. Parameters of the oscillating-cycloid vibrations

Massage Intensity	Acceleration		Amplitude		Frequency	
	Min [m/s2]	Max [m/s2]	Min [mm]	Max [mm]	Min [Hz]	Max [Hz]
1	0.01	6.9	0.01	0.21	10.1	42.5
2	0.1	10.5	0.01	0.21	10.3	43.6
3	0.1	11.5	0.01	0.21	11.6	47.5
4	0.1	13.5	0.01	0.19	19.3	52.2

Source: Rehabilitacyjny Aparat Masujący Vitberg+. Instrukcja użytkowania. Nowy Sącz: Vitberg; 2016.

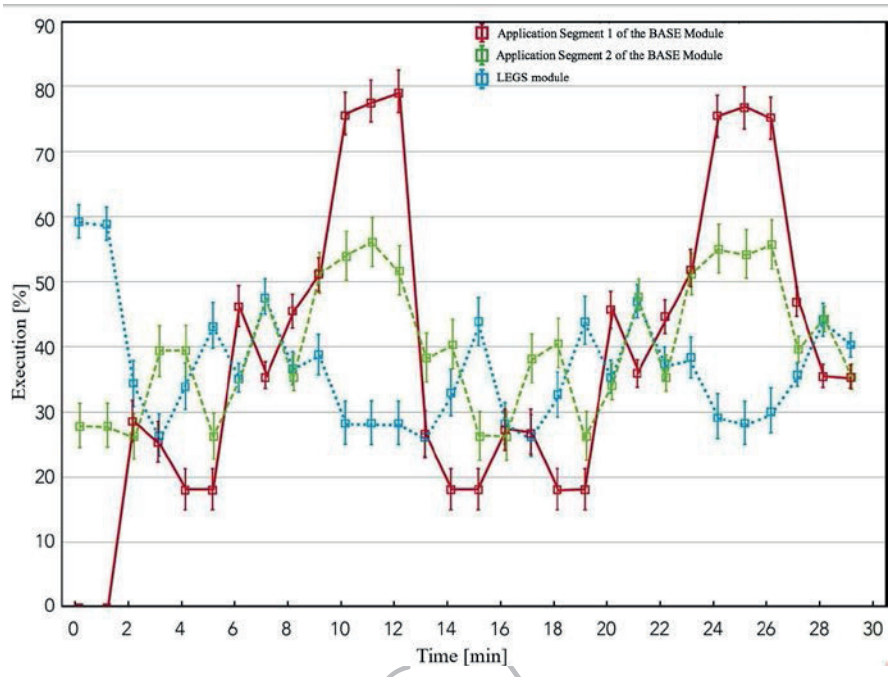

Figure 1. Characteristics of the program A (LEGS) in the Vitberg + apparatus in position A1 [14]

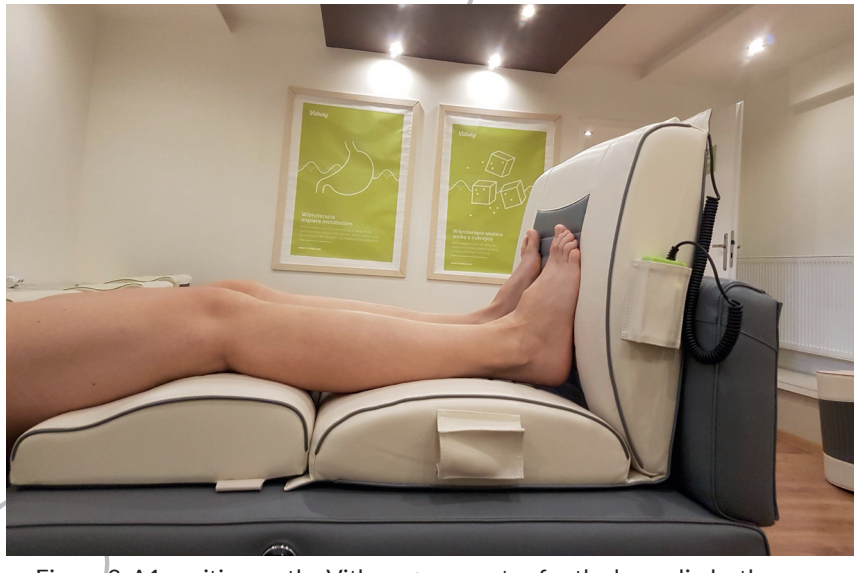

Figure 2. A1 position on the Vitberg + apparatus for the lower limbs therapy

Source: own.

Results

After analysis of the measurement of lower limb circumferences before and after the vibration treatment, it was found that the circumferences are reduced in all four measurements: G1 and G2 left limb and G1 and G2 right limb. The results are presented for each measurement in Tables 2 and 3 separately.

Table 2. Measures of median tendency and dispersion along with the values of t-Student test for dependent samples: circumference of the left calf and ankle – before and after the treatments (N=47)

	Left calf – before treatment	Left calf – after treatment	Left ankle – before treatment	Left ankle – after treatment
Average	41.36	39.15	27.04	25.30
Median	41.00	39.00	27.00	25.00
Standard deviation	3.46	3.09	3.03	2.50
Minimum	36.00	35.00	21.00	21.00
Maximum	52.00	49.00	35.00	30.00
Slant	.798	.833	.271	-.085
Kurtosis	.663	.726	-.273	-.956
t-Student test	t=9.906; p<0.001		t=10.392; p<0.001	

Table 3. Measures of median tendency and dispersion along with the values of t-Student test for dependent samples: circumference of the right calf and ankle – before and after the treatments (N=47)

	Right calf – before treatment	Right calf – after treatment	Right ankle – before treatment	Right ankle – after treatment
Average	40.89	39.11	26.81	25.36
Median	41.00	39.00	27.00	26.00
Standard deviation	3.39	3.18	2.72	2.44
Minimum	35.00	34.00	22.00	21.00
Maximum	52.00	50.00	34.00	30.00
Slant	.669	.807	.305	-.189
Kurtosis	1.081	1.522	-.357	-1.033
t-Student test	t=8.577; p<0.001		t=7.539; p<0.001	

Analysis of the G1 measurement of the left lower limb (Figure 3):

1. Before the treatments, the average circumference of the patients' left calf was 41.36 cm with a standard deviation of 3.46 cm, with the lowest recorded measurement being 36 cm and the highest 52 cm. The median value is 41 cm. The distribution of measurements obtained was rightwards skewed and had a greater concentration around the middle value than the normal distribution.
2. After the procedures, the average circumference of the left calf of the subjects was 39.15 cm, the standard deviation was 3.09 cm. The minimum value of the circumference was 35 cm, while the maximum was 49 cm, and the median obtained was 39 cm. The distribution of recorded measurements was rightward skewed and had a greater concentration around the central value than the normal distribution.

Analysis of the G2 measurement of the left lower limb (Figure 4):

1. Before the treatments, the average circumference of the patients' ankle was 27.04 cm with a standard deviation of 3.03 cm, with the lowest recorded measurement being 21 cm and the highest 35 cm.

The middle value is 27 cm. The distribution of measurements obtained was rightward skewed and had a lower concentration around the median value than the normal distribution.

2. The average circumference of the left ankle of the subjects after treatment was 25.3 cm, the standard deviation is 2.5 cm, with a minimum value of 21 cm and a maximum of 30 cm. The median was 25.5 cm. The distribution of measurements obtained was leftward skewed and had a lower concentration around the median value than the normal distribution.

Analysis of the G1 measurement of the right lower limb (Figure 5):

1. Before the treatments, the average circumference of the patients' right calf was 40.89 cm with a standard deviation of 3.39 cm, and the median value was 41 cm. The lowest recorded measurement is 35 cm, while the highest was 52 cm. The distribution of measurements obtained was rightward skewed and had a greater concentration around the median value than the normal distribution.
2. The average circumference of the right ankle of the subjects after treatment was 39.11 cm, the standard deviation is 3.18 cm, with a minimum value of 34 cm and a maximum of 50 cm. The median was 39 cm. The distribution of measurements obtained was rightward skewed and had a higher concentration around the median value than the normal distribution.

Analysis of the G2 measurement of the right lower limb (Figure 6):

1. Before the treatments, the average circumference of the patients' right ankle was 26.81 cm with a standard deviation of 2.72 cm, with the lowest recorded measurement being 22 cm and the highest 34 cm. The median value was 27 cm. The distribution of measurements obtained was rightward skewed and had a lower concentration around the median value than the normal distribution.
2. The average circumference of the right ankle of the subjects after treatment was 25.36 cm, the standard deviation is 2.44 cm, with a minimum value of 21 cm and a maximum of 26 cm. The minimum value is 21 cm, while the maximum is 30 cm. The distri-

bution of measurements obtained was leftward skewed and had a lower concentration around the middle value than the normal distribution.

Analysis by t-Student test for dependent samples showed a significant difference in the case of G1 and G2 measurements for the left and right lower limbs made before and after the treatments.

Based on all 4 measurements, it was noticed that the performed treatments were highly effective in reducing lower limb oedema.

The subjective feelings of patients were also analysed, and it was noticed that the majority of respondents after the treatments noticed a reduction of oedema (78.7%). A relatively high percentage of respondents also felt smaller cramps (42.6%) and had a feeling of lighter lower limbs (38.3%). In turn, 36.2% of respondents noticed warmer feet. The respondents noticed better feeling in the limbs (17%) the least frequently.

To illustrate the results, a photo of the left limb of one of the patients was taken before and after the procedures, as illustrated in Figure 7.

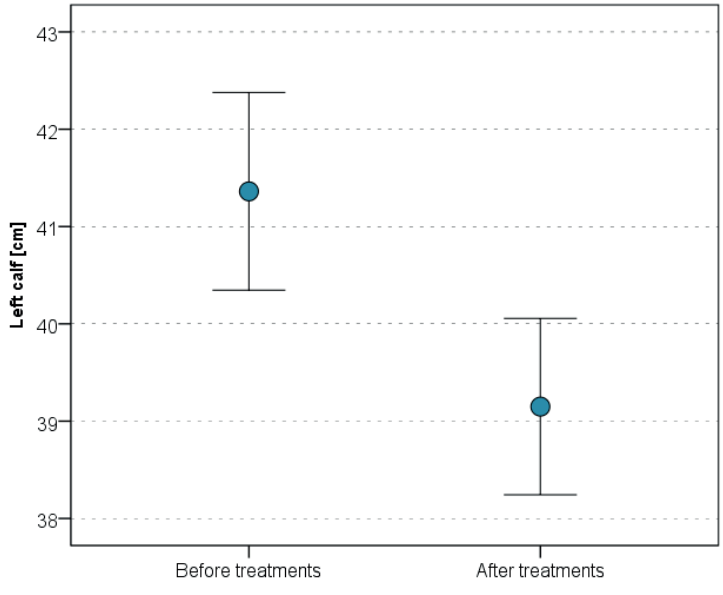

Figure 3. Average with 95% confidence interval: left calf circumference – before and after treatments (N=47)

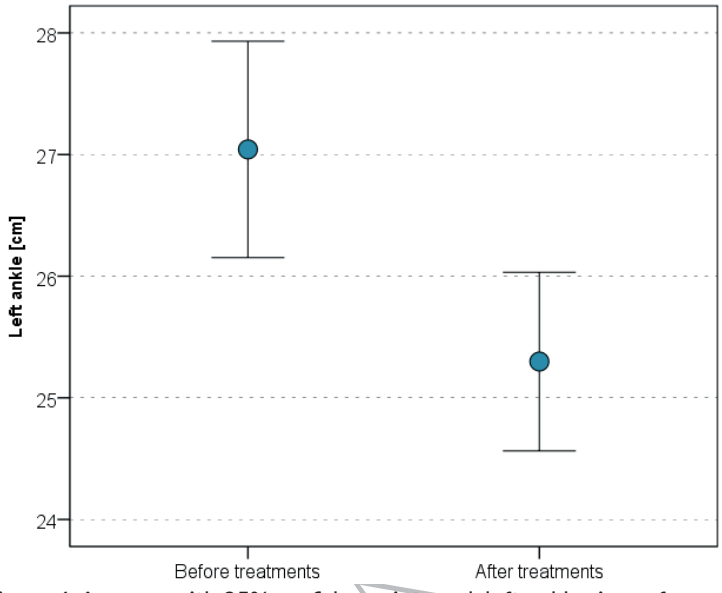

Figure 4. Average with 95% confidence interval: left ankle circumference – before and after treatments (N=47)

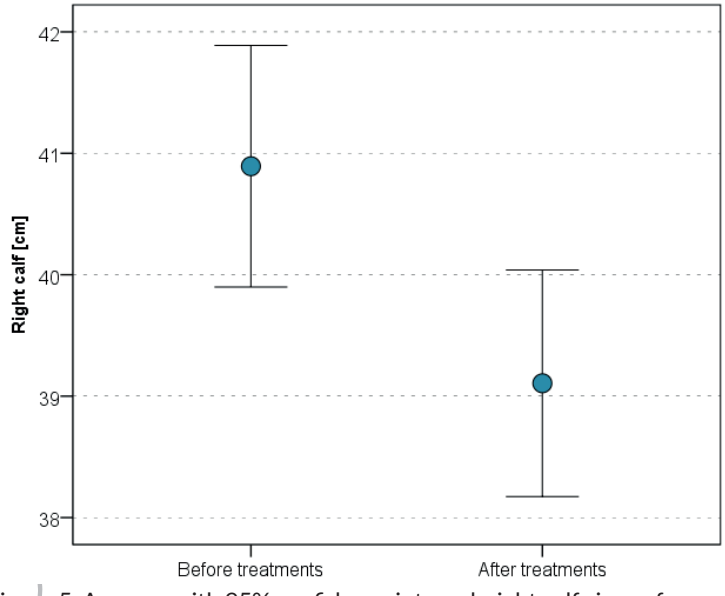

Figure 5. Average with 95% confidence interval: right calf circumference – before and after treatments (N=47)

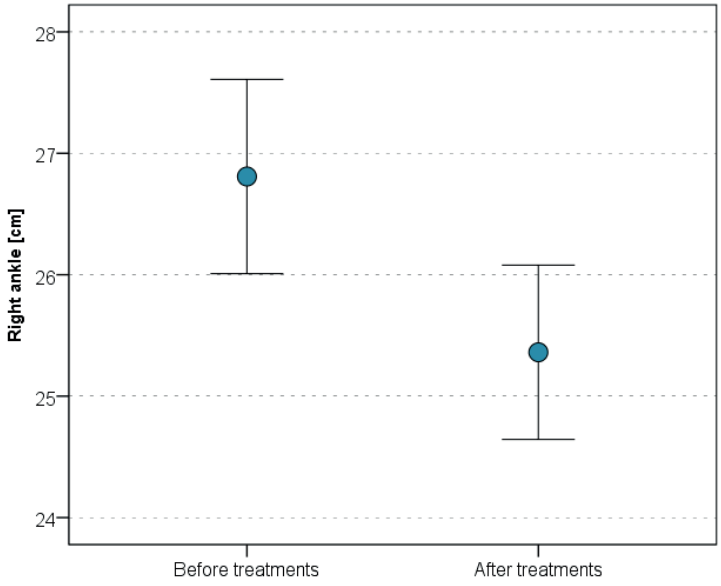

Figure 6. Average with 95% confidence interval: right ankle circumference – before and after treatments (N=47)

Figure 7. Photo of the patient's left lower limb: a – before the vibration treatment, b – after the 10 vibration treatments

Source: own.

Discussion

In the literature there are numerous studies on the effects of vibrations on the cardiovascular system in both healthy people and the elderly who have been diagnosed with cardiovascular insufficiency. The effect of vibrations on the cardiovascular system may have an indirect effect on the lymphatic system, as improving blood flow in the arteries and veins may reduce peripheral circulatory insufficiency and congestive processes, which in turn may reduce the risk of oedema.

Kerschan-Schindl et al. examined 20 healthy adults to assess changes in blood volume in muscles after applying vibrations to the entire muscle. After applying the vibrations, the following effects were achieved: an increase in blood circulation in the calf and thigh muscles, an increase in the average blood flow velocity in the popliteal artery from 6.5 to 13.0 cm/s and its lower resistance index [14].

In turn, Pośpiech et al. in the work "The impact of low-frequency vibrations on selected physiological parameters of athletes" after applying the vibration noticed: a decrease in the value of systolic pressure, a decrease in pulse rate, an increase in body temperature, a decrease in body weight and a decrease in body fat. In their conclusions, the authors pointed out that vibrations increase blood flow due to a decrease in peripheral vascular resistance resulting from greater blood flow through the working muscles that are actively involved in vibration absorption [15].

Similar research was carried out by Z. Damijan who published the results in 2009 in the work entitled: "Trening wibracyjny w rehabilitacji kardiologicznej (Vibration training in cardiac rehabilitation)". During the study, Damijan noticed: in 96% of respondents a decrease in systolic pressure, a decrease in heart rate in 92% of subjects, a lower percentage of body fat in 76% of patients and a lower body weight for all subjects, and a decrease in total cholesterol in 76% of the sample. In addition, he found an increase in temperature in 88% of subjects and an increase in HDL cholesterol in 76% of people participating in the study. The summary states the usefulness of vibration training in cardiac rehabilitation due

to positive effects in the field of hypertension, obesity, atherosclerosis and physical fitness [16].

Among many research works there is also a direct reference to the applied vibration for oedema.

Narin et al. in their work used a device that was designed to produce vibrations similar to the physiological vibrations of the human body, its tissues and organs. These vibrations were called Matrix Rhythm Therapy (MRT). They were used in the case report of a 36-year-old woman with lymphoedema. In the summary, the researchers point out that self-treatment did not effectively reduce oedema, but it can have a positive effect on oedema if it is used for a long time and repeatedly. Researchers also point out that MRT can be combined with compression therapy, which can make a positive contribution to the use of Comprehensive Oedema Therapy [17].

The literature also meets research on the comparison of effects when using manual lymphatic drainage and manual drainage combined with deep oscillations. In 2008, Jahr et al. examined 21 women with secondary lymphoedema of the upper limbs and chest after surgery. They divided them into 2 groups: the first study group (n=11) had 12 manual lymph drainage procedures supplemented with deep oscillations, while the second control group (n=10) had manual drainage alone. Summing up their research, the researchers wrote that the additional deep oscillations complementing manual lymphatic drainage can significantly reduce pain and oedema compared to lymphatic drainage alone [18].

In 2016, Teo et al. also compared the effects of MLD (manual lymphatic drainage) with MLD in combination with deep oscillations, using the HIVAMAT 200 device. The average lower limb volume reduction when using MLD in combination with oscillations was 902 ml, while the average leg volume reduction only for MLD was 707 ml. The study used high resolution ultrasonography to analyse oedema. Researchers concluded that the limbs treated with MLD and deep oscillations showed a much greater reduction in oedema than limbs treated with MLD alone [19].

In the literature, there are also studies on the reduction of oedema after the use of vibrations in other disease entities than circulatory insufficiency in the lower limbs. In "Rheumatology" in 2014 the study of Skopowska et al. was published, who examined 44 people suffering from gonarthrosis. Patients were subjected to vibroacoustic therapy for 15 minutes on a Vitafon-T device, which has a wave frequency from 30 Hz to 18000 Hz and an amplitude of vibrations from 0.0001 to 0.05 mm. They noticed that vibroacoustic therapy had positive analgesic and anti-oedema therapeutic effects, which also improved the functional efficiency of patients [20].

In turn, Vladeva et al. (2018) examined 50 patients with knee joint replacement. For the study, they used Deep Oscillations, which are deep therapeutic oscillations that use tissue vibrations with a minimal external mechanical effect and combined them with kinesiotherapy. During the study, deep oscillations were shown to be effective in reducing inflammation, oedema and pain, and increasing the range of motion in early rehabilitation after knee replacement. The combination of oscillations and appropriate exercises gives better results in terms of the rate of functional regeneration [21].

Other studies that addressed the effect of vibration on the lymphatic system are studies by Stewart et al. who examined 18 women aged 46-63. They used a vibrating platform which they placed on the tilting table footrest using measurements at 0, 15, and 45 Hz. During the study, a change in microvascular filtration under the influence of vibration and an increase in lymphatic flow was observed [22].

The conclusions of the above studies suggest the need for further research and observation of the impact of vibration on the cardiovascular system, including the lymphatic system. The need for research on larger samples and for a long time was also highlighted.

Conclusions

1. The values of the t-Student test for dependent samples to test the effectiveness of the applied procedures testify to the occurrence of a significant difference in measurements of lower limb circumferences made before and after the procedures, which indicates the high effectiveness of the performed procedures in reducing the 1st degree oedema.
2. The subjective feelings of patients confirm the effectiveness of the performed procedures in reducing swelling of the lower limbs.
3. Based on the results obtained, it can be concluded that vibration therapy can be used as a method supporting the treatment of first- and second-degree oedema in patients with peripheral circulatory insufficiency. It can also be used as secondary prevention to maintain effects after the phase of maximum oedema reduction.
4. To confirm the results, further tests should be carried out on a larger sample with 2 groups: test and control with a single blind. It is also worth considering research for a group of patients with 3rd degree lymphoedema.

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