

Impact of oscillatory-cycloid vibration interventions on body composition, waist and hip circumference, and blood lipid profile in women aged over 65 years with hypercholesterolaemia

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Abstract

Introduction: Vibration therapy interventions are an attractive alternative for people with contraindications to physical activity or manifesting kinesiophobia; they constitute an equivalent to physical activity.

Material and methods: A group of female volunteers with hypercholesterolemia (LDL over 3 mmol/l) aged over 65 years were randomized into 2 subgroups: the study group (taking part in interventions on mattresses generating oscillatory-cycloid vibrations) and the control group (receiving interventions on placebo mattresses). All the subjects underwent two 30-minute interventions 5 times a week for the period of 21 days, in the prone position. Before the intervention and after completing the series of sessions, body composition and waist and hip circumferences were assessed. Venous blood for biochemical studies was collected before the intervention, one day after its completion, and one week after completing the series of vibration sessions. On the basis of the lipid profile results, atherogenicity indices were calculated.

Results: After 21 days, a statistically significant decrease in the level of total cholesterol and LDL cholesterol was observed in subjects who received oscillatory-cycloid vibration therapy. No statistically significant changes were noted in the concentrations of HDL cholesterol or triglycerides. The 21-day therapeutic intervention also resulted in lowering the AIP in the study group, as well as a decrease of hip circumference.

Conclusions: Oscillatory-cycloid vibration applied regularly for a longer time can beneficially impact on lowering the level of total cholesterol and LDL cholesterol in people with hypercholesterolemia, although it does not influence body composition in women aged 65 years or more.

Key words: therapeutic use of vibration, hypercholesterolemia, LDL cholesterol, atherogenic indices.

Introduction

Cardiovascular diseases invariably remain the main reason for death in Poland and worldwide; the issue is especially significant among post-menopausal women, when oestrogens cease to fulfil their vasoprotective function and to ensure appropriate rheological blood properties [1]. Atherosclerosis risk factor control constitutes a basic daily challenge for various healthcare professionals. The modifiable risk factors include smoking, lack of physical activity, improper dietary habits, arterial hypertension, type 2 diabetes, and lipid disorders. Lipid profile abnormalities refer to all age groups, and the NATPOL study conducted by Zdrojewski *et al.* [2] re-

vealed that they occurred in up to 61% of the population, i.e. in ca. 18 million Poles. Dyslipidaemia may also result from the applied medicinal agents, and research proves that the number of patients with polypharmacy increases with age [3]. The treatment of dyslipidaemia is based on diet and on changing other (modifiable) risk factors. If these prove to be inefficient, pharmacotherapy is applied [4]. In some patients, vibration therapy interventions can be helpful. They are an attractive alternative for people with contraindications to physical activity or manifesting kinesiophobia, i.e. a psychological blockade against starting exercise. Kinesiophobia is most frequently observed in orthopaedic patients and

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those with chronic pain syndromes, as well as among peri- and post-menopausal women [5].

Vibration can be applied in treatment under the condition of using stimuli with specific parameters, such as frequency, amplitude, time, and propagation method. In research concerning interventions in healthy individuals and those with various health problems, whole body vibration (WBV) is most comprehensively described [6]. Vibration activates muscle spindles, causing their contraction: tonic vibration reflex [7]. Vibration therapy can be applied in patients with neurological [8], orthopaedic [9], and pulmonary [10] disorders.

The available findings allow us to conclude that an appropriately selected form of vibration intervention can have a beneficial impact on the level of blood plasma lipids [11, 12]. However, the literature referring to the issue is scarce. Moreover, there are considerable methodological discrepancies concerning, most frequently, the vibration parameters and the form of stimulus propagation. This inspired the authors to perform a study with the direct aim of determining the influence of 21-day vibration therapy on body composition, waist and hip circumferences, and lipid profile among women aged over 65 years, with an initial LDL cholesterol concentration equal to or higher than 3 mmol/l.

- intake of medicinal agents and/or dietary supplements influencing the metabolism of blood plasma lipids;
- negative medical qualification based on contraindications to vibration therapy or general health status;
- high level of physical activity;
- special or elimination diets applied now or up to three months preceding the project.

Prior to the experiment, the participants were informed about its purpose, the applied method, the potential adverse effects, and the possibility to withdraw at any moment without providing a reason. The female volunteers were randomised into two subgroups: the study group ($n = 16$; taking part in interventions on mattresses generating oscillatory-cycloid vibrations) and the control group ($n = 9$; receiving interventions on placebo, non-vibrating mattresses). The subjects documented their dietary details for five days, including one bank holiday, running a photo album of the products and dishes [13]. The diaries were assessed with the use of Dieta 5 software (National Food and Nutrition Institute, Warsaw, Poland). The participants were asked not to change their dietary habits in the course of the study. Their physical activity was determined with the IPAQ short-form questionnaire [14]. The exclusion criterion was physical activity level exceeding 1500 MET min/week.

Material and methods

Study subjects

The study was approved by the Ethical Committee of the Regional Medical Chamber in Krakow, Poland (approval No. 155/KBL/OIL/2016). The research involved a group of women aged over 65 years, members of the Third-Age University in Nowy Sacz, Poland, who provided their written consent to participate in the scientific project. A patient flow diagram is presented in Figure 1. The following exclusion criteria were applied:

- stimulant intake (at least in the two-week period before the beginning of the study);
- previous participation in vibration therapy interventions;

Vibration therapy interventions

The scientific research was taken in State University of Applied Sciences in Nowy Sacz. All the study subjects underwent two 30-minute interventions five times a week for a period of 21 days. During each session, the women remained in the prone position. Interventions were applied from Monday to Friday, before noon (between 8.00 and 11.00 a.m. at a fixed time for each participant) in a room with the same temperature and humidity. A rehabilitation massage device, Vitberg+ (Rehabilitacyjny Aparat Masujący Vitberg+, Basic module + Metabolism module), a class IIa medical product, served as the source of vibration. The therapeutic stimulus consisted of cycloid vibrations, produced in three per-

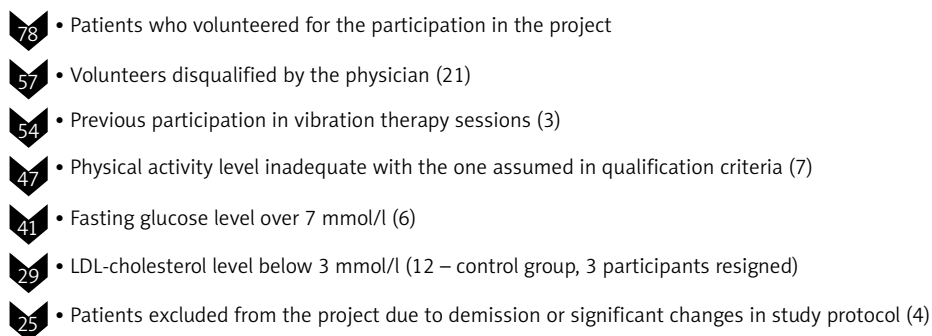


Fig. 1. Patient flow diagram

pendicular directions (3D), inducing intermittent pulsations with variable values of frequency (f), amplitude (A), and acceleration (a), whose ranges were 20-52 Hz, 0.1-0.5 mm, and 6.9-13.5 m/s², respectively.

The control group received identical interventions with the use of specially prepared placebo modules (Vitberg, Poland), in which some performance elements had been modified. The placebo device looked and sounded like the active one, which allowed us to maintain blinded group randomisation.

Body composition assessment and biochemical studies

Before the intervention and on completion of the series, body composition and waist and hip circumferences were assessed. Measurements of the body’s circumferences were made using a non-stretchable measuring tape by the same examiner. During the waist circumference measurements, the measuring tape was placed halfway between the lower edge of the last rib and the iliac crest, while maintaining its position parallel to the ground. Hip circumference was measured at the site of the largest convexity of the buttocks below the hip plates. The subjects’ body height and body mass, including its components (Prodigy densitometer, GE Healthcare, USA), were determined. On the basis of the body composition, the adipose tissue distribution index was calculated (the percentage ratio of android and gynoid adipose tissue, A/G ratio).

Venous blood for biochemical studies was collected by qualified medical personnel from the vein in the elbow pit before the intervention (day 0), on day 21 in the morning, and after the intervention was completed, each time from a fasting patient, at least 12 hours after the previous meal. Total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were determined in full blood. LDL cholesterol concentrations were calculated using the Friedewald formula (for TG concentrations above 4.6 mmol/l, the result is unreliable; these subjects were excluded from the project):

$$LDL-C = TC - HDL-C - TG/2.2 \text{ for concentrations in mmol/l}$$

On the basis of the lipid profile results, atherogenicity indices were calculated, which point at cardiovascular risk, i.e. C I (Castelli risk index I): TC/HDL-C; C II (Castelli risk index II): LDL-C/HDL-C; TG/HDL; AIP (atherogenic index of plasma): log (TG/HDL-C); and AC (atherogenic coefficient): TC – HDL-C/HDL-C [15].

Statistical analysis

Statistical analysis of the results was performed with STATISTICA 13.1 software (StatSoft, Poland). The

results are presented as arithmetical means with standard deviations. The Shapiro-Wilk test served to assess distribution normality, and the Levene test to determine the homogeneity of variance. Outliers were rejected on the basis of Grubbs’ test. In order to demonstrate the significance of differences between means if the assumptions for parametric tests were met, Student’s *t*-test for dependent and independent samples was used, as well as repeated measures analysis of variance (ANOVA) with the *post-hoc* Tukey test for unequal sample sizes. For the remaining variables, non-parametric tests were applied. The assumed level of significance (α) equalled 0.05.

Results

Table 1 presents body composition changes between the pre- and post-intervention time points.

Table 1. General characteristics of the studied women before and after the series of vibrotherapy treatments

	Control group	Study group	<i>p</i>
Body mass (kg)			
before	71.26 ±8.89	72.32 ±6.52	0.363
after	70.70 ±8.22	71.85 ±6.32	0.198
<i>p</i> *	0.234	0.236	
Hight (m)			
	158.11 ±6.64	160 ±7.25	0.257
BMI			
before	28.46 ±2.60	28.20 ±2.74	0.408
after	28.25 ±2.37	28.14 ±2.74	0.351
<i>p</i> *	0.390	0.306	
Fat (g)			
before	29715 ±5872	30285 ±3550	0.377
after	29407 ±5863	30054 ±3903	0.332
<i>p</i> *	0.386	0.166	
Fat (%)			
before	42.77 ±4.26	43.17 ±2.94	0.399
after	42.62 ±5.02	43.01 ±3.33	0.422
<i>p</i> *	0.206	0.450	
LBM			
before	39372 ±3984	39890 ±3951	0.375
after	39201 ±4171	39682 ±3615	0.401
<i>p</i> *	0.207	0.274	
BMC			
before	2090 ±379	2128 ±242	0.375
after	2084 ±368	2113 ±259	0.227
<i>p</i> *	0.332	0.263	

The results are presented as mean values along with standard deviations. %fat – fat percentage; Fat – fat mass; LBM – lean body mass; BMC – bone mineral content; BMI – body mass index. *p* (control group vs. study group) *t*-test for independent means, *p** (before vs. after) *t*-test for dependent means.

Table 2. The average energy and basic nutrients content in the diet of the studied women

	Control group	Study group	<i>p</i>
Energy (kcal)	1496 ±454	1643 ±539	0.497
Protein (g)	75 ±27	74 ±31	0.487
Carbohydrates (g)	231 ±63	240 ±93	0.403
Roughage (g)	22 ±6	23 ±10	0.359
Fat (g)	54 ±17	50 ±16	0.280
SFA (g)	20 ±4	18 ±7	0.309
MUFA (g)	21 ±8	18 ±6	0.164
PUFA (g)	8 ±5	8 ±4	0.466
Cholesterol (mg)	252 ±79	297 ±103	0.163
Water (ml)	2452 ±1045	1850 ±957	0.095

The results are presented as mean values along with standard deviations. SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids. *p* (control group vs. study group) *t*-test for independent means.

Table 3. Changes in the lipid profile in studied women

	Control group	Study group	<i>p</i>
TC (mmol/l)			
before	6.28 ±0.66	6.16 ±0.77	0.346
after	6.13 ±0.64	5.79 ±0.79	0.064
one week after	6.13 ±0.61	5.97 ±0.65	0.276
<i>p</i> *	0.854	0.047	
HDL (mmol/l)			
before	1.85 ±0.40	1.69 ±0.26	0.102
after	1.84 ±0.31	1.72 ±0.27	0.164
one week after	1.75 ±0.27	1.72 ±0.27	0.377
<i>p</i> *	0.780	0.921	
LDL (mmol/l)			
before	3.80 ±0.67	3.76 ±0.69	0.440
after	3.68 ±0.54	3.38 ±0.68	0.030
one week after	3.77 ±0.64	3.60 ±0.57	0.237
<i>p</i> *	0.907	0.041	
TG (mmol/l)			
before	1.25 ±0.46	1.34 ±0.47	0.311
after	1.29 ±0.42	1.22 ±0.44	0.346
one week after	1.17 ±0.22	1.28 ±0.47	0.264
<i>p</i> *	0.831	0.740	

The results are presented as mean values along with standard deviations. TG – total cholesterol; HDL – high-density lipoprotein; LDL – low-density lipoprotein; TG – triglycerides. *p* (control group vs. study group) *t*-test for independent means; *p** (intra-group changes) one-way ANOVA for repeated measurements. Statistically significant results are in bold (*p* < 0.05).

The participants' mean age was 67.0 ±0.9 years. The age means did not differ significantly between the experimental and control groups. Body height was similar in both groups. The performed analysis indicated neither intra- nor inter-group differences (Table 1). The

Table 4. Indicators of fat distribution in the study and control group

	Control group	Study group	<i>p</i>
WC			
before	91.37 ±6.36	92.78 ±8.04	0.663
after	90.00 ±8.03	91.89 ±7.28	0.554
<i>p</i> *	0.258	0.190	
HC			
before	104.00 ±6.59	107.36 ±5.87	0.200
after	104.00 ±6.69	106.42 ±5.63	0.343
<i>p</i> *	1.000	0.003	
A/G ratio			
before	1.07 ±0.09	1.09 ±0.11	0.654
after	1.09 ±0.09	1.09 ±0.10	0.942
<i>p</i> *	0.492	0.816	
WHR			
before	0.87 ±0.02	0.86 ±0.04	0.406
after	0.86 ±0.04	0.86 ±0.04	0.943
<i>p</i> *	0.273	0.972	

The results are presented as mean values along with standard deviations. WC – waist circumference; HC – hip circumference; A/G ratio android-to-gynoid ratio (android fat mass/gynoid fat mass); WHR – waist-hip ratio. *p* (control group vs. study group) *t*-test for independent means, *p** (before vs. after) *t*-test for dependent means; statistically significant results are in bold (*p* < 0.05).

analysis of the dietary diaries provided by the subjects is presented in Table 2.

Table 3 includes the analysis results of concentrations of selected cholesterol fractions and triglycerides in the women's blood. A statistically significant decrease in the concentration of total cholesterol and LDL cholesterol was observed in the experimental group (Table 2). The values for the second measurement point in the experimental group differed significantly from the initial values in the group and from the results obtained in the control group. The remaining fractions, i.e. HDL cholesterol and triglycerides, did not undergo a statistically significant change.

In the experimental group, the vibration therapy resulted in a statistically significant decrease in hip circumference. The other indices of adipose tissue distribution did not change significantly in either group (Table 4).

After 21 days of vibration therapy application, a tendency for lowering the atherogenicity indices was observed among the experimental group participants (Tables 5 and 6).

Discussion

Table 5. Atherogenic indexes of women from the study and control groups

	Control group	<i>p</i> *	Study group	<i>p</i> *	<i>p</i>
CI					
before	3.64 ±0.67		3.69 ±0.59		0.824
after	3.48 ±0.57	0.166	3.49 ±0.59	0.068	0.961
one week after	3.66 ±0.67	0.183	3.55 ±0.63	0.611	0.670
CII					
before	2.24 ±0.49		2.25 ±0.40		0.952
after	2.11 ±0.45	0.155	2.11 ±0.48	0.086	0.974
one week after	2.27 ±0.52	0.138	2.13 ±0.44	0.802	0.506
AIP					
before	0.243 ±0.26		0.284 ±0.23		1.000
after	0.239 ±0.18	0.723	0.223 ±0.22	0.026	0.852
one week after	0.252 ±0.19	0.723	0.251 ±0.23	0.643	0.651
AC					
before	2.64 ±0.67		2.70 ±0.59		0.824
after	2.48 ±0.57	0.166	2.50 ±0.59	0.068	0.962
one week after	2.66 ±0.67	0.183	2.55 ±0.63	0.611	0.670

The results are presented as mean values along with standard deviations. *p** (intra-group changes) CI – Castelli Risk Index I; CII – Castelli Risk Index II; AC – atherogenic coefficient – *t*-test; AIP – Atherogenic Index of Plasma – Mann-Whitney *U* test, *p* (control group vs. study group) CI, CII *t*-test, AIP Wilcoxon signed-rank test; statistically significant results are in bold (*p* < 0.05).

Table 6. Effect of vibrotherapy on atherogenic indexes

	Reference range		Control group (percent of women with abnormalities)	Study group (percent of women with abnormalities)
CI	< 4.0	before	12.5	31.5
		after	12.5	21
CII	< 3	before	0	0
		after	0	0
AIP	< 0.24	before	62.5	47.3
		after	62.5	31.5
AC	< 3	before	12.5	31.5
		after	12.5	21

The results are presented as percent values. CI – Castelli Risk Index I, CII – Castelli Risk Index II, AIP – Atherogenic Index of Plasma, AC – atherogenic coefficient

Vibration can be applied as physical activity substitution. The rhythmical contractions and relaxations of skeletal muscles forced by a vibration device induce whole body reactions and activation of numerous muscle groups [16]. In the course of vibration exposition, a conversion of kinetic energy into thermal energy takes place through activation of friction forces. Hettinger was the first to prove the catabolic action of high-frequency vibrations on the adipose tissue in animals [17]. Today it is known that this effect is observed even in animals without the leptin receptor [18]. McGee-Lawrence [18] found that vibration training brought effects comparable to standardised training on a treadmill. Its

beneficial impact on body mass change, glucose tolerance, muscle fibre status, and parameters of liver function and steatosis has been proven. However, the applied vibration therapy must be appropriately adjusted; Zhao *et al.* [19] observed that high-frequency vibrations exerted an adipogenic effect by promoting adipogenesis on the molecular level.

Studies concerning the influence of vibration therapy in the human model have brought inconclusive results. Damijan and Uhryński [20] observed that exposition to general low-frequency vibrations for 19 days decreased the overall adipose tissue amount by up to 2.37% in 96% of the sample as compared to 1.12% in

66% of the control group. The authors explained this effect by pointing out a reaction to mechanical deformation, increase in temperature in a given region of the body, and activation of adipose tissue burning processes as an element of intensified systemic catabolism [20]. Nevertheless, this impact may result from the applied measurement method, i.e. bioelectrical impedance analysis, which only estimates body composition instead of determining its exact values; the results can be additionally falsified in the conditions of altered body temperature and humidity. In the study by Damijan and Uhryński, the participating women were younger, and collective nutrition under sanatorium conditions was applied, which substantially influenced the observed results, especially when one considers the numerous deviations from norms noted in the diets of our study subjects. Sanatorium-stay nutrition, if not individually arranged with a dietician, can also be affected by numerous mistakes [21].

The nutrition analysis based on the dietary diaries provided by the participants revealed many shortcomings in the diets composed freely by the project subjects (Table 1). Among others, energy shortages and protein and fibre shortages were observed, as well as deficient dietary water intake. The statistical analysis proved that nutrition composition mistakes occurred equally often in both groups. All the participating women ate irrationally.

Analysing the results of the assessments of adipose tissue distribution indices presented in the study, one can see a significant influence of oscillatory-cycloid vibration only on the decrease in hip circumferences among women in the experimental group and a tendency of improvement of randomised indices. However, no significant changes in body composition were observed in the participants undergoing vibration massages in the prone position, contrary to research that showed body composition improvement in healthy individuals and type 2 diabetes patients who received therapeutic vibrations in the upright position [22]. According to Sañudo *et al.* [22], whole body vibration may constitute a modern interventional training, a safe and efficient method to improve body composition, also influencing muscle strength in people unable to perform other forms of physical exercise. With a balanced diet, vibrations additionally stimulating intestinal peristalsis and nutrient absorption function support the process of weight loss [23]. Montero *et al.* [24] noticed that whole-body vibration training seemed to be associated with three pathways involved in weight loss: inhibition of adipogenesis and reduction of fat mass, increase in energy expenditure, and increase in muscle mass. With the vibration stimulus applied in the abdominal area, we did not obtain the body composition improvement observed in the previous studies. Although this was not the issue of our re-

search, the participants reported more frequent bowel movements after vibration therapy. The reason could be a vibration-induced increase in intestinal peristalsis, which has already been observed with other forms of vibration stimulus application [23].

Vibration massage applied for 21 days lowered the levels of total cholesterol and LDL cholesterol, as well as atherogenicity indices among women with evidence of hypercholesterolaemia (LDL above 3 mmol/l), which seems a challenging outcome. Atherogenicity indices calculated on the basis of the lipid profile allow us to assess the concentrations of particular elements of the lipid profile. Exceeding the relevant normal values for each indicator is associated with a higher risk of atherosclerosis and, consequently, of cardiovascular diseases [25]. Although vibration applied as an isolated modification of lifestyle improves the lipid profile, its beneficiary effect was not maintained for a longer period: the last measurement point (a week after the vibration stimulus withdrawal) revealed results that did not differ statistically from the initial values. An interesting issue is whether prolonging the action of the vibrating stimulus would extend its effect.

In the guidelines concerning physical activity, the American College of Sports Medicine and the American Diabetes Association recommend at least 150 minutes per week of moderate aerobic activity (60-85% of maximum heart rate), resulting in weekly energy expenditure at the level of 1000-2000 kcal [26]. However, despite its simplicity, this is not a commonly used means of preventing and treating metabolic diseases. Frequently indicated barriers include lack of time, as well as social (upbringing and negative experiences), psychological, and biological (e.g. neurological) conditions [27]. In such situations, a solution may be the use of vibrations, in accordance with the indication that vibration training is an equivalent to physical effort, without the inconveniences associated with, among others, the locomotor system overload. This can help solve the problem of low physical activity in people who cannot or do not want to perform exercise for a variety of reasons.

It should be emphasised that all participants completed the presented study (four violated the intervention protocol because of symptoms of infectious diseases), which indirectly points at the acceptability of the method and lack of effects that could discourage prolonged use of the therapy. The study design (21-day therapy) was supposed to imitate sanatorium conditions or a recreational stay, and in this form, for specific patients, it may prove to be an effective and safe therapy. This, however, requires sound scientific evidence and further testing among different target groups.

Conclusions

Oscillatory-cycloid vibration applied regularly for 21 days has a beneficial impact on lowering the level of total cholesterol and LDL cholesterol, as well as a decrease in atherogenicity indices in women aged over 65 years with diagnosed hypercholesterolaemia.

Disclosure

The authors report no conflict of interest.

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