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IMPACT OF WHOLE-BODY ELECTROMYOSTIMULATION AND RESISTANCE TRAINING ON BONE MINERAL DENSITY IN WOMEN AT RISK OF OSTEOPOROSIS

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Abstract

In recent years, there has been an increasing interest in physical activity programs for older adults. Questions have been raised about the efficacy of programs regarding real effects on life. The purpose of the study is to compare the impact of ten weeks of Whole-Body Electromyostimulation (WB-EMS) and resistance training (RT) programs on one mineral density (BMD) and T-score values in women at risk of osteoporosis. The WB-EMS was carried out once per week (total: ten sessions), the RT was carried out twice per week (total: 20 sessions). Twenty-eight elderly women participated in the study, nine in a WB-EMS group (weight: 69.84±10.29kg; BMI: 25.04±4.18 kg/m^2), eight in a RT group (weight: 74.16±4.19kg; BMI: 27.35±2.76 kg/m^2), and ten in a control group (CG) (weight: 79.72±15.61kg kg; BMI 28.58±5.70 kg/m^2). A dual-energy X-ray absorptiometry scanner (DXA) was used to assess body composition, BMD, and T-score values. To identify the statistical significance of the differences between pre-test and post-test in all groups, the parametric t-test was used. Statistical significance was set at $p \leq 0.05$. Although no significant differences were found in either BMD or T-score values, the study appeared to elicit some positive behaviour that could have an impact for more than ten weeks. The present study was designed to determine the effect of RT and WB-EMS on selected parameters in groups of women at risk of osteoporosis. Even though the results were not statistically significant, we consider the impact of programs on the level of BMD and T-score beneficial. Results show that the RT method is more practical. More tested subjects of the RT reported the same or higher level of BMD in the post-test compared to the WB-EMS method (RT 50% vs WB-EMS 44.7%). It was impossible to further investigate the significant relationships between selected parameters and intervention because the sample size was too small. Therefore, a further study with more focus on the duration of intervention and an increase in sample size is suggested.

Keywords: *ageing, bone mineral density, BMD, osteoporosis, DXA, resistance training, WB-EMS*

Introduction

Many involutional changes accompany ageing including a decrease in muscle mass volume with concomitant lower levels of muscular strength. On the contrary, adipose tissue increases (Peterson et al., 2011). During ageing, both women and men lose bone mass. Bone mineral density (BMD), the proportion of stored mineral salts on the organic bone matrix, peaks at 25 years of age n woman, albeit it is lower in women than in men at any age. BMD values are affected by several factors such as age, sex, disease, genetics, and lifestyle. Health conditions such as diabetes or hyperthyroidism and other parameters, such as postmenopausal estrogen deficiency, also affect BMD (Kranioti et al., 2019; Sedlak et al., 2000). The level of estrogen, a hormone affecting bone metabolism, decreases after menopause in women (Brady et al., 2014; Ribeiro et al., 2017) with women losing 5% of their bone mineral density each year for the first five years after menopause. After this period, the decline stabilises at 2-3% per year (Kranioti et al., 2019). One of the most common disorders associated with low BMD is osteoporosis.

Osteoporosis is an age-related metabolic disease that mainly affects women and causes bone demineralisation leading to fractures (Sedlak et al., 2000). One of the definitions of osteoporosis is bone degradation which results from an imbalance between the activity of osteoblasts (bone-forming cells) and osteoclasts (bone-degrading cells). Hormone levels, especially estrogen, blood calcium and vitamin D levels, and exercise-induced stressors affect the balance between bone building and bone breakdown (von Stengel et al., 2015). Recommendations for the treatment of osteoporosis include calcium and vitamin D supplementation, sufficient protein intake, and physical activity (Heaney et al., 2001; Rossini et al., 2016).

Many studies focus on the effects of different methods of physical activity on bone mineral density in healthy people, in people at risk of osteopenia, or after injuries, across all age groups. In a study examining the effects of strength and endurance circuit training on bone density, no positive changes were reported (Brentano et al., 2008). Other studies have reached the opposite conclusions with positive effects on bone mineral density being attributed to resistance exercise (Bemben & Bemben, 2011; Chilibeck et al., 2015). The programme based on resistance training and creatine supplementation reduced the decrease of BMD in the area of the femoral neck (the area most prone to fracture in the elderly). A 24-week programme based on aerobic training and box step-ups resulted in an increase in bone density of 2% in the lumbar region and 6.8% in the femoral neck area (Chien et al., 2000). The study compared women with optimal femoral density and women with osteopenia. The results showed that women with optimal femoral density were generally more physically active than women with osteopenia with the latter having spent more time on sedentary activities (Pelclová et al., 2011).

Strength training and plyometric training appear to be suitable types of physical activity, potentially increasing or maintaining bone mineral density, as was the positive effect of whole-body electromyostimulation (Gregov &Šalaj, 2014). WB-EMS technology simultaneously stimulates up to 14–18 regions or 8–12 muscle groups with up to 2,800 cm^2 electrode area. WB-EMS is a method that contracts muscles with low-frequency electrical pulses. This method is timesaving and allows exercise for people with limited mobility. As such, it seems to be a suitable alternative to classical resistance training for seniors (Kemmler et al., 2021) and WB-EMS technology might effectively increase muscle strength and mass in the elderly. Because of the interaction of muscles and bones, these adaptations might relate to changes in bone parameters (Qin et al., 2010) with studies determining the effects of EMS training solely on bone with patients who have disuse-induced bone loss due to spinal cord injury (SCI) supporting this premise. For example, reviews and meta-analyses by Biering-Sørensen et al. (2009) and Chang et al. (2013) noted that the effects of localised EMS training on BMD after SCI, had beneficial effects. Somewhat in contrast, when whole body EMS was used, no significant effects on bone density were found in men with SCI with bone losses being similar in both experimental and control groups (Arija-Blázquez et al., 2014). However, conclusions drawn from studies describing the influence of EMS on bone in the specific situation in SCI patients are not valid for the general population with von Stengel et al. (2015) finding that no significant effect was found at the lumbar spine and the hip in sedentary, lean, and osteopenic elderly females (a cohort at high risk for fractures) following 54 weeks of WB-EMS intervention.

It seems clear that the findings of studies focused on appropriate physical activity for people at risk of lower bone density do not lead to clear conclusions. As such, our study aimed to contribute to the knowledge base by comparing the impact of ten weeks of Whole-Body Electromyostimulation (WB-EMS) and resistance training (RT) programs on bone mineral density (BMD) and T-score values in women at risk of osteoporosis.

Methods

Participants

Our sample for an intervention programme (IP) consisted initially of 32 adult women over 60 years of age; 28 participants finished the IP. The participants were recruited using the *snowball* technique from several sources. Printed leaflets were distributed around the sports grounds in Brno, and electronic brochures were put on the Faculty of Sports Studies website and the Faculty's Facebook page. Women who expressed interest subsequently received an information report before completing our IP form (name, surname, date of birth, contact, contraindications, and other restrictions). Based on the information, they were excluded or included in the research. Inclusion criteria were that participants needed to be aged 60-65 years, without regular physical activity, and having no contraindications. Contraindications included: epilepsy, cardiac pacemaker implant, severe circulatory system disease, abdominal or inguinal hernia, cancer, advanced arteriosclerosis, severe neurological disease, acute bacterial or viral infection, diabetes mellitus, bleeding disorders (haemophilia), liver disease, tuberculosis, severe circulatory system disorders (e.g., unstable angina pectoris), untreated hypertension, uncontrolled heart rhythm disturbances, heart failure, valve stenosis, hypertrophic cardiomyopathy, reduced mobility, and metal implants (due to DXA).

Participation in the research was voluntary. All the participants were informed about the course of the study and their personal data handling. They all signed an Informed Consent Form approved by the Ethics Committee of Masaryk University, Brno (Ethics committee application number was EKV-2019-068).

Twenty-seven women met the inclusion criteria. They were then divided into three groups by random draw. The resistance training group (RT) consisted of ten women (eight of whom completed the study), and the WB-EMS group consisted of eleven women (nine of whom completed the study). Reasons for failure to complete the intervention programme were: absence due to illness, knee pain and related exercise problems (RT), death in the family and back pain (WB-EMS). Participants were asked to maintain their usual daily regimen with the same amount of physical activity and an average daily lifestyle.

The study sample's baseline descriptive characteristics (age, BMI, weight) are shown in Table 1.

Table 1. Baseline characteristics of the WB-EMS, RT and CG

Variable	***WB-EMS*** (n=9)	***RT*** (n=8)	***CG*** (n=10)
Age (years)	63.38 ± 1.79	62.00 ± 1.85	62.73 ± 1.42
Bodyweight (kg)	69.84 ± 10.29	74.16 ± 4.19	79.72 ± 15.61
Body height (m)	1.67 ± 0.68	1.65 ± 0.57	1.67 ± 0.59
Body mass index ($kg \cdot m^{-2}$)	25.04 ± 4.18	27.35±2.76	28.58 ± 5.70

Note: WB-EMS – Whole-body electromyostimulation group; RT – Resistance training group, CG – Control Group

Measures

Dual-energy X-ray absorptiometry (DXA)

DXA measures body composition and bone density. DXA is commonly used to diagnose osteoporosis. This non-invasive method uses a minimal dose (0,001-0,015 **mSv**) of ionising radiation. To measure the body composition, the whole-body scanner was used. The lumbar spine and upper part of the femur were monitored to measure bone density.

Procedures

Whole-Body Electromyostimulation intervention program

WB-EMS was delivered using Miha Bodytec device. The Whole-Body Electromyostimulation intervention programme took place once a week for ten weeks.

The first course lasted about 60 minutes. The tested persons were informed about the interventional programme process. Then a twelve-minute pulse and strengthening programme followed. The intensity of the pulses was set up according to the actual subjective feelings and possibilities of the tested person. These values then became the starting point for the following courses. The subsequent training courses (lasting about 20 minutes) took place once a week, ideally on the same day. The regeneration time (four days minimum between two classes) was kept.

Workouts included in the WB-EMS training protocol were:

0. Basic static position,
1. Half squats (twelve repetitions)
2. Trunk rotation - each side (eight repetitions)
3. Lunges - left leg to the front (each side eight repetitions)
4. Lunges - right leg to the front (each side eight repetitions)
5. Reverse flies - forearms up (twelve repetitions)
6. Chest flies - forearms up - concentric phase only - (six repetitions)
7. Side lunges left/right (eight repetitions)
8. External arm rotation - each side (six repetitions)
9. Back extension (six repetitions)
10. Triceps kickback (six repetitions)

Circuit resistance interventional programme

The minimum participation in the IP was set up at 80%. The possibility of replacing the training session on another day was also provided. Nevertheless, the time interval between training and the training frequency twice a week had to be kept. Before starting the interventional program, the introductory week, including two training sessions, was held. During these two sessions, the participants met with the weight room, fitness machines, their setting, and performed the correct technique of the workouts. On the 2^{nd} training session, the individual load according to ten repetitions maximum (RM) was set (=modification 1RM for older adults, the load they can lift ten times). From the final load, 65-75% of RM was calculated (for the first week of IP), then 70-75% of RM (from the 2nd week of the IP).

Structure of the class
After 5 minutes of warm-up (walking and its modification on the place), five minutes of joint mobilization exercises and dynamic stretching followed. The main part of the unit contained three circuits with ten positions. The participants performed ten to twelve repetitions of each workout. Between each position, a short pause of about one minute took place. The break among circuits lasted three to five minutes (for drinking, fast regeneration).

The individual resistance training workouts were: 1. Activation of the deep stabilisation system, 2. Bench press, 3. Lunges back, 4. Reverse Pec-deck, 5. Squats (with gymnastics ball supported the wall), 6. Lat Pulldown, 7. Leg extensions, 8. Triceps Pulldown, 9. Lying Leg Curls, 10. Biceps Cable Curl. After completing the main part, the static stretching followed.

Statistical analyses
Statistica 12 and Microsoft Excel software were used to analyse data. The data were evaluated using descriptive statistics: arithmetic means, standard deviation, median, maximum, and minimum values. To identify statistical significance of any differences in all monitored variables between pre-test and post-test, the parametric t-test was used. Statistical significance was set at $p \leq 0.05$.

Results

For greater clarity, the obtained results of the BMD and T-score values will be interpreted separately.

The effect of the interventional programs on BMD values
The data from DXA measurements of BMD of all tested groups are presented in Table 2. The table shows the basic descriptive statistics (mean, standard deviation, minimal and maximal value, median) for the baseline (pre-test) and the final measurements after ten weeks (post-test) of regular exercise. As can also be seen from the data in Table 2, neither the WB-EMS group, RT group, nor the control group does not report statistically significant differences ($p \leq 0.05$) between pre-and post-test in values of BMD ($p_{WB\text{-}EMS}$ =0.31; p_{RT} =0.17; p_{cg} =1.00).

Table 2 The effect of different types of interventional programs on BMD in all groups

BMD ($g.cm^{-3}$)	**WB-EMS** pre-test (n=9)	**WB-EMS** post-test (n=9)	**RT** pre-test (n=8)	**RT** post-test (n=8)	**CG** pre-test (n=11)	**CG** post-test (n=11)
M ± SD	0.980 ± 0.060	0.972 ± 0.053	0.984 ± 0.048	0.977±0. 0.054	0.997 ± 0.081	0.997 ± 0.089
Min	0.882	0.892	0.897	0.873	0.891	0.888
Max	1.068	1.059	1.059	1.054	1.181	1.189
Median	0.985	0.990	0.995	0.981	1.013	1.015
p-value	0.31		0.17		1.00	

***Note**: BMD – Bone Mass Density (gram× $cm^{-3)}$, WB-EMS – Whole-body electromyostimulation group; RT – Resistance training group, CG – Control Group, n - number, Min – the minimal measured value, Max – the maximal measured value, M - Mean, SD – standard deviation, $p \leq 0.05$ - statistical significance*

In the WB-EMS experimental group, the mean BMD decreased slightly (from 0.98 grams × cm-3 to 0.972 grams × cm-3). The standard deviation value in the pre-test and post-test reaches almost the same level. The minimum and maximum values also remained the same. Same condition - a slight decrease in the mean value (from 0.984 grams x cm-3 to 0.977 g x cm-3), the stable value of the standard deviation, minimum and maximum values are also evident in the RT group. The average BMD values in the control group in the pre-test and post-test show the best BMD results among the tested groups. This fact could be caused by the value of the standard deviation (0.089), proving the inhomogeneity of the tested sample in the control group.

The effect of the interventional programs on T-score values

Table 3 presents the descriptive statistics (mean, standard deviation, minimal and maximal value, median) and the statistical significance values (p-value) of T-score before (pre-test) and after the ten weeks intervention (post-test) in the WB-EMS group, RT group, and the control group. Regarding T-score values, there were no statistically significant ($p \leq 0.05$) changes in post-test compared with a pre-test in either experimental group after ten weeks lasting interventional programme (p_{WB-EMS} =0.41; p_{RT} =0.17; p_{cg} =0.86).

Table 3 The effect of different types of interventional programs on T-score values in all groups

T-score	**WB-EMS** pre-test (n=9)	**WB-EMS** post-test (n=9)	**RT** pre-test (n=8)	**RT** post-test (n=8)	**CG** pre-test (n=11)	**CG** post-test (n=11)
M ± SD	-1.644 ± 0.803	-1.733 ± 0.714	-1.575 ± 0.650	-1.675 ± 0.742	-1.445 ± 1.059	-1.436 ± 1.152
Min	-3	-2.8	-2.8	-3.1	- 2.9	-2.9
Max	-0.5	-0.6	-0.6	-0.6	0.9	1.0
Median	-1.6	-1.5	-1.45	-1.6	-1.2	-1.2
p-value	0.41		0.17		0.86	

***Note**: T-score, WB-EMS – Whole-body electromyostimulation group; RT – Resistance training group, CG – Control Group, n - number, Min – the minimal measured value, Max – the maximal measured value, M - Mean, SD – standard deviation, p ≤ 0.05 - statistical significance*

The average T-score value decreased in both experimental groups (in the WB-EMS group from -1.644 to -1.733, in the RT from -1.575 to -1.675). The decrease in the standard deviation value for the WB-EMS group in the post-test indicates a levelling of the tested sample in this parameter (from 0.803 to 0.714). Unlike the WB-EMS group, the RT group showed a slight increase in the standard deviation value from 0.650 to 0.742. The results show that the control group achieved the highest measured T-score values in both pre-test and post-test in all essential statistical characteristics (mean, minimal and maximal values). This is also related to the standard deviation's high value, which reaches the highest value among the groups. This shows a big difference in T-score values of individual probands in this group.

Discussion

The purpose of the study was to compare the effect of ten weeks of Whole-Body Electromyostimulation (WB-EMS) and resistance training (RT) programmes on the mineral density (BMD) and T-score values in women at risk of osteoporosis. This survey did not find a significant effect of either intervention programmes.

The arithmetic means of the value of BMD decreased slightly in both experimental groups (WB-EMS). The T-score increased or maintained the same value in 50% of subjects in the experimental resistant training group and in 44.4% of subjects in the WB-EMS group. These values suggest that both types of exercise have a similar effect on bone density of probands. The results differ mainly from the control group. Despite the random division of the test subjects into individual groups, the pretest results were better in the control group than in both experimental groups. The arithmetic means of BMD remained the same in the control group, and improvement or maintenance of the T-score occurred in 72.7% of tested subjects.

Awareness of the importance of physical activity in preventing diseases is very widespread and mentioned by many authors. For example, Pelclová et al. (2011) examined the link between physical activity and inactivity on bone mass density in proximal femur (measured by DXA) in 92 postmenopausal women. Using ActiGraph GT1M, the physical activity/inactivity level was measured during seven days. The results showed a lower level of physical activity in women suffering from osteopenia. Their main mentioned activities were housework, reading, and similar activities.

Our results with the resistance training group correspond with the results of the research of Brentano et al. (2018), focused on the effect of strength and endurance circuit training on bone density. The results also did not show positive changes. On the other hand, studies by Sööt et al. (2005), Bemben & Bemben (2011), and Chilibeck et al. (2015) confirmed the positive impact of this type of physical activity on BMD.

Many studies also described the benefits of the WB-EMS method as timesaving, suitable for people with limited mobility or also older adults, having a positive effect in the increase of muscle mass and strength, or the level of fitness (von Stengel et al., 2015; Pano-Rodriguez 2020; Kemmler et al., 2021). Research confirming the positive effect of WB-EMS on the BMD were also published (Gregov &Šalaj, 2014; von Stengel et al., 2015). Von Stengel et al. (2015) found the positive effect of a one-year lasting WB-EMS intervention programme on BMD at the lumbar spine area in 70 years and older osteopenic women. It does not correspond with our findings. The WB-EMS group does not report statistically significant differences after ten weeks interventional program. More considerable differences would probably be measured if it were a longer interventional program. Although the WB-EMS programme did not have the expected impact, we agree with von Stengel et al. (2015) that this method could be a suitable option for maintaining BMD for people unable to perform resistance training or other more intensive exercise programs.

It is also necessary to mention the effect of eating habits or vitamin supplementation on BMD. Our research did not monitor and influence the participants' eating habits, which could have influenced the intervention results. The European guidance for diagnosing and managing osteoporosis in postmenopausal women recommends a daily intake of at least 1000 mg/day for calcium and 800 IU/day for vitamin D for women over 50 years of age (Rizzoli, 2014). It is suggested that there is possibly an influence of BMD even in adults by calcium and vitamin D intake. Indeed, the study focused on postmenopausal women (n=36000); BMD in the hip was slightly higher in the supplementation group than in the placebo group (Jackson, 2006). Additionally, a meta-analysis from the National Osteoporosis Foundation showed a 15% reduction in risk of total fractures and a 30% reduction in the risk of hip fractures due to the use of combined calcium and vitamin D supplementation (Weaver, 2017). On the contrary, a recent study in subjects older than 50 years showed that a calcium intake below 400 mg/day was associated with lower BMD and femoral cortical thickness, while a calcium intake above 1200 mg/day positively correlated with a higher BMD (Kim, 2014). Furthermore, some studies and meta-analyses focused on vitamin D supplementation in combination with resistance training protocol in the elderly (Kemmler et al., 2020, Antoniak, 2017). The experimental group (EG) with the exercise intervention (resistance training two times a week) and the control group (CG) were adequately supplemented with the recommended doses of protein, calcium, and vitamin D. After 12 months of intervention, the BMD of the lumbar spine and the lean body mass index was maintained in the EG and decreased significantly in the CG, resulting in significant differences between groups. Total hip BMD changes did not differ significantly between groups. However, changes in maximum lower extremity strength were much more prominent in the EG (Kemmler et al., 2020). Meta-analysis has suggested the effect of vitamin D supplementation in combination with resistance training in older adults. There were three groups (vitamin D and exercise, exercise alone, vitamin D supplementation alone). The additive effect of resistance training and vitamin D supplementation on muscle strength parameters was provided in the experimental group (Antoniak, 2017).

The influence of genetics is another factor that can affect the results. It is known that bone mass density can also be affected by a genetic factor, but heredity impacts decrease dramatically with age. Moreover, many genetic variables have not yet been discovered (Trajanoska, 2019; Ralston, 2010) which limits any assumptions.

Although our study did not confirm the positive impact of our intervention programmes on our parameters, the increasing values of BMD or T-score, as well as the steady state of bones in our study must be mentioned. This is a positive result in older adults.

Conclusion

The article aimed to compare the effect of two intervention programmes on BMD and T-score values in older women aged 60 - 65 years. Twenty-nine women underwent ten-week ongoing intervention programmes of WB-EMS (once a week) and resistance training (twice a week).
Even though the results were not statistically significant neither in the WB-EMS group nor in the resistance training group, we consider the effect of programs on the level of bone mineral density positive. As results show, the resistance training method is a little more practical. The tested subjects, included in the resistance training programme, reported the same or higher level of bone mineral density in post-test in comparison with the WB-EMS method (RT 50% vs WB-EMS 44,7%). Excellent results were found in the control group with 72,2% of tested subjects reaching the same or higher-level BMD post-test. It is essential to mention the noticeably better results of this group already in the pre-test. Subsequent longer-lasting research could be aimed at the influence of these two types of intervention programmes in connection with calcium or vitamin D intake.

Besides the effect of the WB-EMS and resistance training programs on the examined parameters, we find it very important to underline the social impact of both experimental programmes. All participants of the study assessed both programmes as valuable and pleasant due to new experiences with unknown types of physical activity and, last but not least, the possibility to meet new people and make friends. Some of them have continued to practice physical activity.

Study limitations
The higher number of participants and the longer duration of the IP would contribute to more objective results.

Conflict of interest
There are no conflicts of interest concerning this paper.

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