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The Effect of Exercise on Bone Mineral Density, Bone Markers and Postural Stability in Subjects with Osteoporosis

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1. Introduction

1.1 Osteoporosis

Osteoporosis, as one of the major causes of disability, morbidity and mortality in older people, is currently considered as a global socioeconomic problem that is increasing in severity and frequency (Dontas & Yiannakopoulos, 2007).

1.1.1 Factors affecting osteoporosis incidence

The diagnosis of osteoporosis is based on the measurement of bone mineral density (BMD), which accounts for 70% of the bone strength, and is, therefore, a good indicator of an impending risk of fracture (Wilkins & Birge, 2005). According to World Health Organization, BMD values are divided into three groups: normal BMD (T-score up to -1.0 standard deviation (SD)), osteopenia (T-score between -1.0 and -2.4 SD), osteoporosis (T-score -2.5 SD and below). Wilkins and Birge (2005) presented these factors as contributing to reduced BMD: nonmodifiable – advanced age, female sex, white/asian race, family history of osteoporosis, family history of hip fracture, lactose intolerance, metabolic disorders affecting the skeleton, certain malignancies (myeloma, lymphoma), and modifiable – smoking, low calcium intake, low vitamin D intake/sunlight exposure, sedentary lifestyle, low body weight, stress/depression, surgical or drug induced hypogonadism, and glucocorticoid therapy.
The risk of fracture is considered as age-related. There are two main reasons: age-related decrease in bone mineral density of the proximal femur and the age-related increase in falls which is associated with worsening balance (Dontas & Yiannakopoulos, 2007).

1.1.2 Effect of physical activity on BMD

Intervention strategies for osteoporosis are based on a combination of pharmacological agents, nutrition and a suitable physical activity (Melendez-Ortega, 2007).
When determining the effect of movement (overcoming gravitational force) on the quality of bone tissue, three basic mechanisms are applied: activation of osteoblasts, storing Ca^{+2} ions

on the bone surface, and increase in the bone substance required for ossification (Němcová & Korsa, 2008).
The results of studies focused on the effect of physical activity on changes in the quality of bone tissue vary. Englund et al. (2005) present the direct effect of weight-bearing training programme on improvement in BMD. Kemmler et al. (2004), Kerry (2003), Uusi-Rasi et al. (2003) and others didn't find the effect of exercise on BMD in postmenopausal women. The results, which were presented in the study of Bloomfield (2005), indicate that exercise may minimize or even stop the bones losing weight in postmenopausal women. However, it does not substitute pharmacological agents nor does it ensure increase in BMD.

1.2 Balance

The human body in standing can be described as a naturally unstable system. The complexity and instability of this system is given by a large number of mobile segments (Véle, 1996) and also by the fact that in standing, 2/3 of body mass is at 2/3 of the individual's height above ground (Winter, 1995).

1.2.1 Factors influencing balance

Besides low bone mineral density, also poor stability contributes to increased risk of fractures associated with a fall (Winters & Snow, 2000).
The basic factors affecting balance include the quality of sensory inputs (vestibular, eyes, tactile, proprioreception …), neural control (central nervous system) and the effectors (muscles, bones …).
Poulain and Giraudet (2008) proved the existence of greater visual sensitivity in posture control from 44 years of age. They also showed that the measurement of the role of vision in posture control among subjects aged 44–60 years strongly depends on the task performed.
The effect of ageing and vision on limb load asymmetry during a quiet stance was observed by Blaszczyk et al. (2000). Their observations may indicate that increased limb load asymmetry in the elderly is a consequence of many kinds of compensatory changes in postural stability control.
Some studies have shown that postural stability is also affected by anthropometric parameters. Chiari et al. (2002) suggested that some anthropometric measurements and standardization or tracing foot position could be considered. The study by Hue et al. (2007) shows that increase in body weight correlates with higher balance instability.
The effect of local fatigue was observed by Caron (2004). The main result of this study was that local fatigue of the lower limbs produced similar effects on postural control and postural stability in the standing with a more pronounced increase in neuromuscular activity with the eyes open as compared to eyes closed.
Hlavačková et al. (2009) suggested that elderly people with some limb deficiencies (transfemoral amputees) were able to integrate augmented visual biofeedback through the use of mirror-reflected body image to improve their stance control during quiet standing.

1.2.2 Balance evaluation

Clinical assessment of balance

The main purpose of the clinical balance assessment is to identify whether or not a balance problem exists and whether treatment is needed (Horak, 1997).

An often used instrument for balance evaluation is "The Berg Balance Test". This test consists of 14 functional subtests with a maximum of 4 points (normal performance) and a minimum of 0 points (no performance) (Berg et al., 1989).
Horak et al. (2009) created "The balance evaluation systems test (BESTest)" to differentiate between balance deficits. This test encompasses six areas:

- biomechanical constraints,
- stability limits/verticality,
- anticipatory postural adjustments,
- postural responses,
- sensory orientation,
- and stability in gait.

Posturography

Instrumental measurement of balance can be performed by posturography, which, by means of force platforms, analyses the centre of pressure (COP) movement on various types of stands. The basic measured parameters are the area of confidence ellipse, the length of COP trajectory, sway of COP and its velocity in the antero-posterior and medio-lateral direction.
In recent years, the focus of attention has been especially on the character of a task being handled and on data analysis. When looking to predict falls, stability evaluation in quasistatic and dynamic situations is better. The basic tasks here are:

- reaction to tripping of a force platform,
- solution when using a dual task,
- testing the stability limits,
- targeted modification of sensory inputs,
- and testing a stand in varying conditions.

Measurement accuracy and reliability

A review of the test–retest reliability of the centre of pressure measurements in the bipedal static condition was presented by Ruhe et al. (2010). They mentioned that the reliability of the traditional COP parameters can be acceptable; however, it depends primarily on factors such as the number of trial recordings and the duration rather than the selection of particular COP parameters. They also recommend that care should be taken to assess the subject's physical status and anthropometric properties prior to the measurements.
Le Clair and Riach (1996) demonstrated that the test duration affects the measurement of postural sway, with 10 s being the least reliable. They also reported that COP, force, and velocity measurements are reliable in retest situations and that only one trial is necessary to obtain reliable measurements.
On the contrary, the results of the theory analysis (Doyle et al., 2007) suggest that COP measurements reached acceptable levels of reliability with at least five 60 s trials.

1.3 Fall risks

One of the biggest problems in people with osteoporosis is an increase in the risk of fall. Patients with osteoporosis do not have a good level of stability and have less muscular strength. This makes the risk of fall a lot higher than in individuals without this illness (Park et al., 2008). Regular balance, strength training and diet supplementation with vitamin D and calcium are important in falls prevention (Kannus et al., 2005).

Reduction of the risk of fall requires identification of the individual with risk of fall and identification of the modifiable risk factors (Wilkins & Birge, 2005).

Causes of falls

Four major categories of the causes of falls were defined by Lach et al. (1991):
- falls related to extrinsic factors,
- falls related to intrinsic factors,
- falls from a non-bipedal stance,
- and unclassified falls.

Extrinsic factors pertain to environmental hazards such as loose carpeting, stairs, and poor footwear or lighting. Intrinsic factors are conditions that relate directly to a specific person such as dizziness, use of medication, osteoporosis, and arthritis (Hale et al., 1992).

A comprehensive prospective study concerning the risks associated with falls in older men was performed by Chan et al. (2007). They found that leg extension power, grip strength, and activity level are significant determinants in assessing the risk of fall. The authors also reported increased activity being associated with higher risk of fall; household activities were associated with the risk whereas leisure activities were not.

Measuring falls

Hauer et al. (2006) presented a systematic review of the definitions and methods of measuring falls in randomised controlled fall prevention trials. Studies focused on assessing the risk of fall have brought forward many issues, one of them being an inconclusive definition of the term “fall” itself. Additionally, the method used in the studies to report falls remains problematic and highly inconsistent. For future research, they recommend a comprehensive and non-exclusive definition of a fall.

Evaluation of the risks of fall

In order to determine the risk of fall, it is important to firstly render an evaluation of the act. Brauer et al. (2000) presented a prospective study of laboratory and clinical measurements of postural stability to predict fallers in community dwellers. They found out that not all older adults with reduced or compromised balance ability reported a fall over a 6-month period. Therefore, they emphasized the importance of the multifactor nature of falls.

Lord et al. (2003) described the use of a physiological profile approach to falls risk assessment and prevention. This evaluation involves a series of simple tests of vision, peripheral sensation, muscle force, reaction time, and postural sway.

The effect of physical activity on balance and risk of falls

Hourigan et al. (2008) found an increase in strength of the hip joint muscles and trunk extensors by 9-23% as well as significant improvement in balance after 20 weeks of exercise. Wendlová (2008) states an increase in muscular strength, improved possibility of reacting to loss of balance and reduced risk of fall as a result of exercising. Vaillant et al. (2006) supplemented exercising for balance development with cognitive tasks. While exercising resulted in improved balance, the use of cognitive tasks brought no further changes.

Karinkanta et al. (2007) analysed four groups with different intervention (resistance training, balance-jumping training, combination of both trainings, and no training) criteria and concluded that training prevented functional decline in home-dwelling elderly women.

For osteoporosis patients, weight-bearing activities, balance exercise and strengthening exercises to reduce fall and fracture risk are recommended (De Kam et al., 2009).

The effect of three types of exercises (resistance training, agility training, and general stretching) on risks of fall and the physical activity level of women with low BMD was observed by Liu-Ambrose et al. (2005). They found significant decrease in the fall risk after a 6-month regimen. Even twelve months after intervention the risks of fall remained significantly lower than before exercising. It is very interesting to note that after all three types of exercise programmes, the benefits remained sustainable for at least 12 months. Thus, these 6-month exercise interventions appeared to act as a catalyst for increasing physical activity with resultant reduction in the fall risk profile.

Exercising leads, above all, to improvement in the medio-lateral direction and individuals are then able to control movement at the hip joints within a greater range and with better results (Nagy et al., 2007). Twiss et al. (2009) found improvements in balance after carrying out yearly exercises focused on the development of muscular strength and weight training. The number of falls in those exercising dropped, though insignificantly. Improvement in balance and quality of life after five weeks of exercising was recorded by Alp et al. (2007).

Multifactor preventive and individually-focused balance programmes may reduce the risk of falls in individuals by 25 to 30% (Dargent-Molina, 2004). Whereas Carter et al. (2001) recorded insignificant differences between the observed group and control group in static and dynamic balance after 10 weeks of exercise intervention.

Swanenburg et al. (2007) observed the effect of a three-month exercise programme that included training for muscular strength, coordination, balance, and endurance when accompanied with nutritional (protein) supplements. They mentioned that the combination of calcium/vitamin D and exercise/protein intervention programme significantly reduced the risk of fall and in addition, these effects lasted for up to 9 months after the end of the intervention programme.

Madureira et al. (2007) compared groups with and without the balance training programme. The percentage of patients in the intervention group whose static balance improved in two sensory conditions (eyes closed, unstable surface; and eyes open, visual conflict, unstable surface) was statistically significant when compared to the control group. Also, significant difference in the functional mobility as well as reduction in the number of falls/patient were observed in the intervention group.

2. Aim

The aim of this study was to assess the effect of exercise on bone mineral density and bone markers in postmenopausal women with osteoporosis and to determine the effect of a specific exercise programme for postural stability.

3. Material and methods

3.1 Characteristics of the group

The tested group included 163 women, patients of the Osteology centre in Zlín, who were randomly divided into groups to perform an exercising programme (n=90) and control (non-exercising) group (n=73). Through a combination of two factors (exercise, specific pharmacological therapy), 6 sub-groups were formed:

1. NEX/NS (n=23, age 57.8±6.05 years): non-exercising group with nonspecific pharmacological therapy (i.e. daily controlled intake of Ca 1000–1500 mg, daily controlled intake of vitamin D3 0.25 μg).

2. EX/NS (n=32, age 59.0±7.11 years): exercising group with nonspecific pharmacological therapy (i.e. daily controlled intake of Ca 1000–1500 mg, daily controlled intake of vitamin D3 0.25 μg).
3. NEX/BP (n=27, age 62.9±7.06 years): non-exercising group with specific pharmacological therapy, suppressing bone resorption (bisphosphonates – Fosamax, controlled intake of Ca, administration of vitamin D3).
4. EX/BP (n=35, age 59.7±7.56 years): exercising group with specific pharmacological therapy, suppressing bone resorption (bisphosphonates – Fosamax, controlled intake of Ca, administration of vitamin D3).
5. NEX/SERM (n=23, age 61.1±6.90 years): non-exercising group with specific pharmacological therapy (selective estrogen receptor modulators – Evista, controlled intake of Ca, administration of vitamin D3).
6. EX/SERM (n=23, age 59.0±6.53 years): exercising group with specific pharmacological therapy (selective estrogen receptor modulators – Evista, controlled intake of Ca, administration of vitamin D3).

3.2 Exercise

Exercise intervention was divided into three parts:

1. Three-week institutionalised exercise intervention in a rehabilitation centre focused on changing posture, adjustment of joint mobility, adjustment of muscle imbalance, coordination and postural correction, relaxing of shortened muscle groups and soft tissues, activation of muscles in the area of axis system, deep stabilization system and extremities, breathing exercises and coordination training, training for activity of daily living and training for walking.
2. Three-month controlled group exercise programme focused on motivating and educating patients towards active approach; once a week of low intensity and of 50 min duration.
3. Daily exercise programme at home lasting 30 minutes, supplemented with walking of minimum 60 min duration.

In the further phase of the research, we evaluated the effect of long-term exercise on postural stability. The observed group consisted of 43 women, which were divided into a group with long-term exercise programme (n=29, age 64.6±4.52 years) and the control group (n=14, age 65.5±4.98 years). Sample size was influenced by agreement of subjects with follow-up to research and limitations of workplace for application of the special exercise. The group went through controlled exercise intervention of low intensity for 50 minutes per week for a period of one year. The exercise unit was focused on maintaining and improving the quality of sensorimotor functions and postural strategies and was also completed by an hour daily home exercises. The progression of exercise consisted in repetition of a selected exercise pattern and in the change of position, i.e. transition from a lower to a higher position. The aim of the exercise in such easier and more demanding positions was to adjust and improve the quality of the respiratory mechanics, postural pattern and motor functions. Exercising in the vertical position was stipulated for adaptation to various types of stands, exercising balance strategies, and enabled an increased self-confidence for motion in space.

3.3 Measurement process, technical equipment, measured parameters

The bone mineral density was measured by the LUNAR-DPX device (GE Healthcare, Madison, WI, USA) and bone markers were determined by ETI-MAX 3000 (Diasorin S.p.A., Saluggia, Italy). The biochemical parameters were evaluated using VITROS 250 (Ortho-Clinical Diagnostics, Rochester, NY, USA) analyser.

For all patient groups, the baseline values of bone density (BMD L1-L4, BMD femoral neck) and bone markers (Ca, P, creatinine, ALP, ALP isoenzyme, osteocalcin, crosslaps) were measured at the beginning of research. For ascertaining the bone marker values, measurement was repeated after 3 weeks and 3 months. The last measurement in the range of baseline measurement was performed after 1 year of starting the research.

In the second phase of the research, all measured women repeatedly completed the six basic types of stands (eyes open, eyes closed, head extension, standing on foam, tandem stand twice), whereas each such stand was of 30 s duration. The feet position during such stand (with the exception of tandem stand) was set at pelvic width (the distance between the anterior superior iliac spines).

Two Kistler piezoelectric platforms, type 9286AA (Kistler Instrumente AG, Winterthur, Switzerland) were used for evaluating postural stability. The changes in the load on the lower limbs during standing as well as changes to the centre of pressure (COP) displacement (postural sway of COP and its velocity in antero-posterior and in medio-lateral directions) were determined by the software Bioware, version 3.2.6.104.

3.4 Statistical data processing

The measured data was processed by the Statistica 8.0 (StatSoft, Inc., Tulsa, OK, USA) programme. In order to compare the impact of exercise on BMD and bone markers, one-way ANOVA with Fisher's post-hoc test were used. The comparison of differences between the exercising and control groups upon evaluating postural stability was performed by means of t-test for independent groups. Any p-value less than 0.05 was deemed significant.

4. Results

4.1 Bone mineral density, bone markers

The basic statistical characteristics of the measured parameters for non-exercising groups as well as groups undergoing the intervention programme are stated in Tables 1 and 2.

BMD L1-L4 (Fig. 1)

During the monitored period, statistically significant increase in BMD L1-L4 value occurred in all measured groups with the exception of EX/SERM. A higher increase in BMD L1-L4 occurred in persons who did not undergo the targeted exercise intervention. The highest increase was recorded in NEX/BP and NEX/SERM. The difference in values between the groups with same medication is not statistically significant at baseline and after 1 year with $p<0.05$.

BMD femoral neck (Fig. 2)

Increase in the value of BMD femoral neck occurred in all measured groups with the exception of EX/NS. The extent of changes is comparable in the exercising as well as in the non-exercising patients. This increase is statistically significant in NEX/BP, EX/BP and NEX/SERM. Between groups with the same medication, there is a statistically significant difference at baseline and after 1 year measurements for NEX/BP (7.1%) and EX/BP (7.6%).

		NEX/NS (n=23)	NEX/BP (n=27)	NEX/SERM (n=23)
Age at baseline		57.8±6.05	59.7±7.56	59.0±6.53
Height (cm)		162.1±6.09	158.7±5.74	158.2±5.05
Weight (kg)	baseline	72.2±8.67	64.9±9.00	65.2±10.05
	1 year	73.6±8.68	66.1±8.65	65.2±9.37
BMD L1-L4 (g/cm²)	baseline	0.99±0.089	0.92±0.110	0.93±0.089
	1 year	1.03±0.107	0.97±0.110	0.98±0.102
BMD femoral neck (g/cm²)	baseline	0.93±0.115	0.91±0.115	0.87±0.082
	1 year	0.94±0.109	0.93±0.111	0.88±0.080
Calcium (mmol/l)	baseline	2.36±0.112	2.42±0.167	2.39±0.060
	1 year	2.38±0.113	2.41±0.133	2.48±0.154
Phosphorus (mmol/l)	baseline	1.11±0.164	1.12±0.232	1.11±0.205
	1 year	1.06±0.162	1.08±0.166	1.07±0.151
Creatinine (μmol/l)	baseline	81.2±10.21	83.2±10.06	78.4±11.16
	1 year	79.0±12.78	79.0±9.09	75.3±16.08
ALP (μkat/l)	baseline	1.09±0.409	1.28±0.481	1.17±0.383
	1 year	1.03±0.317	1.03±0.358	1.01±0.263
ALP isoenzyme (μkat/l)	baseline	0.54±0.008	0.53±0.011	0.54±0.006
	1 year	0.54±0.007	0.53±0.042	0.53±0.029
Osteocalcin (ng/ml)	baseline	25.0±19.20	30.0±26.51	21.3±12.72
	1 year	19.0±10.88	20.1±30.77	13.8±6.18
Crosslaps (ng/ml)	baseline	0.46±0.246	0.63±0.449	0.45±0.209
	1 year	0.37±0.190	0.42±0.652	0.31±0.167

Table 1. Characteristics of measured parameters for the non-exercising groups (Mean ± SD)

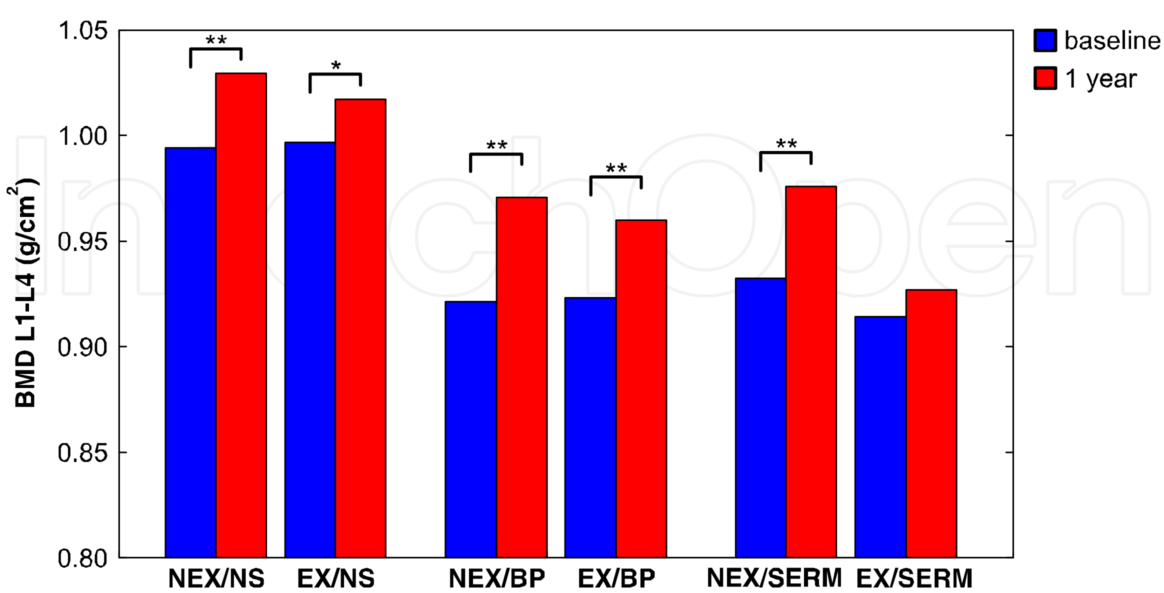

Fig. 1. Changes between the baseline and after 1 year measurements – BMD L1-L4 (* $p<0.05$, ** $p<0.01$)

		EX/NS (n=32)	EX/BP (n=35)	EX/SERM (n=23)
Age at baseline		59.0±7.11	62.9±7.06	61.1±6.90
Height (cm)		161.2±6.48	159.4±6.02	158.3±7.17
Weight (kg)	baseline	73.0±13.49	65.4±8.55	68.2±10.84
	1 year	72.6±13.36	66.0±8.50	68.4±11.01
BMD L1-L4 (g/cm^2)	baseline	1.00±0.079	0.92±0.114	0.91±0.147
	1 year	1.02±0.086	0.96±0.110	0.93±0.151
BMD femoral neck (g/cm^2)	baseline	0.94±0.093	0.85±0.123	0.85±0.148
	1 year	0.94±0.091	0.86±0.129	0.86±0.140
Calcium (mmol/l)	baseline	2.40±0.109	2.37±0.101	2.42±0.180
	1 year	2.38±0.093	2.41±0.158	2.34±0.112
Phosphorus (mmol/l)	baseline	1.02±0.162	1.02±0.129	1.05±0.130
	1 year	1.06±0.167	1.05±0.115	1.06±0.171
Creatinine (μmol/l)	baseline	80.0±12.46	81.7±9.13	79.4±9.60
	1 year	81.4±16.61	81.4±12.08	79.2±11.90
ALP (μkat/l)	baseline	1.15±0.437	1.09±0.320	1.10±0.309
	1 year	1.13±0.490	1.01±0.265	1.19±0.461
ALP isoenzyme (μkat/l)	baseline	0.54±0.005	0.53±0.007	0.54±0.006
	1 year	0.52±0.043	0.53±0.008	0.53±0.010
Osteocalcin (ng/ml)	baseline	14.7±10.55	17.6±17.72	18.0±10.44
	1 year	16.9±15.00	11.5±5.41	18.7±8.79
Crosslaps (ng/ml)	baseline	0.33±0.168	0.33±0.199	0.39±0.223
	1 year	0.38±0.198	0.27±0.170	0.45±0.187

Table 2. Characteristics of measured parameters for the groups performing the targeted exercise intervention (Mean ± SD)

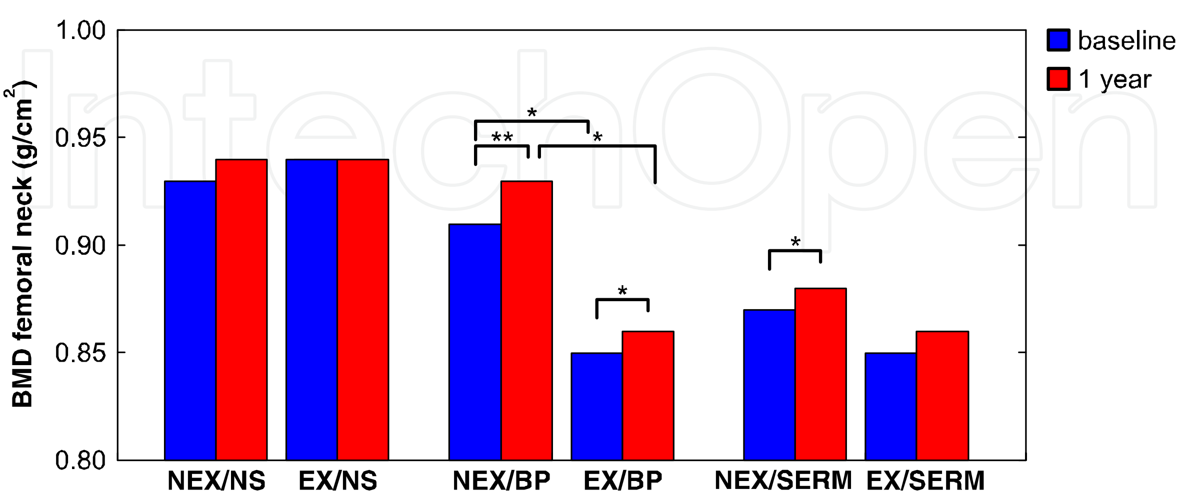

Fig. 2. Changes between the baseline and after 1 year measurements – BMD femoral neck (* $p<0.05$, ** $p<0.01$)

Calcium

Differences between baseline and after 1 year measurements are statistically insignificant, when compared for the exercising and non-exercising patients, with the exception of NEX/SERM. In this group, there was an increase in Ca during the entire period of monitoring; differences are also significant in the measurements after 3 weeks or 3 months in comparison with the values measured after 1 year.

Phosphorus

When comparing groups with the same medication, the value measured at baseline was significantly lower in groups of patients that were starting exercise intervention. Such difference was not found in any other measurements.

Creatinine

In NEX/BP and NEX/SERM, statistically significant decrease ($p<0.05$) in the value of this parameter occurred after 1 year. Throughout the entire period, no significant differences were found in groups undergoing targeted intervention.

ALP (Fig. 3)

In NEX/BP and EX/BP decrease in ALP value occurred during the monitored period. Differences between baseline and after 1 year measurements are significant (NEX/BP, $p<0.01$). A similar result is also valid for NEX/SERM where the parameter had a declining tendency throughout the entire monitored period.

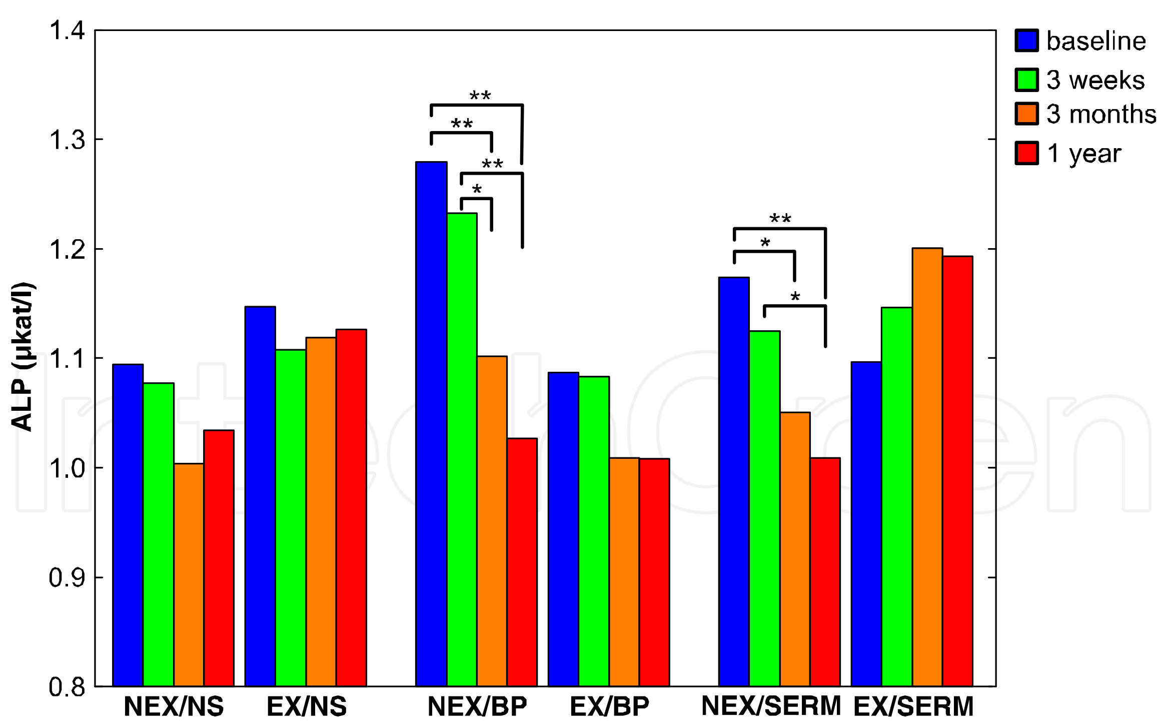

Fig. 3. Changes of the ALP in the course of the monitored period (* $p<0.05$, ** $p<0.01$)

ALP isoenzyme

With the exception of EX/NS, differences in the values between individual measurements in all other groups were not statistically significant at level $p<0.05$.

Osteocalcin (Fig. 4)

In groups with the same medication, the value at baseline is higher in patients, who did not undergo exercise intervention. No significant difference was recorded at measurement after 1 year. Throughout the monitored period, a significant reduction in this parameter occurred in NEX/NS, NEX/BP and NEX/SERM. A similar result was also valid for EX/BP.

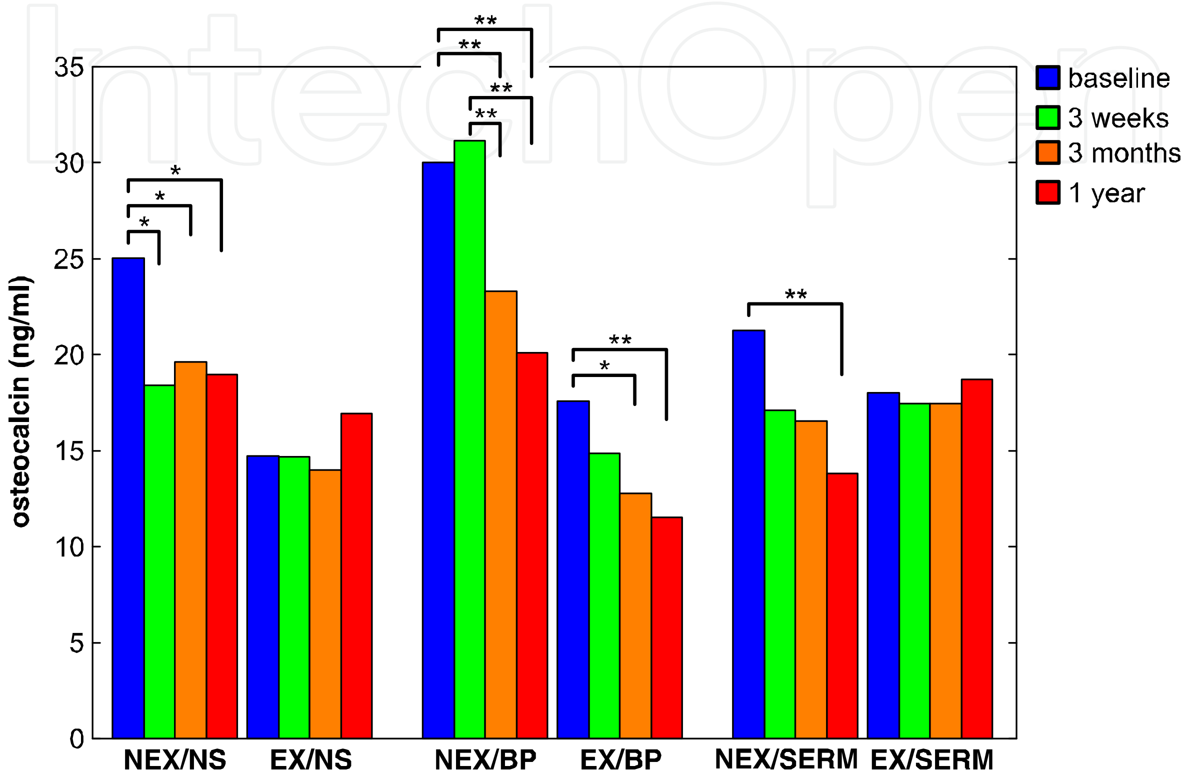

Fig. 4. Changes of osteocalcin in the course of the monitored period (* $p<0.05$, ** $p<0.01$)

Crosslaps

At baseline, the parameter was significantly higher in patients who did not undergo exercise intervention in comparison to the group of exercising patients. This difference was not recorded at measurement after 1 year. The decrease in value for the monitored period is significant for NEX/BP ($p<0.05$) and NEX/SERM ($p<0.01$).

4.2 Postural stability evaluation

No differences in weight-bearing distribution between the left and right lower extremity were found in any measured group or individual type of stand. Differences vary between 0.09 and 0.56% in the group of exercising and between 0.13 and 1.68% in the group of non-exercising patients.

Amongst both groups, we found no significant differences in COP sway in any directions measured for individual types of stand. In the group of non-exercising patients, faster change in COP position in the medio-lateral direction ($p<0.05$) occurs when standing with eyes closed, and such changes are reflected in higher resulting velocity of COP movement ($p<0.05$). A similar result applies to the velocity of COP in the antero-posterior direction, and for the resulting velocity of COP when standing on foam (Fig. 5).

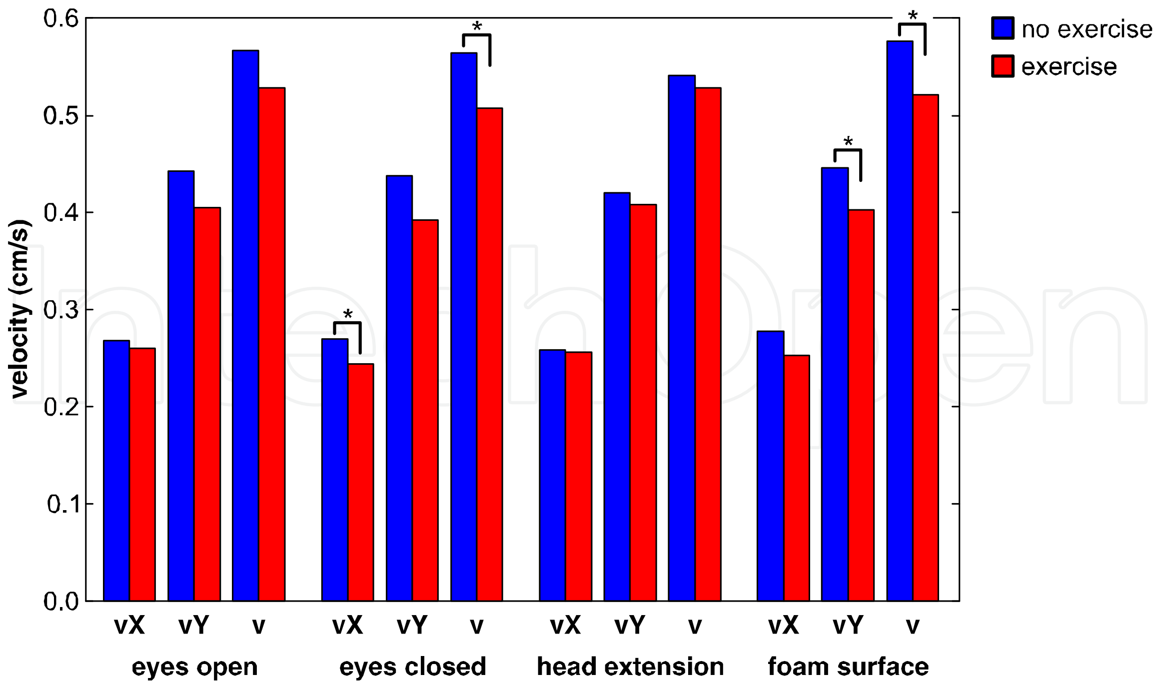

Fig. 5. The COP velocity in different types of stands for exercising and non-exercising patients (vX – COP velocity in medio-lateral direction, vY – COP velocity in antero-posterior direction, v – resultant COP velocity, * $p<0.05$, ** $p<0.01$)

With the exception of standard deviation for COP movement in the antero-posterior direction at stand with eyes open and stand on foam in the group of exercising patients, we found no significant differences ($p<0.05$). The exclusion of visual control or head extension thereby did not reflect in the change(s) of the measured parameters.

5. Discussion

5.1 Exercise, medication and bone mineral density

In order to maintain desirable optimal amount of BMD, it is required to keep an optimal level of tension relating to functional load given by physical activity (Melendez-Ortega, 2007). Mechanic load, induced in the course of exercise, is essential for adaptation of bone architecture in the place of the load (Vainionpää et al., 2005). That is the reason why movement is a significant element in prevention and treatment of osteoporosis.

5.1.1 Effect of exercise on postmenopausal bone

From the results of our study follows that BMD was increased in all participants who were involved in the exercise intervention. The changes are, however, not significantly higher in comparison with the non-exercising groups. For bone density of the colli femoris (BMD femoral neck), the increase was smaller than in the area of lumbar spine (BMD L1-L4) for all types of medications.

Opinions of authors concerning the effect of exercise on the quality of bone tissue vary. The effect of exercise on regional BMD in postmenopausal women was evaluated by Kelley (1998). Across all designs and categories, treatment effect changes in bone density ranged from -17.10 to 17.30%. Meta-analytic review of included studies suggests that exercise may slow the rate of bone loss in this group of patients.

The results of Angin and Erden (2009) demonstrate positive influence of the exercise program in increasing BMD and quality of life. The efficacy of a 5-year exercise program on the BMD and balance was investigated by Walker et al. (2000). For the post-menopausal women with osteoporosis who participated in the program it was possible to stabilize the BMD of the lumbar site, and to reduce fractures. Lange et al. (2007) presented that physical activity has a decelerating effect on the bone loss rate in postmenopausal women, independent of hormone replacement therapy. A significant increase in BMD and decrease in bone markers was found by Ďurišová and Zvarka (2004) in both exercise and control group. Authors state that regular exercise should become an important component of the comprehensive management of osteoporosis. Bergström et al. (2008) indicated a positive effect of physical training on hip BMD. No significant effect of exercise was found in the lumbar spine.

The effect of exercise on BMD can be influenced by its type, intensity and frequency. Kerr et al. (1996) examined the effect of a 1-year progressive resistance training program (strength and endurance group) on bone mass. They state that postmenopausal bone mass can be significantly increased by strength exercise with high-load low repetitions. For an endurance regimen this change was not established. On the contrary, Bemben and Bemben (2011) found positive BMD responses for the hip and spine (not for the total body) for all types of resistance training, regardless of intensity and frequency.

The effect of exercise over a period of 3 years on stopping or decelerating of bone loss during the early postmenopausal years was assessed by Engelke et al. (2006). The application of the high-intensity exercise program succeeded to maintain bone mineral density at the spine, hip and calcaneus, but not at the forearm. Chow et al. (1987) evaluated the effect of 1-year aerobic and strength exercise programmes on bone mass. They found that both exercise groups showed a significant improvement in measured parameters. The effect of a 2-year exercise intervention and calcium supplementation (600 mg) on BMD was assessed by Kerr et al. (2001). Three groups of patients (strength, fitness, no exercise control) participated at this study. There was no difference between the groups at the forearm, lumbar spine, or whole body sites. The significant effect of the strength program was found at the hip (intertrochanter hip site). Judge et al. (2005) tested the effect of the resistance home-based training on the femoral BMD in long-term users of hormone therapy. The exercise decreased bone turnover and increased femur BMD. Korpelainen et al. (2006) didn't found the effect of long-term impact exercise on BMD at the radius and hip, while there was a positive effect on bone mineral content at the trochanter. High-impact loading exercise in osteopenic postmenopausal women was assessed by Chien et al. (2000) and Vainionpää et al. (2005). A 24-week program had a positive effect on the deceleration of the decline in BMD (Chien et al., 2000). Vainionpää et al. (2005) suggested that this type of exercise may be an efficient way to prevent osteoporosis. Martyn-St James and Carroll (2009) assessed the effects of mixed exercise programmes on postmenopausal bone loss at the hip and spine. The exercise programmes combining jogging with other low-impact loading activity and programmes mixing impact activity with high-magnitude exercise could be effective in reducing bone loss at the hip and spine. The effects of slow (strength) and fast (power) resistance exercises on various osteodensitometric parameters were compared by Von Stengel et al. (2005) and Von Stengel et al. (2007). The changes in BMD after 1 year of training were not significant for the power exercise group, whereas the BMD value in strength exercise group was significantly lower.

A comparison of the effect of exercise on BMD in postmenopausal women described in various studies is very difficult because of different number of subjects, exercise intensity, type of exercise, medication etc. In future research it will be necessary to exactly determine all factors involved and attempt to assess their influence on research results. Physical activity should be observed not only during exercise units but also during ordinary daily activities. However, results of most studies show that exercise has an important positive effect on the deceleration of decline in BMD.

5.1.2 Type, intensity and method of exercise

In order to evaluate the effect of physical activity on the change of bone markers, it is also important to take into consideration its parameters (type, intensity, duration …). In our case the exercise was of a lower intensity and was focused mainly on rehabilitation. And so the major effect did not lie in changing the physiology of the load but rather in improving body posture, adjusting muscle imbalances and postural stability.

Melendez-Ortega (2007) states that the amplitude of the load plays a more important role for bone density than number of repetitions. Repeated strain of bones above the physiological limit might lead to injury or even bone fracture. Englund et al. (2005) and other authors regard long-term weight-bearing training as the most suitable activity influencing the BMD. Vainionpää et al. (2005) proved that this type of exercise not only affects the bone density but also improves its architecture. To the contrary, Schwab and Klein (2008) claim that short repetitive loading of the bone has a positive impact on the biology of the bone.

Intensive aerobic activity, heavy-load and resistance exercises are, according to Yamazaki et al. (2004), much more effective in increasing BMD than physical activity with lower intensity (e.g. slow walking). Similar results were ascertained by Maddalozzo and Snow (2000) who believed that the highest effect is brought through a programme with high intensity of exercises. Heinonen et al. (1996) and Chien et al. (2000) determined that intensity of physical activity should hover above the aerobic threshold, i.e. above 60-70% of maximum aerobic capacity.

Brooke-Wavell et al. (2001), Yamazaki et al. (2004) and other authors recommend walking as a suitable activity for increasing bone density. Walking is the easiest and best available form of physical activity, which can be practiced virtually anywhere, poses only small risks of injury and requires negligible financial demands (it is, however, necessary to take into account risks of fall on uneven or slippery terrains). The most effective method of prevention of osteoporosis is brisk walking (Brooke-Wavell at al., 2001). Feskanich et al. (2002) point out, however, at increasing risks of fall at higher walking speed. Nevertheless, there exist studies which did not prove effect of walking on the increase of BMD (Martyn-St James & Carroll, 2008).

Exercise regimes encompassing a combination of weight-bearing, balance and coordination exercises but excluding jumping activities, improve BMD, enhance muscular strength and walking ability and thus reduce the risks of fall and suffering consequent fractures (Englund et al., 2005). According to Feskanich et al. (2002), activities improving balance and flexibility significantly contribute to reducing the risks of fall, whereas heavy-load and resistance exercises enhance muscular strength and BMD.

One of the shortcomings of the presented study is its limited scope of quantifying physical activity performed by women in the course of the monitored period. Common daily activities can have the same or even higher impact than directed exercise intervention. A survey conducted within the study research, whose rate of return was, however, only approx. 25%, showed that in the run of one day, every woman had on average about 4.5 hours of physical activity (walking 1.2 hr; tidying up/cleaning 1.2 hr; meal preparation 1.1 hr; gardening 0.7 hr; shopping 0.3 hr).

Regrettably, these common everyday activities of monitored women are, in many studies, neither taken into account nor specified nor quantified. Most authors limit themselves to stating that the monitored applicants lead a sedentary type of life. It is, however, evident that such a definition of the level of everyday activities may not be sufficient.

Williams (1999) claims that women who never exercised can increase their BMD through physical training by 3-5% per year. Women who exercised regularly already have higher BMD and in order to maintain this level, they have to walk or run for 30 min a day, at least 5 times a week. The individual extent of physical activity in monitored patients can differ significantly with regards to the previous style of life. Kerry (2003) did not find any positive effect of physical activities related to house chores on the quality of bone tissue. On the other hand, most other researches do confirm the above-mentioned positive effect.

5.1.3 Medication

In the event that a patient does not suffer from any associated health disorder and is sufficiently hydrated, we do not expect significant changes in values of Ca, P and creatinine brought about by medications. Indicators of Ca and P do not have any direct relation to the level of bone remodelling (Štěpán et al., 2002). Changes in the values of osteocalcin and crosslaps express the activity of bone metabolism. In this case, a wide range of physiological values can be found, determining the standards in post-menopausal women (0.251-0.760 ng/ml resp. 4.9-30.5 ng/ml). It follows that it is necessary to evaluate measured changes in a strictly individual way. We have to keep this in mind also when evaluating statistically significant differences. Application of bisphosphonates (NEX/BP, EX/BP) is the most effective means for reduction of resorption expressed by the crosslaps parameter. Application of selective modulator (ralofixen; NEX/SERM, EX/SERM) influences these changes less and after a longer period of time. The decisive element is, however, a particular individuality of the given patient.

Some authors regard, as the most effective way to prevent loss of BMD, the combination of physical activity and hormonal treatment (Angin & Erden, 2009; Yamazaki et al., 2004). Specker (1996) claims that in order to create positive effect of physical activity on BMD, exercise must be complemented by application of calcium.

Results presented in this study confirm the opinion that exercise can in women after menopause minimize or inhibit the loss of BMD, it cannot, however, substitute pharmacological treatment and ensure increase in BMD (Bloomfield, 2005).

5.2 Exercise and balance

Risks of fall count among the most momentous problems in people with osteoporosis. Decrease of BMD of colli femoris in elderly people increases the risks of occurrence of fractures up to 2.6 times (Cummings et al., 1993). Awareness of the risks of fall can lead to intentional decrease in daily living activities, which is reflected in reduction of life quality. That is why it is essential to try and improve, using non-invasive interventions, the level of postural stability. One of the options bearing positive impact on improving balance control is regular physical activity.

Among interventions focused on reduction of the risks of fall counts, among others, training of balance keeping and walking (Messinger-Rapport & Thacker, 2003). For better stability, balance training is more effective than general exercise programmes including merely aerobic, weight-bearing or stretching activities (Rogers et al., 2003; Madureira et al., 2007).

In order to evaluate the stability in various modifications of stand, we used parameters of confidence ellipses created on the basis of COP movement. Differences in sizes of COP sway between both monitored groups are not significant. These findings differ from conclusions of other authors.

Effect of physical activity on improving balance and quality of postural stability is reported by Binder et al. (1994), Hopkins et al. (1990) and Gerdhem et al. (2003). Reducing COP sway after performing targeted exercises was noted by Perrin et al. (1999). Park et al. (2008) inquired into the effect of physical activity (48 weeks) on balance and compared postural sway between participants who did or did not do exercises. He found a significant difference in the COP sway in medio-lateral direction, whereas antero-posterior sway remained unchanged. Kuczyński & Ostrowska (2006) recorded the size of COP sway in medio-lateral direction higher by 50% in patients with osteoporosis than in healthy individuals. These authors also discovered that medio-lateral sways are higher in people who had fallen at least once in the past than in people without such history. Limitation or loss of lateral stability thus increases the probability of fall occurrence (Melzer et al., 2004). According to Hu and Woollacott (1994), multisensory training influences postural stability in a form of improving its parameters, among others, also when standing with head extended.

Differences in size of COP sway measured in our study, which are different from trends in the above-mentioned studies, can be caused by low demands of selected types of postures and by incoherence of the monitored group. The group was put together on the basis of diagnostics of osteoporosis or osteopenia, excluding women with neurological, cognitive and sensory disorders. When putting the groups together, associated disorders and occurrence of suffered injuries in the past were not taken into account. The monitored group represents just a small sample and the numbers of women in the exercising and non-exercising groups were not even.

Conclusions concerning deterioration of posture stability with closed eyes, which were ascertained for various groups of population, from few-month-old babies (Jouen, 1988) up to elderly people (Lord & Menz, 2000) were not confirmed. Influence of vision is further accentuated also in situations when the proprioceptive element of the stability control is reduced (Redfern et al., 2001).

Unlike the size of COP sways, effect of balance exercises was discovered for the speed of COP sway. In the stance with closed eyes and stance on foam, the exercising group significantly reduced speed of COP sway in comparison with the non-exercising group. Significant differences in reduction of the COP velocity in the exercising group were found also by Rogers et al. (2001).

Postural stability decreases with increasing asymmetry in distribution of physical weight (Genthon & Rougier, 2005). In our study, we did not find any significant differences between weight-bearing distribution on left and right legs in individual types of stands in any of the measured groups. Ascertained differences are significantly lower than the size

10%, which is considered as marginal for determining the asymmetry of weight-bearing (Véle, 1995).

5.3 Future research

Similar researches stated in literature do not pay sufficient attention to analysing daily living activities of patients. But in fact, the style of life of the monitored women can significantly influence obtained results. That is why it is necessary for any further research to evaluate physical activities performed above the scope of the targeted intervention. In order to determine their range and intensity, devices enabling quantification of these parameters should be employed.

In our research, the final measurements were conducted one year after the initial measurements, i.e. in the same season of the year. In the event of control measurements, which are conducted in shorter time intervals or under significantly different climatic conditions, it is important to determine the effect of these changes on the measured parameters.

Taking into account the level of motor skills and fitness of monitored people, it is necessary, when evaluating postural stability, to perform more demanding motor tasks (while abiding by all safety rules). When examining the effect of exercise, measuring dynamic stability could be more conclusive. Another option is to determine the level of stability when performing a specific task (dual task), whether motor or cognitive. Patients would then concentrate not only on their stance, but also on the performance of these tasks. Another means of achieving more reliable results could be a combination of exclusion or limitation of two sensory systems, as well as the modification of the visual signal with the use of special tools.

6. Conclusion

BMD in the L1-L4 area and colli femoris increased in all monitored groups (exercising as well as non-exercising). The change was caused by application of nonspecific (Ca+D3) and specific (Fosamax, Evista) pharmacological treatment. Increase was higher for the area of lumbar spine. Sizes of measured bone markers did not significantly change in the course of the monitored period.

A significant effect of exercise applied in the course of one year on the level of bone mineralisation was not confirmed. Thus, physical activity is a necessary requirement for positive changes of BMD in women after menopause, it is, however, not sufficient.

Effect of repeated exercise units focused on postural stability did not manifest in the sizes of the COP sway in a bipedal stance, however, it had an effect on decrease in the velocity changes of the COP positions.

In order to evaluate the postural stability in women with osteoporosis (osteopenia) without any significant limitations in the motor control area, it is essential to complement the execution of current tests with a simultaneous solution of other tasks.

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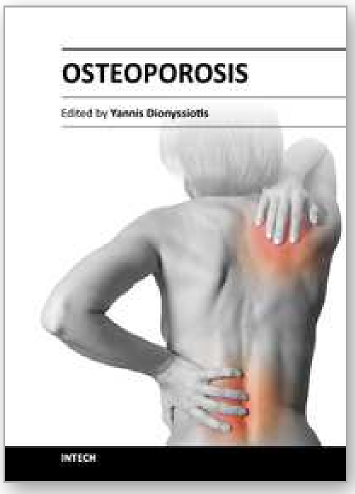

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