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ACUTE RESPONSE OF BONE METABOLISM TO VARIOUS RESISTANCE EXERCISES IN WOMEN

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Abstract. The study examines the acute response of bone turnover markers to two different single bouts of resistance exercises in women. Serum bone alkaline phosphatase and sclerostin concentration were measured before, 24 and 48 hours after the interventions to detect the dynamics of bone turnover. Subjects performed two exercises and a control experiment without exercise (CONTR) on different occasions, with 3-week breaks between the interventions, in a random order. First exercises protocol had a constant resistance of 75 % 1 RM (ISOF). Second, serial stretch loading (SSL), was isokinetic: velocity of concentric and eccentric phase of the movement was 50 and 40 cm/s, respectively. Short stops were incorporated into both phases of the movement after every 20 mm, resulting in a frequency of the force peaks of 10 Hz in concentric as well as in eccentric phase. Both protocols consisted of 6 sets of 6 repetitions and 2-minute resting periods. The exercises interventions had no statistically significant effect on either bone turnover marker concentration at any of the time points.

Key words: serial stretch loading, bone turnover, bone alkaline phosphatase, sclerostin

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Introduction

Sedentary lifestyle and insufficient amount of regular physical activity are believed to contribute to the development of metabolic disorders, which lead to atherosclerosis and cardiovascular complications (Booth et al. 2008). Substantial body of evidence exists which prove that physical exercises plays an important role in the prevention of vascular diseases progression (Joyner et al. 2009; Thompson et al. 2003). Apart from that, in recent decades also substantial epidemiological evidence of beneficial effects of strength exercises on bone tissue has accumulated.

The fact that bone responds positively to mechanical loading has been known for more than 100 years and is marked as Wolff´s law. The strains produced by external loading represent the stimulating input for bone adaptive processes. The response of bone turnover varies in relation to different strain characteristics. Animal studies of different types of external loads show that bone tissue does not adapt to static strains (Lanyon et al. 1984). On the other hand, exercises studies using human subjects prove that high strains changing at fast rates and presented in unusual directions result in greater bone adaptive responses than dynamic strains changing at slower rates. Thus high impact activities such as badminton, squash, triple jumping, etc. cause larger osteogenic responses than swimming or cycling (Nordstrom et al. 1998). It is therefore assumed that the character of the strain-related stimulus rather than particular strain intensity maintains and eventually improves the bone architecture.

A computer-controlled leg press device used in this study is capable of generating fast and precisely defined counter movements, which evoke repetitive force peaks exceeding the strength produced by a maximum voluntary contraction occurring during traditional resistance training. As such, a potential of a more effective means for improvement of bone formation with the use of this novel kind of stimulation exists. Acute response of bone metabolism to a single exercises session can be indirectly assessed by serum level of bone turnover markers. Their concentration values provide information on the acute state and dynamics of bone remodelling. Pronounced disruption of homeostasis by means of mechanical stimulation assumes higher intensity of bone adaptive changes. The magnitude of the changes in these markers can be used for the assessment of the efficiency of tested stimulus.

Aim

The purpose of this study was to examine the acute response of serum bone turnover markers (bone alkaline phosphatase and sclerostin) to two single sessions of different resistance exercises in women.

Methods

Subjects

Seven women (22.7 ± 1.9 years old) participated in the study. None of them were competitive athletes, smokers, nor were they on hormonal or osteoporosis medications. The study was approved by Ethical Committee of Faculty of Physical Education and Sports Comenius University in Bratislava.

Experimental design

A familiarization session took place one week prior to the beginning of the study. After the subjects had been informed about the aim of the study, they gave their written informed consent to participate in this study and after that, they familiarized themselves with the resistance exercises equipment. One repetition maximum test (1RM) was carried out on a supine leg press device. The results served for setting the workloads in the subsequent exercises protocols. The individual range of lower extremities motion and the initial position of leg press pedals were also set. This information was recorded for a simpler and time-saving work during the exercises protocols execution itself. The familiarization and one repetition maximum testing was supervised by experienced personnel.

Each subject completed two resistance exercises bouts on an isokinetic leg press dynamometer, either with a constant resistance (ISOF) or a serial stretch loading (SSL) and one control experiment without exercises (CONTR) on different occasions and in a random order. There were 3 weeks between the three experiments.

The subjects were instructed not to perform any high-demanding physical activity within 24 hours before testing and the follow-up blood collections.

Isokinetic leg press dynamometer

Both resistance exercises bouts were performed on a horizontal leg press device, which is operated, by a pair of computer controlled linear motors. Each of them can generate maximal force of 1800 N, velocity up to 10 m/s both forwards and backwards

and potentially accelerate at the rate of 15 g. As such, various training modes of this equipment can be set. A constant resistance and a serial stretch loading mode were used in the present study.

Exercises protocol with a constant resistance (ISOF)

The initial position of pedals and the resistance need to be set for this mode. The device generates constant resistance independent of external force produced by the subject. The pedals start to move forward from their starting position only when the force produced by the muscles exceeds the preset resistance value. If the exerted force decreases below the preset resistance, the pedals will move backwards to the starting position. The resistance in this study represented 75 % of individual 1 RM and the exercises protocol consisted of 6 sets with 6 repetitions and 2-minute breaks between the sets.

Isokinetic mode

The pedals in isokinetic mode move according to the preset velocity of concentric and eccentric phase of the movement regardless of the force applied by the subject. The range of lower extremities motion during both phases needs to be set in forward. The pedals accelerate from 0 at the initial position to the specified velocity and then move at this speed uniformly during the whole phase. They decelerate to 0 just before the final position is reached. Immediately after that, they accelerate to the preset velocity of the other phase of the movement. The speed is again uniform during the whole phase and the pedals decelerate to 0 just before the initial position is reached. One loading cycle (repetition) represents 1 concentric and 1 eccentric phase of the movement. If more than 1 repetition is set, the whole process described above starts again (fig. 1)

Exercises protocol with serial stretch loading (SSL)

However, the equipment in isokinetic mode is also capable of evoking repetitive force peaks of a controllable magnitude and frequency. It is achieved by incorporating short counter movements into concentric and segments of increased velocity into eccentric phase of the movement. The peaks can also be produced by sudden stops during both phases of the movement (fig. 2). The velocity of concentric and eccentric phase of the movement for this study was set to 50 $cm.s^{-1}$ and 40 $cm.s^{-1}$, respectively. Short interruptions, lasting few tens of milliseconds, were incorporated into both phases of the

movement after every 20 mm. This setting resulted in a frequency of the force peaks of 10 Hz in concentric as well as in eccentric phase. The subjects performed 6 sets of 6 repetitions with 2-minute resting periods between the sets and were instructed to push against the foot pedals with a maximal effort during the whole repetitions.

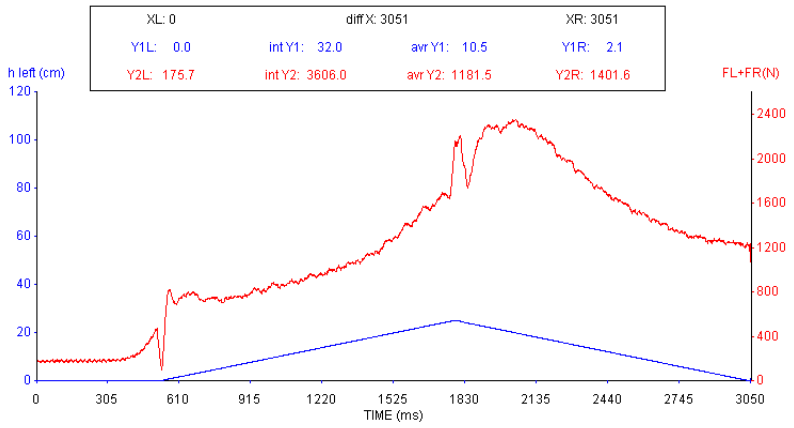

Figure 1
Force and distance during one isokinetic cycle

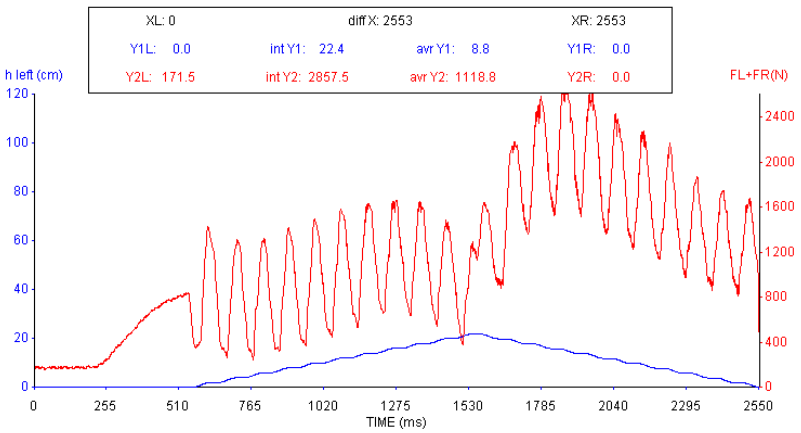

Figure 2
Force and distance during one serial stretch loading cycle

Control protocol (CONTR)

Control experiment was conducted without exercises but using the same time schedule for the blood samples withdrawal (a fasting baseline sample and 2 follow-up samples: 24 and 48 hours after the baseline sample).

Blood sampling

The response of bone metabolism to two exercises protocols and a control protocol was monitored by serum bone turnover markers: bone alkaline phosphatase (bALP) and sclerostin. Medical professionals obtained the blood samples by venipuncture of the antecubital vein at baseline (fasting) after 5 minute seated rest, 24 and 48 hours after the exercises. Baseline blood samples were collected between 7:00 and 8:00 AM.

For both bone turnover markers, 9 ml of blood was taken into a closed system collection tube containing beads coated with a clotting activator (silicate) and a polyacrylic ester gel (Sarstedt AG & Co, Germany). The samples were centrifuged at 2,000 rpm for 10 minutes at 4 °C no later than 60 minutes after the blood draw. Sera were stored immediately after the centrifugation at -80 °C for subsequent analyses. The follow-up samples were collected at the same time of day. Serum bone alkaline phosphatase and sclerostin concentrations were measured by enzyme-linked immunosorbent assay (ELISA) kit. All the samples were analysed in one assay.

An overview of experimental design

Fasting baseline blood sample → breakfast (provided by the investigators) → warm up (20 minutes after the breakfast) → first exercises protocol (ISOF or SSL) → fasting blood sample 24 hours after the exercises → fasting blood sample 48 hours after the exercises → 3-week break → completion of the second exercises protocol (SSL or ISOF) following the same procedures as during the first one. Control protocol (CONTR) was conducted according to randomized order as either first, second or third protocol.

Results and discussion

Repeated-measures multi-factorial ANOVA was used to measure the main effect of exercises and interaction of time. There was no statistically significant effect of SSL protocol on serum bALP (fig. 3) or sclerostin (fig. 4) concentration at any time point.

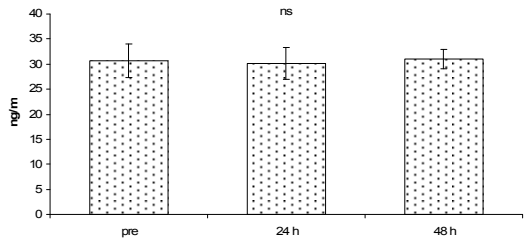

Figure 3
Effect of SSL protocol on bALP concentration

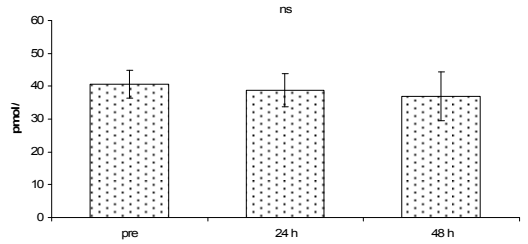

Figure 4
Effect of SSL protocol on sclerostin concentration

Neither ISOF protocol had any statistically significant effect on serum bALP (fig. 5) or sclerostin (fig. 6) concentration at any time point.

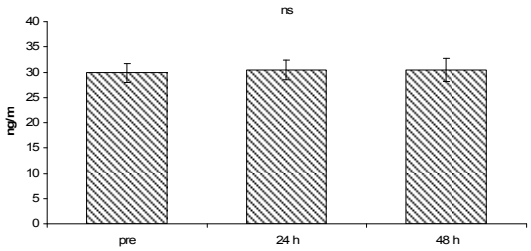

Figure 5
Effect of ISOF protocol on bALP concentration

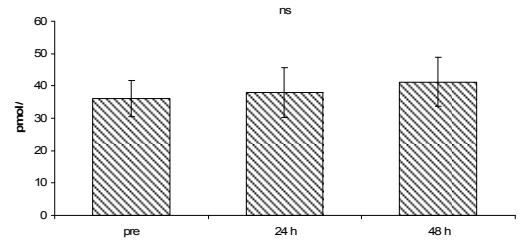

Figure 6
Effect of ISOF protocol on sclerostin concentration

No significant differences in the concentration of bALP (fig. 7) or sclerostin (fig. 8) in relation to two interventions and a control protocol were found.

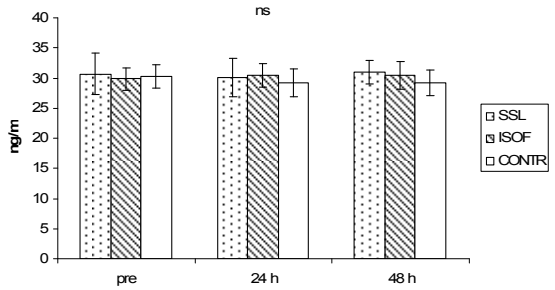

Figure 7
Control and intervention bALP concentration

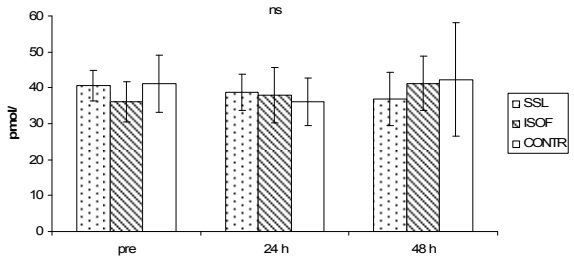

Figure 8
Control and intervention sclerostin concentration

We expected the force peaks generated during the SSL protocol would disrupt the homeostasis in a more pronounced way than the application of ISOF protocol. Such a condition would result in a more pronounced acute response of the selected bone turnover markers in comparison with ISOF protocol. The assumption was also based on studies confirming that bone adapts to intermittent and dynamic, but not static loadings (Hert et al. 1971; Nordstrom et al. 1998) and that mechanical load applied at frequency 10 to 60 Hz seems to be more osteogenic than the same amount of load applied at the rate of 1 Hz (Rubin et al. 2001).

However, neither of the exercises protocols had significant effect on the serum bone turnover markers concentration. Apart from that, no significant change in their concentration was found within two follow-up days in case of both exercises

interventions. The possible reasons of the results could be that the selected markers of bone turnover could not be appropriate to detect minor changes of acute bone metabolism dynamics even though they are widely used in research studies. Another possible reason could be insufficient number of subjects.

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