Structured resistance training increases bone mineral density in postmenopausal frail women: a quantitative computer tomography study

Poster No.: C-0387
Congress: ECR 2015
Type: Scientific Exhibit
Authors: V. Huovinen¹, M. Bucci¹, H. Lipponen¹, J. Raiko¹, S. Sandboge², J. G. Eriksson², P. Iozzo³, P. Nuutila¹, R. Parkkola¹; ¹Turku/Fl, ²Helsinki/Fl, ³Pisa/IT

Keywords: Bones, Musculoskeletal spine, Musculoskeletal bone, CT-Quantitative, Diagnostic procedure, Experimental investigations, Osteoporosis, Demineralisation-Bone, Geriatrics

DOI: 10.1594/ecr2015/C-0387

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.
Aims and objectives

Frailty is a growing problem in developing countries [1]. It can be divided into physical and psychosocial components. The most characteristic symptoms are decreased muscle strength and sarcopenia, which expose to decreased quality of life, falls, hospitalization and even death [2]. Low bone mineral density (BMD), osteopenia and osteoporosis, has been associated with frailty in elderly male and female subjects [3-5]. Effects of exercise on BMD in postmenopausal women are encouraging but still unambiguous [6,8-13]. However, the effect of resistance training on BMD in frail postmenopausal women remains uncertain.

Whole body vibration, jumping and high impact exercises seem to be an effective mean for increasing BMD in premenopausal and postmenopausal female [7,14-17]. Walking seems to have a positive effect on femoral neck BMD but no to lumbar spine BMD [8,18]. In addition, according to several meta-analyses it seems that resistance training may have a beneficial effect on BMD in premenopausal and postmenopausal women [6,9,11,19]. However, there are studies concluding that resistance training does not improve BMD in postmenopausal women [13,20-21] and studies concluding that resistance training maintains BMD better than strength training in postmenopausal women [22,23]. Only one study has been conducted in frail postmenopausal women in which BMD increased in response to combined resistance training and HRT [24]. Studies investigating solely the effect of resistance training on BMD in frail postmenopausal women have not been conducted.

The golden standard of measuring BMD is dual-energy X-ray absorptiometry (DXA) [25]. Another mean for measuring BMD is quantitative computer tomography (QCT) [26]. It may be more sensitive than DXA for detecting osteoporosis in postmenopausal women [27]. In addition, it may avoid the overestimation of BMD by DXA associated with spinal degeneration, abdominal aortic calcification and other sclerotic lesions [27]. There are also suggestions that QCT over DXA should be used in subjects with osteoarthritis [28]. QCT is also found to be preferable method over DXA in subjects with changing body composition for example overweight subjects losing weight. Yu et al found that fat-associated errors were greater in spine and hip with DXA than with QCT [29]. They also found discordant results in hip BMD between QCT and DXA after bariatric surgery [30].

In this study we tested the effect of four-month three times a week instructional resistance training intervention on BMD in frail postmenopausal women. According to our hypothesis, we expected to see an increase in BMD as a consequence of resistance training. As a definition of frail we used lowered grip strength. BMD was assessed with QCT.
Methods and materials

We studied 37 postmenopausal frail female subjects and 11 age-matched controls. Characteristics of the subjects are shown in Fig. 1 on page 5. Frail subjects underwent instructional resistance training intervention three times a week under supervision of a licensed physiotherapeutist for four months. Frail subjects were studied before and after the intervention. Control subjects were studied only at the baseline. Clinical studies were part of a larger project which main goal was to investigate the role of the maternal obesity on the health of the offspring in later life.

The study subjects were recruited from the Helsinki Birth Cohort Study II (HBCS II), the largest, best-characterized longitudinal cohort in the world. HBSC II includes 13345 subjects born in 1934-1944. The study subjects were selected from a sub-cohort of 2000 subjects that had been deeply clinically characterized throughout the years. The main inclusion criteria for all subjects were the age of 68-78 and female gender. Inclusion criteria for the frail subjects were lowest quintile of the muscle strength (grip strength). Inclusion criteria for the control subjects were that they did not have clinical signs of frailty. The last screening of the cohort subjects was carried in 2006 and the selection was based on the clinical characterization available for that year.

The subjects participated in a four-month individualized progressive circuit-type resistance training programme three times a week, under supervision of a licensed physiotherapist. The sessions included aerobic warm-up on a bicycle. The programme consisted of 8 different movements per circuit; two sets of 10-12 repetitions were performed at each station. Each station exercised a different large muscle group (e.g. thigh flexors and extensors, trunk flexors and extensors, upper arm muscles), alternating between upper and lower body. The subjects moved from station to station in a continuous fashion with short rests (<60 s) between the stations. Based on the one repetition maximum (1 RM) or a modest intensity (with the previously mentioned number of repetitions), according to the Borg scale, the start-up intensity of the training was set. As strength was improved, the intensity of the programme was progressively increased. No other changes in exercise habit was be made on behalf of the study group. The programme was according to general exercise recommendations for the general population including elderly subjects.

BMD was measured from the hip and lumbar vertebrae (L1-L3) using quantitative computer tomography (An integrated PET/CT) with resolution of 3.75 mm and Mindways phantom. Hip and lumbar BMD results were analysed using Mindways QCT Pro-software (version 4.2.3). In the analysis of lumbar BMD, extraction and axial, sagittal and coronal rotations were performed. Auto-ROI shaped of ovale was drawn. In axial image the ROI was positioned into the anterior 1/3 to 3/4 of the vertebral body excluding cortical bone
and basivertebral plexus. In sagittal image the ROI shaped of rectangle was placed to the center of vertebral body. In the analysis of hip, appropriate BMD extraction, isolation and rotation of the hip were performed. Femoral neck ROI shaped of rectangle with thickness of 15 millimeters was used and it was placed in the femoral collum resting on top of the trochanters. Distal extent line was set to the base of lesser trochanter. Trochanteric and intertrochanteric BMD was assessed automatically.

Images for this section:

<table>
<thead>
<tr>
<th></th>
<th>Frail (n = 37)</th>
<th>Control (n = 11)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>72 ± 3</td>
<td>72 ± 3</td>
<td>0.83</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.2 ± 4.7</td>
<td>26.8 ± 4.4</td>
<td>0.82</td>
</tr>
<tr>
<td>Fat %</td>
<td>39.5 ± 5.9</td>
<td>38.8 ± 5.2</td>
<td>0.73</td>
</tr>
<tr>
<td>Hemoglobin (g/l)</td>
<td>128 ± 9</td>
<td>136 ± 8</td>
<td>0.018</td>
</tr>
<tr>
<td>Leukocytes (10⁹/l)</td>
<td>5.1 ± 1.4</td>
<td>5.4 ± 1.1</td>
<td>0.49</td>
</tr>
<tr>
<td>Trombocytes (10⁶/l)</td>
<td>224 ± 51</td>
<td>241 ± 75</td>
<td>0.39</td>
</tr>
<tr>
<td>fP-glucose (mmol/l)</td>
<td>6.0 ± 0.7</td>
<td>6.2 ± 0.4</td>
<td>0.33</td>
</tr>
<tr>
<td>fP-insulin (mU/l)</td>
<td>8.9 ± 4.3</td>
<td>8.10 ± 1.1</td>
<td>0.76</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>5.49 ± 0.26</td>
<td>5.45 ± 0.27</td>
<td>0.73</td>
</tr>
<tr>
<td>RR systolic (mmHg)</td>
<td>162 ± 16</td>
<td>158 ± 15</td>
<td>0.58</td>
</tr>
<tr>
<td>RR diastolic (mmHg)</td>
<td>90 ± 10</td>
<td>90 ± 12</td>
<td>0.97</td>
</tr>
<tr>
<td>Waist-hip ratio</td>
<td>0.90 ± 0.05</td>
<td>0.89 ± 0.04</td>
<td>0.43</td>
</tr>
</tbody>
</table>

**Fig. 1:** Characteristics at the baseline
Results

BMD and characteristics at the baseline

There were no differences in age, body mass index, body fat %, waist-hip -ratio, leucocytes, thrombocytes, fasting plasma glucose, fasting serum insulin, HbA1c, systolic blood pressure or diastolic blood pressure between the groups at the baseline. Hemoglobin was slightly lower in frail group but value was in normal limits ( Fig. 1 on page 6 ).

Lumbar BMD was higher in control group although significance was not observed (Table 5). In addition, total hip BMD, trochanteric BMD and intertrochanteric BMD were higher in control group. Femoral neck BMD was similar between the groups ( Fig. 2 on page 7 ).

Effect of intervention on BMD and characteristics

There was no change in body mass index, body fat %, leucocytes, thrombocytes, fasting plasma glucose, fasting serum insulin, waist-hip -ratio, diastolic blood pressure or HbA1c but a lean increase in hemoglobin and a decrease in systolic blood pressure was observed. Muscle strength increased significantly in every trained muscle (Simonen M et al. Unpublished data).

Paired measures were received from 24 subjects considering vertebral BMD and 29 subjects considering hip BMD. Intervention increased vertebral BMD 14.4% (preintervention 89.8 ± 32.7 mg/cm$^3$, postintervention 102.7 ± 39.2 mg/cm$^3$, p = 0.009, Fig. 3 on page 7 ) and total hip BMD 6.0% (preintervention 0.67 ± 0.09 g/cm$^2$, postintervention 0.71 ± 0.07 g/cm$^2$, p = 0.006, Fig. 4 on page 8 ). Analysing hip areas separately, intertrochanteric (IT) BMD increased 11.7% (preintervention 0.76 ± 0.14 g/cm$^2$, postintervention 0.86 ± 0.11 g/cm$^2$, p = 0.002) while there was no significant change in trochanteric (preintervention 0.58 ± 0.10, postintervention 0.59 ± 0.07 g/cm$^2$, p = 0.38) g/cm$^2$ and femoral neck (FN) (preintervention 0.70 ± 0.14 g/cm$^2$, postintervention 0.69 ± 0.13 g/cm$^2$, p = 0.47) ( Fig. 4 on page 8 ). No significant changes in any BMD values were observed after correcting for age, body mass index or calcium and vitamin-D -supplement usage.

Images for this section:
<table>
<thead>
<tr>
<th></th>
<th>Frail (n = 37)</th>
<th>Control (n = 11)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>72 ± 3</td>
<td>72 ± 3</td>
<td>0.83</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.2 ± 4.7</td>
<td>26.8 ± 4.4</td>
<td>0.82</td>
</tr>
<tr>
<td>Fat %</td>
<td>39.5 ± 5.9</td>
<td>38.8 ± 5.2</td>
<td>0.73</td>
</tr>
<tr>
<td>Hemoglobin (g/l)</td>
<td>128 ± 9</td>
<td>136 ± 8</td>
<td>0.018</td>
</tr>
<tr>
<td>Leukocytes (10⁹/l)</td>
<td>5.1 ± 1.4</td>
<td>5.4 ± 1.1</td>
<td>0.49</td>
</tr>
<tr>
<td>Trombocytes (10⁹/l)</td>
<td>224 ± 51</td>
<td>241 ± 75</td>
<td>0.39</td>
</tr>
<tr>
<td>fP-glucose (mmol/l)</td>
<td>6.0 ± 0.7</td>
<td>6.2 ± 0.4</td>
<td>0.33</td>
</tr>
<tr>
<td>fP-insulin (mU/l)</td>
<td>8.9 ± 4.3</td>
<td>8.10 ± 1.1</td>
<td>0.76</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>5.49 ± 0.26</td>
<td>5.45 ± 0.27</td>
<td>0.73</td>
</tr>
<tr>
<td>RR systolic (mmHg)</td>
<td>162 ± 16</td>
<td>158 ± 15</td>
<td>0.58</td>
</tr>
<tr>
<td>RR diastolic (mmHg)</td>
<td>90 ± 10</td>
<td>90 ± 12</td>
<td>0.97</td>
</tr>
<tr>
<td>Waist-hip ratio</td>
<td>0.90 ± 0.05</td>
<td>0.89 ± 0.04</td>
<td>0.43</td>
</tr>
</tbody>
</table>

**Fig. 1:** Characteristics at the baseline

<table>
<thead>
<tr>
<th></th>
<th>Frail (n = 33)</th>
<th>Control (n = 11)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertebral BMD (mg/cm³)</td>
<td>95.5 ± 34.9</td>
<td>117.1 ± 50.0</td>
<td>0.16</td>
</tr>
<tr>
<td>Total hip BMD (g/cm²)</td>
<td>0.67 ± 0.09</td>
<td>0.74 ± 0.12</td>
<td>0.042</td>
</tr>
<tr>
<td>Femoral neck BMD (g/cm²)</td>
<td>0.69 ± 0.13</td>
<td>0.72 ± 0.13</td>
<td>0.435</td>
</tr>
<tr>
<td>Trochanteric BMD (g/cm²)</td>
<td>0.58 ± 0.09</td>
<td>0.66 ± 0.11</td>
<td>0.023</td>
</tr>
<tr>
<td>Intertrochanteric BMD (g/cm²)</td>
<td>0.77 ± 0.14</td>
<td>0.89 ± 0.19</td>
<td>0.036</td>
</tr>
</tbody>
</table>

**Fig. 2:** Vertebral and hip BMD at the baseline
Fig. 3: Four-month resistance training improved vertebral BMD
Fig. 4: Four-month resistance training improved total hip and intertrochanteric BMD. No changes were observed in femoral neck and trochanteric BMD.
Conclusion

We studied the effect of four-month resistance training on vertebral and hip BMD in frail postmenopausal female with quantitative computer tomography. A significant increase in vertebral and total hip BMD was observed. Increase in BMD was localized on intertrochanteric area while femoral neck and trochanteric BMD remained unchanged.

To our knowledge there is no earlier publications in a similar study design. In our cohort the subjects were frail postmenopausal female. Frailty is characterized by decreased muscle strength which was our only inclusion criterion. Increase in BMD may be explained with increase in muscle strength. Armamento-Villareal et al. found that changes in thigh hip volume in obese old subjects predicts change in hip BMD [31]. On the other hand, Ma et al. introduced a concept of muscle-bone unit. They found that as a result of aging, muscle mass in paravertebral muscle decreases parallel with vertebral bone mass [32]. This seems to be in line with our finding because in our cohort muscle strength increased in every exercised muscle group (Simonen M et al. Unpublished data).

In conclusion, four-month resistance training increased BMD of lumbar vertebrae and proximal femur significantly in frail postmenopausal female. It may be an effective strategy to prevent fractures of lumbar vertebrae and proximal femur.

Personal information

Huovinen Ville, MD, Turku PET Centre, Turku University and Department of Radiology, Turku University and Medical Imaging Center of Southwest Finland and Turku University Hospital; vkhuov@utu.fi

Bucci Marco, PhD, Turku PET Centre, Turku University, Finland; bucci.marco@gmail.com

Lipponen Heta, BM, Turku PET Centre, Turku University, Finland; heta.lipponen@utu.fi

Raiko Juho, MD, PhD, Turku PET Centre, Turku University, Finland; juho.raiko@utu.fi

Sandboge Samuel, MD, Folkhälssan Research Centre, Helsinki, Finland; samuel.sandboge@thl.fi
Eriksson Johan G, MD, professor, Folkhälsan Research Centre, Helsinki, Finland; johan.eriksson@helsinki.fi

Ioizzo Patricia, MD, PhD, National Research Council, Pisa, Italy; patricia.iozzo@ifc.cnr.it

Kiviranta Riku, MD, PhD, Department of Endocrinology, Turku University and Turku University Hospital, Finland; rikkiv@utu.fi

Nuutila Pirjo, MD, Professor, Turku PET Centre, Turku University and Department of Endocrinology, Turku University and Turku University Hospital, Finland; pirnuu@utu.fi

Parkkola Riitta, MD, Professor, Turku PET Centre, Turku University and Department of Radiology, Turku University and Medical Imaging Center of Southwest Finland and Turku University Hospital; riitta.parkkola@tyks.fi

References


