Power training is more effective than strength training for maintaining bone mineral density in postmenopausal women

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Running title: Strength and power training effects on BMD
1 Abstract
Physical exercise has a favourable impact on bones, but optimum training strategies are still under discussion. In this study we compared the effect of slow and fast resistance exercises on various osteodensitometric parameters.

53 postmenopausal women were randomly assigned to a strength (ST) or a power training group (PT). Both groups carried out a progressive resistance training, a gymnastics session, and a home training over a period of 12 months. During the resistance training the ST group used slow and the PT group fast movements, otherwise there were no training differences. All subjects were supplemented with Ca/Vit-D.

At baseline and after 12 months, BMD was measured at the lumbar spine, proximal femur, and distal forearm by DXA. We also measured anthropometric data and maximum static strength. Frequency and grade of pain were assessed by questionnaire.

After 12 months, significant between-group differences were observed for BMD at the lumbar spine (L1-L4) (p<0.05) and the total hip (p<0.05). While the PT group maintained BMD at the spine (+0.7±2.1%, n.s.) and the total hip (0.0±1.7%, n.s.), the ST group lost significantly at both sites (spine: -0.9±1.9%; p<0.05; total hip: -1.2±1.5%; p<0.01). No significant between-group differences were observed for anthropometric data, maximum strength, BMD of the forearm, or frequency/grade of pain.

These findings suggest that power training is more effective than strength training in reducing bone loss in postmenopausal women.

Key words: postmenopausal women; exercise; strength training; power training; bone mineral density.
2 Introduction
Recent meta-analyses of longitudinal studies confirmed that exercise has a positive influence on the skeleton and increases or, in more elderly subjects, maintains bone mineral density (BMD) (26, 27, 60, 62). Although optimum training strategies are still under discussion, it is generally acknowledged that the training should be population specific. For example, exercises that were highly effective in premenopausal women did not show a major impact on bone after menopause (5, 49). Crossectional studies with athletes demonstrated that BMD was strongly associated with high impact load bearing activities, such as sports games or gymnastics (12, 34, 37, 40). BMD was also highly associated with activities that required high muscular tension such as weight lifting (17, 18, 37, 39).
In order to develop an effective exercise program it is important to understand the interaction between exercise, bone turnover and formation. Data on this subject is still rare, but the dose response relationship of isolated mechanical loading parameters has been investigated in several in-vivo loading studies of animal bones. Various models such as the functionally isolated avian ulna (44), the four point bending of the rat tibia (53), the axial loading of the rat ulna (51), and models of ground-based vibrations (42, 43) have been applied successfully. Typical endpoints are histomorphometric parameters of bone formation. These studies show that strain magnitude, strain rate, cycle number, strain frequency, strain distribution, and rest periods are associated with osteogenic impact.
Many results based on animal studies can be integrated in human exercise regimen (8, 22), but this has rarely been done (41, 58). Furthermore, studies that compared the effects of mechanical parameters on BMD in humans, almost exclusively focused on strain magnitude. This parameter was predominantly investigated in studies comparing the effect of low versus high intensity resistance training (4, 6, 32, 33, 35, 59). Only one study specifically investigated the effect of strain rate (4). The study showed that high impact (jumping) exercises were significantly more efficient than low impact exercises. The positive effect of a high strain rate on BMD was confirmed indirectly by several other studies (1, 5, 16, 49).
In our study we also focussed on strain rate. Our major hypothesis is based on the assumption that high-velocity resistance training (power training) results in more pronounced stimuli than low-velocity resistance training (strength training) and should be more effective in maintaining bone density in postmenopausal women. In our two-year-program for which we report first-year-results we included pre-trained women who had participated in
the training arm of the Erlangen fitness osteoporosis prevention study (EFOPS) for 3 years (29, 31).

3 Materials and Methods
The current study was approved as an extension of the EFOPS-Study by the ethics committee of the University of Erlangen (Ethik Antrag 905, S9108-202/97/1, S21-22112-81-00), and the German and Bavarian radiation safety agencies (Bundesamt für Strahlenschutz: Z2.1.2-22462/2-2002-016 and Bayerisches Landesamt für Arbeitssicherheit: 13B/3443-4/5/98). All study participants gave written informed consent.

3.1 Subjects
53 osteopenic postmenopausal women (4 – 11 years post menopause) were included in the study. These women had participated in the training arm of the EFOPS study for three years prior to start of the study. None of the subjects had a disease or used medication affecting bone metabolism. The subjects were group-wise randomly assigned to a strength (n = 28) or a power training program (n = 25).

3.2 Exercise program
Both groups carried out the following weekly training program: two weight lifting sessions (60 min each), one gymnastic session (60 min), and one home training session (25 min) with at least one day of rest between the joint exercise sessions. Attendance was assessed every 12 weeks using subject specific training logs as well as attendance lists kept by the trainers.

3.2.1 Weight lifting session
The weight lifting session started with a 20-minute warm up (running, low/high impact aerobic at 70 – 85% maximum heart rate), followed by a jumping sequence with 4 x 15 multidirectional jumps. Machines for multi-joint exercises (Technogym, Gambettola, Italy) were used for horizontal leg press, leg curls, bench press, rowing, leg adduction and abduction, abdominal flexion, back extension, lat pulley, hyperextension, leg extension, shoulder raises, and hip flexion.

12-week intervals of periodized high intensity training (70 - 90% 1 RM) were intermitted with 4-5 weeks of lower training intensity (50% 1 RM). The only difference between the two groups was the movement velocity. The training protocol specified a 4 s concentric --4 s eccentric sequence in the strength training group (ST) and a concentric fast/explosive --4 s eccentric sequence in the power training group (PT).
3.2.2 Gymnastics session
The objective of the gymnastics program was to improve fall related abilities. It consisted of coordination, strength, endurance, and flexibility training.

3.2.3 Home training session
All participants were requested to carry out a 25-minute home training session once a week with rope skipping, stretching, isometric exercises, and exercises with rubber bands.

3.2.4 Power versus Strength training
Six months after study start, when the participants were accustomed to the training scheme, ground reaction forces were measured with a force plate (mtd-Systems®, Neuburg v. Wald, Germany) mounted on the leg press machine. In a subset of the participants (PT: n = 16, ST: n=18) force-time-curves were recorded over a period of six repetitions carried out with loads corresponding to approximately 75% 1 RM. Relative loading magnitude and – amplitude, loading frequency, and maximum loading and unloading rates were extracted from the curves and used to compare power and strength training.

The relative loading magnitude (given in %) was calculated by normalizing the average of the six force maxima (figure 1) with the lifted weight. The relative loading amplitude was determined in the same way using the differences between maxima and minima. Maximum loading and unloading rates [N/ms] were determined from the derivatives (figure 2) of the smoothed force-time-curves, again by averaging the results from the six repetitions.

The frequency spectrum or loading distribution was determined by a fast Fourier transform of the force-time-curve, which decomposes the signal into its sinusoidal components, providing a force-versus-frequency-graph (figure 3). For the statistical analysis, the frequency spectrum was divided into six intervals of 0.5 Hz each, covering 0 to 3 Hz. Finally, a Fourier synthesis was performed to analyze the contribution of each 0.5 Hz interval to the total frequency bandwidth of the original signal.

Figure 1 shows characteristic force-time-curves of power (A) and strength training (B). Due to the fact that during strength training the velocities are small, the force increases and decreases more or less continuously. In contrast, during power training each repetition shows ‘double peak’ behaviour. The large peak can be attributed to the first phase of the explosive leg extension, when pushing the weight forward and pausing in a short unloading phase. Then the force is increased again resulting in a second peak that is usually lower than the first. The loading rates can directly be obtained from the derivatives of the force-time-curves and are shown in figure 2.
Quantitative results of group differences are displayed in table 1. Differences range from 16\% for the relative loading magnitude to 61\% for the unloading rate. Table 2 and figure 4 display the results from the Fourier synthesis. In the ST group, low frequencies up to 1 Hz account for 86\% of the total signal strength, whereas the frequency distribution in the PT group extends to higher frequencies. 27.4\% of the total strength is associated with frequencies beyond 2 Hz compared to only 6.6\% in the strength training group. Compared to the specified training protocols both groups carried out the leg press exercise at higher speed. In the example shown in figure 1 the slow movement took 5.8 instead of 8 seconds and the fast movement only 3.8 seconds. Average values were 5.6±0.8 s in the ST and 3.5±0.6 s in the PT group.

3.3 **Ca and Vitamin D supplementation**
Depending on the individual Ca and Vit-D intakes, each participant received supplemental Ca and Vitamin-D to ensure a total daily intake of 1500 mg Ca and 500 IE Vit-D (28). The individual dietary intake was assessed with a 5-day protocol. The consumed food was weighed precisely. The analysis of the protocols was performed using Prodi-4,5/03 Expert software (Wissenschaftlicher Verlag, Freiburg, Germany).

3.4 **Measurements**
For each study subject, the measurements described in the following sections were carried out at baseline and repeated after twelve months. The measurements can be grouped into four blocks: anthropometry, bone densitometry, exercise, and pain.

3.4.1 **Anthropometry**
We measured height, weight, and body composition (percent body fat, lean body mass (LBM), total body water (TBW)). Body composition was assessed with the impedance technique (Tanita BF 305, Tanita, Japan).

3.4.2 **Bone densitometry**
Bone mineral density was measured by dual-energy X-ray absorptiometry (DXA) (QDR 4500A, Hologic, Bedford, Ma) at the lumbar spine (L1-L4), the proximal femur, and the distal forearm using standard protocols.

3.4.3 **Exercise Tests**
Maximum isometric strength values of the trunk extensors and -flexors, the hip flexors, the leg-adductors and –abductors, and the arm-flexors and -extensors were determined isomet-
rically using a Schnell-Trainer-dynamometer and a Schnell M-3 isometric tester (Schnell, Peutenhausen, Germany) following Tusker’s protocol (57). Strength was recorded as the product of force and lever arm in Newton meter [Nm].

At baseline, endurance was measured by a stepwise treadmill test up to voluntary maximum. Starting with 6 km/h (0° slope) the velocity was increased every 3 minutes by 1 km/h. VE, VO_{2max} and VCO_{2max} were determined using a Zan 600 open spirometric system (Zan, Oberthulba, Germany). All subjects achieved a minimum HR_{max} of 155 min^{-1}. This measurement was not repeated after 12 months.

### 3.4.4 Pain

Pain frequency and -intensity at various skeletal sites were assessed by questionnaires according to Jensen (21) and the Osteoporosis Quality of Life Study Group (20). The reproducibility of the questionnaires had been evaluated in an earlier study (30). A random sample of 10 women had answered the questionnaires twice within 2 weeks. The mean difference between the first and the second score was less than 5%.

### 3.5 Statistical analysis

Unless stated otherwise, all measured values are reported as means and standard deviations. The Kolgomorov-Smirnov-test was used to check for normal distributions; Levine’s F-test was used to check for homogeneity of variance. In the analysis we evaluated the training effect on bone, that is, we used all densitometric parameters as dependent variables. Specifically, the following questions were investigated: (1) Were groups comparable at baseline? Here unpaired t-tests for normally distributed variables and Mann-Whitney-U-tests for not normally distributed variables were applied. (2) Was the power training more effective than the strength training? Here we used a two way analysis of variance (Anova) with repeated measures. Within-group factor was time (baseline versus 12 months) and between-group factor was type of training (PT versus ST). (3) Were within-group changes between baseline and follow-up significantly different from zero? For this purpose paired t-tests or Wilkoxon-tests were used.

All three analysis steps were carried out twice. First we excluded subjects with insufficient training frequency (< 2 joint sessions/week averaged over the 12 month period). Then we repeated the analysis independent of training frequency. All tests were two-tailed, a 5% probability level was considered significant (*). We used SPSS 12.0 (SPSS Inc, Chicago,
IL) for statistical analysis. The fast Fourier transformation and the spectral analysis of the force-time curves were carried out in EXCEL 2003 (Microsoft Corp).

4 Results
All 53 enrolled study subjects completed the first study year. However, two subjects of the strength training group were excluded from all analyses because they took medications (glucocorticoids) or had acquired diseases (hyperparathyreodism) affecting bone metabolism. Another nine subjects (PT: n = 4; ST: n = 5) were in the category “insufficient training frequency”. Thus in the first analysis, 21 women of the ST and 21 women of the PT group were included in the 12-months analysis. The important parameters describing the two training regimen have been described and analyzed in the materials and methods section above. There were no significant differences in the weekly training attendance rates between the ST (2.48±0.31 sessions) and the PT (2.43±0.32 sessions) group.

Table 3 lists baseline data for non-densitometric parameters and table 4 includes the baseline data for densitometric parameters. None of the non-densitometric parameters showed significant between-group differences. Furthermore, at baseline there were no differences in maximum static strength at any skeletal region. Average BMD values at the spine and hip tended to be lower in the power training group, yet those at the forearm tended to be higher. However, levels of significance were only achieved in the forearm and the intertrochanteric regions.

Using the two way analysis of variance, all between-group differences for height, weight, LBM, percent body fat, TBW, and for maximum isometric strength and endurance were non significant after 12 months. This result was independent whether subjects with insufficient training frequency were excluded or not.

4.1 Training effects on osteodensitometric parameters
Table 4 displays baseline and 12-month values for the densitometric parameters. Here subjects with insufficient training frequency were excluded. After one year, power training resulted in larger effects than strength training at the lumbar spine, total hip, and intertrochanter. For the trochanter differences of the training effects were almost significantly different (figure 5). Corresponding F and p values of the time*training group interaction term, resulting from the Anova, are shown in table 4. For the hip within-group t-tests showed significant BMD losses for all regions in the strength training group and stable BMD in the power training group.
Corresponding relative changes in the ST group were: LS: -0.9±1.9%, total hip: -1.2±1.5%**, femoral neck: -1.6±2.5**, trochanter: -0.9±2.2*, intertrochanter: -1.4±3.0**, total forearm: -0.2±1.3, and ultradistal radius: -0.5±3.1. Relative changes in the PT group were: LS: +0.7±2.1%, total hip: 0.0±1.7%, femoral neck: -0.4±2.8, trochanter: 0.2±2.3, intertrochanter: 0.1±2.9, total forearm: -1.0±1.4**, and ultradistal radius: -0.5±2.9. The levels of significance indicate whether the changes were different from zero.

When inadequate training frequency was not an exclusion criterion, there were no principal changes in the Anova results for the time*training group interaction term. However, with the exception of the lumbar spine significance levels were lower (LS: F=11.63, p=0.001; total hip: F=4.26, p=0.044; trochanter: F=3.11, p=0.084; intertrochanter: F=5.11, p=0.028). All insignificant between-group differences remained insignificant.

4.2 Pain
With exception of the neck there were no between-group differences with respect to changes in pain frequency or -grade for any of the skeletal sites assessed (big joints, small joints, neck, and lower and upper back). In the neck, pain intensity was constant in the ST group, but decreased in the PT group. Within-group changes were significant for pain frequency in the big joints in the PT group. Figure 6 shows results for the lower back and the big joints (hip, knee, shoulder), which are of special interest.

5 Discussion
Embedded in a high impact loading and aerobic exercise program, we investigated the effect of different training velocities in the strength training sequence. We specifically modified the velocity of the concentric movements during the machine training. Our analysis of the force-time-curves shows that weight adjusted loading magnitudes and amplitudes, and strain rates and frequencies, were significantly increased in the power training group carrying out the fast movements. Animal studies (19, 24, 25, 38, 45, 54-56) have shown that each of the four parameters has an osteogenic impact but their combined effect has not been investigated. In our study, we focussed on this issue by an increase of training velocity that impacted simultaneously on loading magnitudes and amplitudes, and on strain rates and frequencies.

Which parameter is most important when applied in combination is not clear yet. From experiments in roosters, Judex and Zernicke, who had determined strain magnitudes and
rates with strain gauges in vivo, concluded that strain rate was more important than strain magnitude (24, 25). In two studies they had compared the effects of low (walking and treadmill running) and high impact (drop jumps) exercises at the tarsometatarsus. Drop jumps had increased peak strain magnitudes only moderately by +30% (relative to walking) and +11% (relative to running), but had produced much higher strain rates of +740% and +256%, respectively. After three weeks with 200 jumps daily, bone formation rates had significantly increased periostally (+40%) and endocortically (+370%) whereas treadmill running had not increased bone formation. As determined in a rat ulna loading model, reported by Skerry and Peet (47), loading and unloading rates have similar osteogenic impacts. Therefore, in our study the large difference in the loading rates and, in particularly, the unloading rates may be essential for the superiority of the power training approach.

Models that regard fluid flow as the central mechanism for the stimulation of bone adaptation (7, 9, 48, 54, 61) suggest that the loading amplitude, which in our study was 82% higher in the PT compared to the ST group, should also play an important role. Furthermore, Turner et al. (54) showed that in the range between 0.2 and 2.0 Hz a higher loading frequency was associated with a higher osteogenic response. In our study most loading frequencies ranged from 0.2 to 1.0 Hz in the ST and up to 2.5 Hz in the PT group.

In accordance with the animal studies summarized above, we observed significantly higher anti-resorptive effects in the PT compared to the ST group (see table 4 and figure 5), although the follow-up time of our study of one year was short and the number of subjects was relatively small. Even when not excluding subjects with low training frequency, the effect was maintained, although lower in magnitude. Our group was too small in order to investigate a dose-response-relationship, nevertheless we recommend higher (> 2 joint sessions / week) training frequencies.

Similar to the EFOPS training period (29, 31) preceding this study, there were no significant group differences at the distal forearm. Of course, this may also be attributed to the limitations in study design mentioned above. However, due to the EFOPS results, in which a significant BMD decrease of 3.5 - 4.0 % was observed in the training group, we now believe that our specific forearm exercises (lat pulley, rowing, and bench press) are less effective compared to the exercises applied to the other skeletal sites. Actually, only bench press exercises result in a direct compression of the distal forearm, whereas the other two exercises cause tension. In line with this observation, a protocol with substantially higher
loading variations generated by bending, tension, torsion, and compression, demonstrated significant exercise effects on BMD of the distal radius (33, 46).

One may argue that a direct comparison between loading studies in animals and exercise studies in humans is problematic. In animals, the strains applied to bone can be measured directly whereas in humans only the surrogate measurement of external forces is possible. However, in favour of the contrary, Bassey (3) found that at the proximal femur peak ground reaction forces as well as force rates of different activities (walking, jogging, jumping) significantly correlated with internal forces measured by a specially equipped hip implant. Also within physiological loading ranges, forces are directly proportional to strains exerted on bone (22). Thus it seems likely that the mechanical parameters which we determined are comparable to the strain parameters in animal studies. Therefore, general conclusions drawn from animal models should be transferable to humans, even if direct strains are usually not assessable.

Power training, characterized by explosive muscle contraction, produces higher stresses on tendons and joints than strength training. Therefore, as a measure of precaution, in recreational sports activities slow movements are recommended for weight lifting exercises in order to minimize injuries. This particularly applies to elderly subjects, whose adaptability to intensive stimuli might be reduced (11). However, with the exception of pain intensity at the neck, we did not observe significant pain intensity or pain frequency related differences between the PT and the ST group at any skeletal site. There was a trend towards pain frequency reduction in the big joints in both groups that was significant at the p <0.05 level in the power training group. We attribute these results to the three-year-EFOPS-training preceding this study. During that period weight lifting exercises with moderate (2 s concentric–1 s static–2 s eccentric) velocities were carried out. Thus the subjects randomized to power training were well-trained and already adapted to heavy loading. At the EFOPS baseline there were also no significant differences between the ST and the PT group (data not shown here).

Furthermore, the periodized training design with 12 weeks of high intensity (70-90% 1 RM), interleaved by 4-5 weeks of lower training intensity (50% 1 RM) provided ample time for regeneration. Therefore, with an adequate training regimen the maintenance of bone density does not necessarily conflict with increased pain. This contradicts earlier arguments (52). Nevertheless, we do not claim that for elderly subjects power training is generally unproblematic. In particular, long term effects in the elderly are yet unknown
because none of the studies investigating this question exceeded six months (10, 13-15, 36). On the other hand, some studies suggest that muscle power is an essential component of functional mobility in elderly people (2, 23, 36, 50) and that power training might be at least as important as strength training (36). It would be interesting to know, whether our results could be repeated in sedentary women, and a corresponding study should be carried out.

In summary, this contribution clearly demonstrates the superiority of power versus strength training on BMD at the lumbar spine and the proximal femur. It also demonstrates that our power training approach with postmenopausal women did not increase pain. These findings highlight the importance and feasibility of power training and encourage its incorporation in training programs for the elderly, although its use and impact on pain in untrained women requires further validation.

Further research should be undertaken to quantify the exercise-induced mechanical milieu that is associated with different physical and sportive activities in order to identify those mechanical parameters that trigger the modelling and remodelling process. With this knowledge the optimization of exercise programs would be much easier.

6 Acknowledgements

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7 References


15. Hakkinen K, Kraemer WJ, Newton RU, and Alen M. Changes in electromyographic activity, muscle fibre and force production characteristics during heavy resistance/power


Figure Captions

Fig. 1: Characteristic force-time-curves for strength (A) and power training (B). For each of the six repetitions maximum and minimum loading forces are marked by circles. Maximum loading and unloading rates are determined in the derivatives (Fig. 2) and are marked by triangles. The dashed line indicates the subject’s specific force of gravity (body weight multiplied by 9.81).

Fig. 2: Derivatives of Fig. 1 used to determine maximum loading and unloading rates for strength (A) and power training (B).

Fig. 3: Frequency distribution of strength (A) and power training (B) derived form a Fourier transform of the force-time-curves in Fig. 1.

Fig. 4: Contribution of the six frequency bins to the total signal.

Fig. 5: Absolute changes of DXA measurements between baseline and year 1. (A) lumbar spine, (B) proximal femur, and (C) distal forearm. Between- and within-group levels of significance are shown. Between-group levels resulted from Anova, within-group levels from paired t-tests.

Fig. 6: Pain frequency (A) and intensity (B) of the lower back and the main joints at baseline and after year 1.
8 Figures

Fig. 1

Fig. 2
Fig. 3

Fig. 4
Fig. 5
Fig. 6

A) Pain frequency

<table>
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<th>Baseline</th>
<th>Year 1</th>
<th>Baseline</th>
<th>Year 1</th>
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<td>ST (n=21)</td>
<td>2</td>
<td>3</td>
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<td>2</td>
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<td>PT (n=21)</td>
<td>4</td>
<td>5</td>
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* p < 0.05

B) Pain intensity

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<th>Year 1</th>
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9 Tables

<table>
<thead>
<tr>
<th></th>
<th>ST (n = 16)</th>
<th>PT (n = 18)</th>
<th>Difference [%]</th>
<th>p</th>
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<tr>
<td>Relative loading magnitude [%]</td>
<td>121.5±5.9</td>
<td>140.8±15.7</td>
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<tr>
<td>Relative loading amplitude [%]</td>
<td>61.5±6.8</td>
<td>112.2±24.3</td>
<td>82.3</td>
<td>&lt;0.001</td>
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<td>Loading rate [N/s]</td>
<td>1414±330</td>
<td>5125±1946</td>
<td>262</td>
<td>&lt;0.001</td>
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<td>Unloading rate [N/s]</td>
<td>-1157±383</td>
<td>-8232±3548</td>
<td>611</td>
<td>&lt;0.001</td>
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</table>

Tab.1: Characteristic differences of strength (ST) versus power training (PT) derived from the analysis of the force-time-curves shown in Figs. 1-3.

<table>
<thead>
<tr>
<th>Frequency interval [Hz]</th>
<th>Contribution to total signal [%]</th>
<th>p</th>
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<tr>
<td></td>
<td>ST (n=16)</td>
<td>PT (n=18)</td>
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<tr>
<td>0 – 0.5</td>
<td>74.0±5.9</td>
<td>13.2±5.4</td>
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<td>0.5 – 1.0</td>
<td>11.8±4.0</td>
<td>20.0±7.0</td>
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<td>1.0 – 1.5</td>
<td>5.1±1.7</td>
<td>23.6±7.0</td>
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<td>1.5 – 2.0</td>
<td>2.5±1.0</td>
<td>15.8±4.1</td>
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<tr>
<td>2.0 – 2.5</td>
<td>1.3±0.4</td>
<td>12.2±4.6</td>
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<td>2.5 – 3.0</td>
<td>0.8±0.3</td>
<td>3.8±2.5</td>
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Tab. 2: Results of the Fourier synthesis (see text): Contribution of frequency intervals to the total force signal.
<table>
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<th>ST (n = 21)</th>
<th>Difference</th>
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<tr>
<td>Age [years]</td>
<td>57.7±3.2</td>
<td>57.6±3.0</td>
<td>n.s.</td>
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<td>Height [cm]</td>
<td>164.0±6.1</td>
<td>162.7±6.7</td>
<td>n.s.</td>
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<tr>
<td>Weight [kg]</td>
<td>68.5±7.7</td>
<td>64.3±9.2</td>
<td>n.s.</td>
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<tr>
<td>BMI [kg/m²]</td>
<td>25.5±3.3</td>
<td>24.3±4.4</td>
<td>n.s.</td>
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<td>Body fat [%]</td>
<td>35.4±5.8</td>
<td>33.8±6.1</td>
<td>n.s.</td>
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<td>LBM [kg]</td>
<td>43.9±3.1</td>
<td>42.3±4.8</td>
<td>n.s.</td>
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<td>Waist/Hip-Index</td>
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<td>0.81±0.05</td>
<td>n.s.</td>
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<tr>
<td>Maximum grip strength</td>
<td>30.76±3.97</td>
<td>31.14±4.72</td>
<td>n.s.</td>
</tr>
<tr>
<td>Maximum strength body flexion</td>
<td>72.76±15.65</td>
<td>77.52±17.59</td>
<td>n.s.</td>
</tr>
<tr>
<td>Maximum strength back extention</td>
<td>131.90±25.27</td>
<td>133.19±29.76</td>
<td>n.s.</td>
</tr>
<tr>
<td>Maximum strength leg adduction</td>
<td>120.24±21.01</td>
<td>120.29±19.28</td>
<td>n.s.</td>
</tr>
<tr>
<td>Maximum strength leg abduction</td>
<td>94.10±17.53</td>
<td>88.95±18.63</td>
<td>n.s.</td>
</tr>
<tr>
<td>Maximum strength arm flexion</td>
<td>78.81±10.82</td>
<td>85.19±16.81</td>
<td>n.s.</td>
</tr>
<tr>
<td>Maximum strength arm extention</td>
<td>68.86±12.23</td>
<td>69.67±10.22</td>
<td>n.s.</td>
</tr>
<tr>
<td>Maximal oxygen consumption [l/min]</td>
<td>2.01±0.23</td>
<td>1.98±0.29</td>
<td>n.s.</td>
</tr>
<tr>
<td>Energy intake [kJ/d]¹</td>
<td>8848±1111</td>
<td>8861±1501</td>
<td>n.s.</td>
</tr>
<tr>
<td>Protein intake [g/d]¹</td>
<td>72.4±12.8</td>
<td>68.9±12.2</td>
<td>n.s.</td>
</tr>
<tr>
<td>Calcium intake [mg/d]¹</td>
<td>1219±417</td>
<td>1235±415</td>
<td>n.s.</td>
</tr>
<tr>
<td>Phosphor intake [mg/d]¹</td>
<td>1484±259</td>
<td>1450±349</td>
<td>n.s.</td>
</tr>
<tr>
<td>Vitamin-D intake [µg/d]¹</td>
<td>4.9±3.8</td>
<td>4.5±3.9</td>
<td>n.s.</td>
</tr>
<tr>
<td>Osteoporosis in the family [%/group]</td>
<td>19%</td>
<td>14%</td>
<td>n.s.</td>
</tr>
<tr>
<td>Coffee consumption [ml/d]¹</td>
<td>701±394</td>
<td>705±388</td>
<td>n.s.</td>
</tr>
<tr>
<td>Smoker [%/group]</td>
<td>10%</td>
<td>10%</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Tab. 3: Baseline data of study subjects included in the analysis. ¹Data from 5-day dietary records.
Tab. 4: Results for osteodensitometric parameters. Columns 2-5 show the absolute values at baseline and after year 1. Significant between-group differences at baseline are marked in the power training group: *p<0.05, **p<0.01. Columns 6 and 7 show F and p values of the interaction term of time and training type from the two-way Anova. The critical $F_{1,40}$ value ($\alpha = 0.05$) is 4.08. The data shown apply to the groups in which subjects with insufficient training frequencies were excluded.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Strength training group (n=21)</th>
<th>Power training group (n=21)</th>
<th>Anova interaction term</th>
</tr>
</thead>
<tbody>
<tr>
<td>dxa pa l1-l4 [g/cm²]</td>
<td>baseline</td>
<td>year 1</td>
<td>baseline</td>
</tr>
<tr>
<td>dyad total hip [g/cm²]</td>
<td>0.884±0.083</td>
<td>0.867±0.069</td>
<td>0.873±0.081</td>
</tr>
<tr>
<td>dxa total forearm [g/cm²]</td>
<td>61.18±4.99</td>
<td>60.90±5.19</td>
<td>60.80±5.60</td>
</tr>
<tr>
<td>dxa femoral neck [g/cm²]</td>
<td>0.858±0.094</td>
<td>0.834±0.045</td>
<td>0.834±0.042</td>
</tr>
<tr>
<td>dxa trochanter [g/cm²]</td>
<td>0.705±0.065</td>
<td>0.703±0.059</td>
<td>0.700± 0.054</td>
</tr>
<tr>
<td>dxa intertrochanter [g/cm²]</td>
<td>0.670±0.096</td>
<td>0.623±0.048</td>
<td>0.624±0.049</td>
</tr>
<tr>
<td>dxa total forearm [g/cm²]</td>
<td>1.020±0.128</td>
<td>0.997±0.064**</td>
<td>0.998±0.065</td>
</tr>
<tr>
<td>dxa ulradistal radius [g/cm²]</td>
<td>0.390±0.057</td>
<td>0.388±0.056</td>
<td>0.414±0.043*</td>
</tr>
</tbody>
</table>