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ENHANCED BALANCE AND BONE MINERAL DENSITY ASSOCIATED WITH DIFFERENT EXERCISE TRAINING PROGRAMS IN OLDER WOMEN

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The purpose of this study was to compare the alterations in postural stability and bone mineral density (BMD) after 3 different exercise interventions. 94 women were randomly assigned to either a resistance exercise group (RE), aerobic exercise group (AE), combined weight-bearing exercise group (CE) or control group. Training was performed for 8 months. RE and AE interventions were conducted 3 days/week and CE only 2 days/week. After 8 months, all exercise training groups had improved dynamic and static balance. RE significantly improved BMD at the trochanter while CE significantly improved femoral neck BMD. In summary, all exercise interventions demonstrate to protect against postural instability that is strongly related to fall risk. Moreover, 8 months of RE may be more effective than AE and CE for inducing favourable changes in BMD and lean mass.

KEY WORDS: postural stability, force platform, dual-energy X-ray absorptiometry.

INTRODUCTION: Poor postural stability and low bone mass have been associated with an increased risk of fracture, so both topics rank high among the serious clinical problems faced by older adults. With increasing age, osteoblast activity decreases, osteoclast activity increases and there is a diminished differentiation potential of bone marrow stem cells, due to a relative decline in trophic factors (e.g. oestrogen, IGF-1, vitamin D) favoring local expression of molecules such as interleukins and TNF*α* (Khosla & Riggs, 2005). As a result, the amount of bone tissue is reduced which consequently motivate bones to become weaker. Exercise is considered to play a crucial role in improving balance and lower extremity strength, and also in bone modelling and remodelling (Borer, 2005). However, evidence regarding the effectiveness of different types of exercise in counteracting age-related declines in balance and bone mineral density (BMD) has been controversial. Depending of the type, intensity and frequency of training the results have pointed toward different direction, and less information is available regarding the effect of exercise interventions on both balance and BMD simultaneously. It has been described that osteogenic responsiveness to load bearing declines with age, which is predicted to cause an even great challenge to design exercise-based interventions suitable to older adults.

METHODS: Ninety-four women were randomly assigned to either a resistance exercise group (RE), aerobic exercise group (AE), combined weight-bearing exercise group (CE) or control group (CON). Eighty-eight subjects completed the study (n=22 in each group). Training was performed for 8 months. RE and AE interventions were conducted 3 days/week and CE only 2 days/week. The participants in the CON maintained their physical activity routine. Outcome measures included proximal femur BMD assessed by dual-energy X-ray absorptiometry (DXA; QDR 4500A, Hologic, Bedford, MA), dynamic balance (Up and go test), and single leg postural stability (one leg stance). Static postural stability was quantified on a 40x60cm^2 force platform (Bertec Force Plate AM 4060-15, USA) using anterior-posterior (AP) and medial-lateral (ML) center of pressure velocity (COPvel), and the elliptical area

(EA). Potential confounding variables included dietary intake assessed using 4-day diet records, body composition assessed by whole-body DXA scans, and accelerometer-based physical activity (PA).

All statistical analyses were performed using PASW Statistics (version 18; SPSS, Inc., Chicago, IL) for Windows with a significance level of 0.05. Data were checked for normal distribution, and the means ± SD were calculated. Potential differences among groups in baseline measurements (age, body composition, nutrition, PA, BMD) were evaluated using one-way analysis of variance (ANOVA) with Holm's correction. A two-way (group, time) factorial ANOVA, with repeated measures on one factor (time), was performed for differences in main effects and time by group interactions for each dependent variable. Main effects were considered when interactions were not significant. When significant interactions were found, Bonferroni post hoc tests were used to determine significant differences among mean values. The meaningfulness of the primary outcomes was estimated through the effect size (ES, means divided by the standard deviation): 0.2 or less is a small ES, about 0.5 is a moderate ES and 0.8 or more is a large ES.

RESULTS: Total energy intake was similar among the groups at baseline and during the period of intervention. No group differences were apparent in baseline values or change in dietary protein, phosphorus, caffeine, calcium, and vitamin D intake in response to the interventions. No significant changes in moderate to vigorous PA level were observed at eight months. There was no significant interactive or main effect of group and time on changes in PA. Changes in moderate to vigorous PA were not related to changes in the primary outcomes. No significant interaction occurred for body mass index, percent fat mass or waist circumference in response to exercise interventions. There was a main effect of time on waist circumference and percent fat mass ($p < 0.001$). Interaction was observed for lean mass ($p=0.020$). Thus, only the RE group significantly increased lean mass.

Regarding primary outcomes, no significant differences between groups for the balance variables were apparent at baseline. There were significant interactions between group and time on one leg stance time, elliptical area and COP velocity for AP-direction (Table 1). Accordingly, CE group improved the time to perform the static balance test, and a significant difference for post-training results was evident between AE and CE groups and the CON group. There was a significant main effect of time on changes in up and go performance and COPvel for ML-direction, where both measures decreased over time. All exercise training group significantly decreased the mean velocity of the COP displacement for AP-direction. Balance improvements were normally of large magnitude. Indeed, for COP displacement the effect size was large for AE and CE training groups (ES>1), and was moderate for RE group (ES≈0.7). Both RE and AE groups endorsed a large effect size for the EA variable. However in the CE the magnitude of change was small (ES=0.38). The ES was also large for the up and go test in all training groups (ES>1).

At baseline, there were no significant differences among the groups in BMD at any site measured (Table 1). There were significant interactions between group and time on BMD at the femoral neck ($p = 0.033$) and trochanter ($p = 0.030$). Accordingly, the RE group significantly increased BMD by 2.9% at the trochanter and CE group significantly increased BMD by 3.0% at the femoral neck. A significant main effect of time on total hip was observed ($p=0.009$), showing an overall increased for BMD over time. RE showed higher treatment effects for trochanter, intertrochanteric sites and total hip changes after exercise training. No significant changes in BMD were observed for the AE and CON groups ($p > 0.05$).

DISCUSSION: Because falls and fracture susceptibility is directly related to balance impairment of older adults (Peeters, van Schoor & Lips, 2009), exercise-induced enhancement of this skill may reduce the risk of falls and fall-related fractures (Rubenstein, 2006). In the present study, we observed that dynamic balance and postural stability-related measures significantly improved after interventions in RE, AE and CE groups. These data are in accordance with other reports using similar exercise interventions (Gillespie et al., 2009; Marques, Carvalho, Soares, Marques & Mota, 2009; Nalbant et al., 2009).

Table 1
Pre- and post-training values for balance and BMD variables

	Pre-training				Post-training				ANOVA		
Variable	RE	AE	CE	CON	RE	AE	CE	CON	P (t)	P (i)	P (g)
Time (s)	26.29 ± 13.22	28.80 ± 14.88	27.56 ± 15.27	26.89 ± 16.17	31.69 ± 12.79	32.88 ± 9.49^{a}	35.39 ± 13.07^{ab}	22.31 ± 13.60	0.029	0.011	0.232
EA (cm^2)	7.37 ± 4.84	7.24 ± 4.30	9.21 ± 10.02	7.24 ± 4.37	3.31 ± 1.01^{cb}	3.27 ± 1.29^{cb}	10.68 ± 11.03	7.44 ± 4.39	0.066	0.045	0.012
Veloc AP (cm/s)	4.01 ± 1.06	3.73 ± 1.15	3.72 ± 0.84	4.02 ± 1.12	3.51 ± 0.76^{b}	2.95 ± 0.81^{ab}	3.10 ± 0.78^{ab}	4.35 ± 1.53	0.001	0.001	0.013
Veloc ML (cm/s)	4.71 ± 2.07	4.34 ± 1.85	4.31 ± 1.70	4.80 ± 2.13	3.32 ± 0.85	2.90 ± 0.80	3.72 ± 1.87	4.62 ± 2.38	<0.001	0.077	0.143
UG (s)	5.46 ± 0.53	5.90 ± 0.94	5.89 ± 1.20	6.34 ± 1.21	4.88 ± 0.33	5.13 ± 0.60	5.01 ± 0.84	5.98 ± 0.86	<0.001	0.287	0.001
Neck (g/cm^2)	0.684 ± 0.082	0.657 ± 0.105	0.698 ± 0.101	0.676 ±0.069	0.676 ± 0.090	0.660 ± 0.111	0.718 ± 0.095^{b}	0.676 ± 0.065	0.278	0.033	0.346
Troch (g/cm^2)	0.646 ± 0.095	0.638 ± 0.099	0.619 ± 0.086	0.623 ± 0.051	0.666 ± 0.106^{b}	0.641 ± 0.098	0.627 ± 0.090	0.621 ± 0.046	0.006	0.030	0.566
Inter (g/cm^2)	1.035 ± 0.168	1.022 ±0.141	0.986 ± 0.159	0.979 ± 0.122	1.047 ± 0.164	1.020 ± 0.142	0.989 ± 0.165	0.980 ± 0.113	0.312	0.589	0.521
Total Hip (g/cm^2)	0.859 ± 0.124	0.848 ± 0.125	0.827 ± 0.114	0.821 ± 0.081	0.873 ± 0.132	0.849 ± 0.124	0.833 ± 0.116	0.824 ± 0.082	0.009	0.195	0.630

[a] Significant different from CON at post-training
[b] significant different from baseline
[c] significant different from CE group
EA= elliptical area; Troch = Trochanter; Veloc = velocity; UG = Up and go test; inter= intertrochanteric region; t= time; i = interaction, g =group
Time= time spent on one leg stance

Although positive changes in anthropometric indices have not been consistently related with the positive effect of exercise on falls and bone fractures prevention, improve body composition seem beneficial from the standpoint of counteracting the age-related disability. RE training resulted in a significant increase in body lean mass. Nutritional variables can independently affect bone material properties (Bass, Eser & Daly, 2005). Our dietary assessment revealed a non-significant change in diet patterns and no significant association with changes on BMD were found. In addition, no significant changes in the moderate to vigorous PA levels after 32 wk were observed. Taken together, these findings suggest that training protocols had *per se* an important modulator role on bone and balance adaptations. Our results showed a significant improvement of BMD mostly after RE and CE training which are consistent with prior studies that have similarly reported on the effectiveness of exercise in promoting an osteogenic response in the elderly (Bemben & Bemben, 2010; Englund, Littbrand, Sondell, Pettersson & Bucht, 2005; Park, Kim, Komatsu, Park & Mutoh, 2008). Together, these observations suggest that AE training protocols, which include concentric and eccentric muscle actions and loading impacts although at a lower intensity than with RE, produce modest effects on BMD in older women. One possible explanation is that aerobic protocols based only on walking activities, which lack lateral and twisting movements, do not represent a unique stimulus to bone. Our results suggest that the strain levels induced by the present AE were not sufficient to improve bone mass.

CONCLUSION: Data suggest that 8 months of resistance exercise may be more effective than aerobic exercise and combined exercise for inducing favourable changes in bone mineral density and lean mass, while the three interventions demonstrate to protect against postural instability that is strongly related to fall risk.

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