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BRIEF NOTE

Influence of three different types of physical training programs on bone mineral density in a group of elderly subjects

Influence de trois différents types de programmes d'entraînement physique sur la densité minérale osseuse dans un groupe de sujets âgés

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Bone mineral density;
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Summary
Introduction. — The aim of the present study was to explore the effect of resistance, endurance, and combined exercise training on bone mass in a group of elderly subjects.
Summary of facts and results. — Fifty-two healthy elderly subjects (35 women and 17 men) whose ages range between 65 and 75 years were included in the study. Subjects were randomly assigned to a resistance training group, an endurance training group, a combined resistance and endurance training group or a control group. The bone mineral density at the whole body, lumbar spine, total hip and femoral neck was measured by Dual-energy X-ray absorptiometry before and after 12 months of intervention. At the end-point of this experiment, bone mineral density at the total body, lumbar spine, total hip, and femoral neck increased in the resistance group ($P < 0.05$). Bone mineral density at the total body, total hip, and femoral neck remained unchanged in the endurance group. Bone mineral density at the whole body and lumbar spine increased

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in the combined resistance and endurance training group ($P < 0.05$), while bone mineral density of the total hip and femoral neck remained unchanged. The resistance training group showed the highest improvements in bone mineral density values compared to other groups.
Conclusion. — Resistance training can stimulate bone gain while endurance training can mitigate bone loss at clinically important sites of osteoporotic fractures in elderly subjects.

MOTS CLÉS
Densité minérale osseuse ;
Entraînement physique ;
Personnes âgées

Résumé
Introduction. — Le but de cette étude était d'explorer l'effet de l'entraînement physique en résistance, endurance ou bien combiné (aérobie et résistance) sur la masse osseuse dans un groupe de sujets âgés.
Synthèse des faits et résultats. — Cinquante-deux sujets sains (35 femmes et 17 hommes) âgés de 65 à 75 ans ont été inclus dans l'étude. Les sujets ont été répartis au hasard dans le groupe d'entraînement en résistance, le groupe d'entraînement en endurance, le groupe d'entraînement combiné (résistance et endurance) ou bien le groupe témoin. La densité minérale osseuse du corps entier, du rachis lombaire, de la hanche totale et du col fémoral ont été évalués par ostéodensitométrie avant et après 12 mois d'intervention. Après 12 mois d'intervention, la densité minérale osseuse au niveau du corps entier, du rachis lombaire, de la hanche, et du col fémoral a augmenté chez le groupe d'entraînement en résistance ($p < 0{,}05$). La densité minérale osseuse au niveau du corps entier, de la hanche totale et du col fémoral est demeurée inchangée chez le groupe d'entraînement en endurance. La densité minérale osseuse au niveau du corps entier et du rachis lombaire a augmenté ($p < 0{,}05$) tandis que la densité minérale osseuse de la hanche totale et du col fémoral est demeurée inchangée dans groupe d'entraînement combiné. Le groupe d'entraînement en résistance a montré les améliorations les plus importantes des valeurs de densité minérale osseuse par rapport aux autres groupes.
Conclusion. — L'entraînement en résistance peut stimuler le gain osseux tandis que l'entraînement en endurance peut atténuer la perte osseuse au niveau des sites de fracture ostéoporotiques les plus fréquents chez les sujets âgés.

1. Introduction

Aging is associated with changes in musculoskeletal system including a gradual and progressive decline in bone mass and deterioration in bone architecture. Exercise is believed to be the most effective environmental factor proposed to improve bone health. We have recently shown that resistance training increases lumbar spine BMD, trabecular bone score and whole body bone mineral content (BMC) in young individuals [1]. Furthermore, we have shown that endurance training increases whole body BMC in adolescents [2]. In the present study, we sought to extend these findings and explore the effect of resistance, endurance, and combined exercise training on bone mass in elderly men and women.

2. Materials and methods

This study included 52 healthy elderly subjects (35 women and 17 men) whose ages range between 65 and 75 years. Subjects were randomly assigned to 4 groups: resistance training group (RTG), endurance training group (ETG), combined resistance and endurance training group (CRETG), or a control group (CG). The experimental groups performed incremental training of two sessions per week for the period of 12 months. They were selected from an autonomous and independent population, living in their ordinary environment in north Lebanon. Participants were healthy and not engaged in other muscle strengthening programs neither before nor during the study. Non-inclusion criteria included: smoking, alcoholism, history of major orthopedic problems, presence of disorders known to affect bone metabolism (endocrine abnormalities, malabsorption or infectious diseases), and pharmacotherapy that may affect bone and calcium metabolism (corticosteroid or anticonvulsant therapy). This study was approved by the ethical committee of the University of Balamand, and written informed consent was obtained from all participants. For bone measurements, BMD (in gram per square centimeter) was determined for each individual by dual-energy X-ray absorptiometry (GE Lunar Healthcare, Madison, WI, USA) at whole body (WB), lumbar spine (L1-L4), total hip (TH), and femoral neck (FN). Bone measures were conducted at baseline and after 12 months of training.

Each endurance training session consisted of speed walking with changing directions for one hour on a sports field

Table 1 Clinical characteristics and bone measurements before training.

	RTG($n = 13$: 4 M; 9 W)	ETG($n = 13$: 4 M; 9 W)	CRETG($n = 13$: 5 M; 8 W)	CG($n = 13$: 4 M; 9 W)
Age, (years)	69.01 (3.06)	67.97 (3.27)	68.41 (2.33)	68.40 (3.83)
Weight, (kg)	70.19 (16.96)	68.23 (14)	82.07 (16.05)	71.92 (16.28)
Height, (m)	1.55 (0.11)	1.54 (0.07)	1.62 (0.1)	1.56 (0.08)
BMI, (kg/m^2)	28.75 (5.68)	28.36 (4.86)	31.09 (4.23)	29.37 (6.35)
WB BMD, (g/cm^2)	0.910 (0.116)[b]	0.984 (0.101)	1.067 (0.122)[a]	0.925 (0.133)
L1-L4 BMD, (g/cm^2)	0.843 (0.170)[b,c]	0.976 (0.137)	1.060 (0.167)[a]	0.931 (0.126)
TH BMD, (g/cm^2)	0.800 (0.104)[b]	0.861 (0.102)	0.951 (0.120)[a]	0.822 (0.167)
FN BMD, (g/cm^2)	0.754 (0.103)	0.829 (0.112)	0.873 (0.109)	0.775 (0.162)

RTG: resistance training group; ETG: endurance training group; CRETG: combined resistance and endurance training group; CG: control group; M: men; W: women; BMI: Body mass index; WB: whole body; TH: total hip; FN: femoral neck; BMD: bone mineral density.
[a] $P < 0.05$ vs. CG.
[b] $P < 0.05$ vs. CRETG.
[c] $P < 0.05$ vs. ETG.

Table 2 Percentage of variation of bone measurements after 12-month training in the four groups.

	RTG($n = 13$: 4 M; 9 W)	ETG($n = 12$: 3 M; 9 W)	CRETG($n = 13$: 5 M: 8 W)	CG($n = 13$: 4 M; 9 W)
WB BMD	6.64 (4.99)[a,b,c,d]	−0.02 (4.56)[a]	1.95 (1.42)[a,b]	−1.82 (1.02)[a]
L1-L4 BMD	5.42 (2.45)[a,b,c,d]	2.21 (4.48)[a,b]	3.01 (2.20)[a,b]	−1.31 (1.33)[a]
TH BMD	1.83 (2.70)[a,b,d]	−0.44 (6.36)[a]	1.19 (2.74)[a]	−1.25 (1.87)[a]
FN BMD	2.12 (3.22)[a,b]	−0.92 (4.99)[a]	0.77 (3.87)[a]	−2.22 (1.99)[a]

RTG: resistance training group; ETG: endurance training group; CRETG: combined resistance and endurance training group; CG: control group; M: men; W: women; BMI: Body mass index; WB: whole body; TH: total hip; FN: femoral neck; BMD: bone mineral density.
[a] $P < 0.05$ vs. baseline.
[b] $P < 0.05$ vs. CG after 12 month of training.
[c] $P < 0.05$ vs. CRETG after 12 month of training.
[d] $P < 0.05$ vs. ETG after 12 month of training.

at 65—75% of maximal heart rate. Each resistance training session consisted of weight exercises for the limbs and the trunk; 3×10 repetitions at 70—75% of one maximal repetition for each muscle group. The participants of the ETG performed 2 sessions of endurance training per week. The participants of the RTG performed 2 sessions of resistance training per week. The participants of the CRETG performed one session of each resistance and endurance training per week. Attendance was taken every time the subjects exercised.

All variables were tested for normality using the Shapiro-Wilk test. Statistical analysis was performed using two-way repeated-measures Anova; post-hoc tests were performed in case of differences. Differences were considered significant at P-value ≤ 0.05. Data were analyzed using SPSS 20 for windows release (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY, USA).

3. Results

The training compliance rates for the experimental groups were as follows: 83.3% for the RTG, 80.7% for the ETG and 84.6% for the CRETG. Clinical characteristics and bone outcomes for each of the four groups are displayed in Table 1.

The percentage of variation of bone measurements after 12-month training in the four groups is presented in Table 2. CG showed significant decreases in WB BMD, L1-L4 BMD, TH BMD and FN BMD values ($P < 0.05$). RTG showed the highest improvements in BMD values at all sites ($P < 0.05$). ETG showed significant improvement of BMD only at the lumbar spine. CRETG showed significant increases in WB BMD, and L1-L4 BMD ($P < 0.05$). Among training groups, the variations of WB BMD and L1-L4 BMD were significantly higher in RTG than ETG and CRETG ($P < 0.05$). The variation of TH BMD was also significantly higher in RTG than ETG.

4. Discussion

This study examined the implementation of a 12-month supervised resistance, endurance, and combined exercise training on bone mass in elderly men and women. We have shown that physical training has great potential to be useful for improving bone health and preventing osteoporosis in older adults. We demonstrated that resistance training increases bone mass while endurance training mitigates bone loss at the WB, LS, TH, and FN over the follow-up period. We have also shown that combining the two types of training increases bone mass at the WB and LS and mitigates bone loss at the TH and FN.

Endurance and resistance exercises are dynamic and promote several musculoskeletal adaptations. During endurance exercises, muscle contractions are repetitive and of lower magnitude. This contributes to the improvement of muscle endurance without having a remarkable positive effect on muscle strength and thus on bone mass. Not unexpectedly, we demonstrated that this type of exercise can mitigate bone loss without having significant effects on bone gain at several bone sites. On the other hand, resistance exercises are potentially osteogenic and have a more profound effect on bone metabolism than aerobic exercises in elderly individuals. We demonstrated that resistance training can increase bone mass at the WB, LS, TH, and FN. Resistance exercises are able to [3]:

- generate higher joint reaction forces that elicit myocyte synthesis of osteogenic molecules such as inflammatory cytokines and growth factors;
- solicit the use of fast-twitch muscle fibers that generate powerful muscle contractions and;
- reduce intramuscular fatty infiltration which increases muscle strength and power.

These muscular responses toward resistance exercise are potential mechanisms that may explain the positive effect of such training on bone mass in our group of elderly subjects. Physical exercise can also influence bone metabolism via a direct impact on mechano-sensitive cells such as osteocytes and an indirect impact by inducing changes in several anabolic hormone levels such as growth hormone, insulin-like growth factor-1, testosterone, parathyroid hormone, vitamin D, leptin and ghrelin [4].

When combining endurance and resistance training, the participants experienced a significant increase in WB and LS BMD while showing maintenance of TH and FN BMD. Therefore, it seems that resistance training loses some of its potential effect in stimulating bone gain when combined with endurance training. This may be due to the ''interference effect''. Combining two types of training induces lower muscle strength gains when compared with resistance training alone. Therefore, lower magnitude of muscle strength gains in CRETG may explain the lower bone adaptations observed in this group.

Strengths of the present study include the randomized controlled trial design and measures of BMD at clinically important sites of osteoporotic fracture. Study limitations include the low number of participants. Further studies with larger samples are needed to confirm our results and to clarify the effect of exercise training on bone variables in older individuals.

5. Conclusion

In conclusion, resistance training is more effective in increasing BMD than endurance or combined resistance and endurance training in elderly subjects. In addition, all training methods have limited the bone loss when compared with the control group. Such findings may be clinically important. Promoting regular and systemic resistance training in this population could be effective in reducing bone loss and preventing osteoporotic fractures.

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Disclosure of interest

The authors declare that they have no competing interest.

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