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Effectiveness of resistance training or jumping-exercise to increase bone mineral density in men with low bone mass: A 12-month randomized, clinical trial

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ABSTRACT

Purpose: To examine the effects of 12 mo of resistance training (RT, 2×/wk, N = 19) or jump training (JUMP, 3×/wk, N = 19) on bone mineral density (BMD) and bone turnover markers (BTM) in physically active (≥4 h/wk) men (mean age: 44 ± 2 y; median: 44 y) with osteopenia of the hip or spine.
Methods: Participants rated pain and fatigue following each RT or JUMP session. All participants received supplemental calcium (1200 mg/d) and vitamin D (10 μg/d). BMD was measured at 0, 6, and 12 mo using DXA scans of the whole body (WB), total hip (TH) and lumbar spine (LS). BTM and 25 OHD were measured by ELISA. The effects of RT or JUMP on BMD and BTM were evaluated using 3x2 repeated measures ANOVA (time, group). This study was conducted in accordance with the Declaration of Helsinki and was approved by the University of Missouri IRB.
Results: At baseline, 36 of 38 participants were vitamin D sufficient (25OHD > 50 nmol/L); at 12 mo, all participants were 25OHD sufficient. 25OHD did not differ between groups. WB and LS BMD significantly increased after 6 months of RT or JUMP and this increase was maintained at 12 mo; TH BMD increased only in RT. Osteocalcin increased significantly after 12 mo of RT or JUMP; CTx decreased significantly after 6 mo and returned to baseline concentrations at 12 mo in both RT and JUMP. Pain and fatigue ratings after RT or JUMP sessions were very low at 0, 6, and 12 mo.
Conclusion: RT or JUMP, which appeared safe and feasible, increased BMD of the whole body and lumbar spine, while RT also increased hip BMD, in moderately active, osteopenic men.

1. Introduction

1.1. Male osteoporosis

Osteoporosis affects more than 2 million men in the United States today and nearly 16 million more have low bone mass [1]. Men account for approximately 40% of the 9 million new osteoporotic fractures that occur annually [2] and the lifetime fracture risk in men aged ≥60 years is estimated to be as high as 25% [3]. Compared with women, men have a significantly greater risk for complications after a hip fracture, including increased morbidity, mortality, loss of independence, and rate of institutionalization [4,5], yet treatment rates are much lower in males than females [6]. Recent estimates indicate that one-third of Caucasian males over 65 years and greater than one-half over 75 years would be recommended pharmacologic treatment for osteoporosis based on National Osteoporosis Foundation guidelines [7]. Yet, even after suffering an osteoporosis-related fracture, >90% of men remain undiagnosed and untreated [8,9]. Post-fracture, men are less likely to receive follow-up care than women [10], including calcium and vitamin D supplementation [11] and prescription of anti-resorptive pharmacotherapy [6].

Although anti-resorptive medications are an FDA-approved treatment for osteoporosis in males [12], less than 10% of men with osteoporotic fractures are treated with bisphosphonates. Enthusiasm for use of these medications in men appears to be limited by the relative lack of long-term safety and efficacy studies in men, the especially poor treatment compliance in males [13], and data suggesting poor cost effectiveness of bisphosphonate treatment in men [14]. Drug treatments for osteoporosis have low rates of compliance and persistence, and most patients who stop taking their osteoporosis medication do not restart [15].

1.2. Exercise interventions to improve bone outcomes

Exercise-based interventions are an attractive alternative to medication due to the reduced cost, fewer serious side effects, and additional

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health benefits, including improved balance and fall reduction [16,17]. Moreover, because osteoporotic fractures occur most frequently at the hip and spine, site-specific interventions to increase bone mineral density are highly desirable. Physical activity allows for targeted strengthening of the hip and spine because sufficient skeletal loading stimulates net bone formation at the stressed skeletal sites [18]. A recent meta-analysis and review by an expert panel strongly recommends multi-component exercise for individuals with osteoporosis to improve bone health outcomes [16].

Most of the data that support this recommendation are from exercise intervention trials in women. Exercise that exerts in high muscle-contraction or ground-reaction forces on the skeleton, such as resistance training [19] or structured jump-training, respectively, increase BMD in pre- and post-menopausal women [20–22]. Consistent with controlled studies of high-impact exercise and resistance training in women, voluntary long-term participation in running or weight-lifting was associated with greater BMD compared with participation in cycling, a weight-supported activity, in adult men [23,24]. However, there are very few controlled trials that examine the effects of resistance training or high-impact exercise on bone mass in men [25–32]. Unfortunately, most of these studies have included men and women, elderly men, or a mixed study population of men who had either normal or low BMD. Thus, intervention trials that test the efficacy of exercise-based interventions to increase BMD in *adult males with low bone mass* are needed.

1.3. Study objectives and hypotheses

Thus, the objective of this randomized clinical trial was to determine the effects of 12 months of resistance training (RT) or jump training (JUMP) on whole body (WB), total hip (TH), and lumbar spine (LS) BMD and on markers of bone formation and resorption in apparently healthy men with low TH or LS bone mass. We hypothesized that both the RT and JUMP interventions would significantly increase BMD of the TH and LS, and that bone formation would increase relative to resorption based on changes in serum markers.

2. Materials and methods

2.1. Trial design

This was a 12-month randomized, parallel intervention clinical trial with a 1:1 allocation ratio of participants to either resistance training or high-intensity jump training. We did not include a no-exercise control group, as we did not feel it was ethical to do so in men with clinically significant low bone mass [33,34]. This study was conducted in accordance with the Declaration of Helsinki and was approved by the University of Missouri IRB. Informed written consent was obtained from each study participant.

2.2. Participants

2.2.1. Inclusion and exclusion criteria and screening

Apparently healthy, physically active (≥4 hours of leisure time physical activity/week for the past 24 months) men aged 25–60 years with low BMD of the lumbar spine or hip (> -2.5 SD T-score ≤ -1.0 SD) were eligible to participate in this study. Exclusion criteria were as follows: use of medications or supplements that affect bone metabolism or prevent exercise; previous or current medical condition affecting bone health; osteoporosis of the lumbar spine and/or hip (T score < -2.5 SD); cardiovascular disease; metal implants; current smoker (i.e., within the past 6 months); current regular participation in high-intensity resistance training and/or plyometrics; reversed sleep/wake cycle, i.e., sleep during the day, work at night; and drink excessive amounts of alcohol (more than 3 drinks per day).

The Physical Activity Readiness Questionnaire (PAR-Q) and a medical history questionnaire were used to screen for exclusion criteria. Study personnel reviewed each subject's responses on the medical history questionnaire and PAR-Q to verify completeness of the written responses. In addition, DXA scans of the whole body, total hip and lumbar spine to screen for eligibility based on BMD of the hip or lumbar spine (i.e., low bone mass, which was defined as -2.5 SD < T-score ≤ -1.0 SD) [35].

2.2.2. Recruitment

Potential subjects were recruited from the university and local community via email to university employees and fliers posted on campus, at local sporting goods stores, parks and recreation areas and at community events. Because most potential participants would not know their BMD status (i.e., would not have had a BMD assessment as part of routine healthcare), recruitment was targeted to moderately active, apparently health men aged 25–60 years.

2.3. Exercise interventions

2.3.1. Intervention design

The RT and JUMP exercise interventions tested in this study were designed to optimize the osteogenic response. Unlike cardiovascular and metabolic adaptations to exercise, which depend on exercise volume (quantity and intensity, i.e., rate of energy expenditure), the bone response does not increase with exercise volume [36]. Therefore, we did not attempt to equalize exercise time or energy expenditure between the RT and JUMP interventions; rather, each intervention was independently designed to result in the greatest increases in BMD of the TH and LS. The frequency of the RT and JUMP interventions (2 and 3 times per week, respectively) was determined by the recovery period required for RT (48 hours) and JUMP (24 hours).

2.3.2. Exercise intervention training sessions

All training sessions were supervised by study personnel and were performed in McKee Gym Fitness Center. Participants were required to complete all training sessions. If a participant missed a scheduled training session (e.g., due to illness), he was required to make up the missed session. Make-up of missed sessions was feasible because RT trained twice per week with a minimum of 48 hours between sessions and JUMP three times per week with at least 24 hours between training. Because the training sessions were supervised and participants were required to complete all sessions, the "compliance" with the RT or JUMP training was 100%.

Study personnel recorded information for each RT or JUMP training set (i.e., resistance exercise or jump type, weight lifted and % of 1-repetition maximum (RM) for RT, and number of repetitions) in each participant's exercise intervention log book. Before and after each training session, participants were asked to rate their pain and fatigue on a visual analog scale from 0 to 100 with 100 being the worst pain or fatigue imaginable. These data, which were collected to evaluate the pain and fatigue associated with the JUMP and RT interventions and to monitor the participants' pain and reduce risk of injury during each training session, were also recorded by the study personnel in the participant's exercise intervention log book.

2.3.3. Supplemental calcium and vitamin D

All participants were provided supplemental calcium (1200 mg calcium carbonate/d) and vitamin D (10 μg vitamin D_3/d) (Nature Made, Mission Hills, CA, USA) to ensure adequate intake of these nutrients by all participants. Participants were instructed to take one calcium and vitamin D supplement (each supplement contained 500 mg calcium and 5 μg vitamin D_3) in the morning and the other in the evening. Every 6 weeks, participants were provided a 6-week supply of supplements. Participants were required to return unconsumed