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Review

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Effects of Resistance Training on Bone and Muscle Mass in Older Women: A Review

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ABSTRACT

Aging is associated with declines of different physiological systems. These reductions are directly related to loss of mobility in older individuals, reducing the independence and quality of life for this population. Regular physical activity (e.g, resistance training, RT), has been shown to decrease mortality and age-related morbidity in older adults, including women. A fracture is closely related to the typical decline in bone mass (i.e, osteoporosis) especially in postmenopausal women. In fact, up to 30% of postmenopausal females have osteoporosis. In postmenopausal women the rate of bone mineral density loss progressively increases with age. In addition, decreases in muscle tissue (i.e, sarcopneia) may begin to occur before the fourth decade and gradually worsens through the later stages of adulthood. Sarcopenia, is characterized by low muscle mass, low muscle strength, and low physical performance, which can lead to disability, risk of falls and fractures, and death. Further, sarcopenia occurs to a greater degree in older women than men. Menopause is characterized by important changes in hormonal status and these changes have a significant effect on body composition (i.e, bone mass density, muscle mass, and body fat). Importantly, RT is effective in increasing bone and muscle mass and improving measurements of physical performance. Thus, this review is intended to summarize the effects of RT on bone and muscle mass in older postmenopausal women.

KEY WORDS: Exercise; Postmenopausal women; Osteoporosis; Sarcopenia; Aging.

ABBREVIATIONS: ADLs: Activities of Daily Living; QOL: Quality of Life; RT: Resistance Training; ACSM: American College of Sports Medicine; BMD: Bone Mineral Density; WBV: Whole Body Vibration.

INTRODUCTION

The aging process is associated with declines of different physiological systems, including the neuromuscular system, through the loss of strength, power and muscle mass,[1] as well as the cardiovascular system, which presents through a reduction in Activities of Daily Living (ADLs). These reductions are directly related to loss of mobility in older individuals, reducing the independence and Quality of Life (QOL) for this population.[2] On the other hand, regular physical activity, including Resistance Training (RT), is a keystone intervention to counteract many age-associated diseases, to increase functional independence, and have a positive effect on several health outcomes in the elderly.[3,4] Moreover, regular exercise has been shown to decrease mortality and age-related morbidity in older adults.[5] Although the positive benefits of aerobic exercise are widely accepted, the importance of RT especially in the older female population has not been as well recognized or implemented. Indeed, the addition of RT guidelines to the 1998 American College of Sports Medicine (ACSM) position statement was the result of overwhelming evidence of the health and functional benefits associated with this type of training.[6] The 2011 ACSM guidelines[7] updates the scientific evidence published since the 1998 Position Stand in regards to RT.[6] Further, ACSM currently recognizes that weight-bearing exercise confers beneficial effects for bone health across the age spectrum.[8] Not only does RT significantly impact strength and endurance, it contributes to the maintenance of functional ability (i.e, ADLs), and is an important factor in preventing osteoporosis, sarcopenia and disabilities.[6-10] RT is particularly effective in increasing muscle mass and strength and improving several measurements of physical performance.[11] Furthermore, integrating balance training and RT into regular physical activity programs appears particularly efficient in reducing the rate of falls in older people, and in improving the overall QOL.[12]

It is well-known that the risk of fractures is closely related to the typical decline in bone mass (i.e, osteoporosis) during the aging process, in both women and men.[13] Since osteoporosis is a major public health concern, the prevention of osteoporosis is a national health initiative by the Surgeon General's office. Certainly, the Surgeon General predicts that, by 2020, there will be 13.9 million individuals with osteoporosis (more than 75% of these will be women) and 47.5 million with low bone mass (64% women).[14] Further, the World Health Organization reports 30% of postmenopausal females have osteoporosis.[15] Notably, osteoporosis is more prevalent among women with an accelerated rate of bone loss for 4 to 8 years following menopause due to estrogen withdrawal.[16,17] These women also experience a decline in physical activity.[18] In their early 50s,women lose up to 5% of bone mass in the first few years after menopause, followed by 2-3% annual loss thereafter, while men lose approximately 1-2% of Bone Mineral Density (BMD) per year, starting from a higher baseline.[19] For instance, in postmenopausal women the rate of bone mineral density (BMD) loss progressively increased with age: -0.6%, -1.1% and -2.1% per year for the 60-69, 70-79 and ≥ 80 years age groups, respectively.[20] Importantly, RT seems to be a powerful stimulus to improve and maintain BMD during the aging process.[21]

Correspondingly, it has been reported that muscle strength declines by 15% per decade after age 50 and 30% per decade after age 70.[22] Indeed, decreases in muscle tissue quantity and quality may begin to occur before the fourth decade and gradually worsens through the later stages of adulthood.[23] Muscle cross-sectional area and single-fiber atrophy account for some of the variability in strength loss among elderly persons, and this atrophy appears to be exaggerated in Type II fiber.[24] Sarcopenia, frequently observed in the elderly, is characterized by low muscle mass, low muscle strength, and low physical performance, which can lead to disability, risk of falls and fractures, and death.[25,26] In sarcopenic or frail patients, RT is capable of improving lean tissue mass, muscle strength and several physical performance measures; such as, time up and go, stair-climbing power, aerobic capacity, gait speed and 6-minute walking distance. All of these performance measures require increased muscle mass or strength.[27,28] Moreover, Peterson at el, reported that there is a strong association between RT and increases in lean body mass among adults >50 years of age (n=1328).[29] These investigators revealed that following 20 weeks of RT, both men and women experienced an approximate 1-kg (2.2-lb) increase in lean body mass. Interestingly, that finding is in contrast to the nearly 0.2-kg (0.44-lb) annual decline that might occur through sedentary lifestyles beyond 50 years of age.[30] Additionally, sarcopenia occurs to a greater degree in older women than men. For instance, results from the Framingham disability study demonstrated that 45% of women older than 65 years and 65% older than 75 years could not lift 10 pounds.[31] Further, it has been reported that there is an accelerated decline in muscle mass that has been shown to occur after the 5th decade, or around the years of menopause.[32] Across-sectional study reported a decline in muscle mass of 0.6% per year after menopause.[33] Menopause is characterized by important changes in hormonal status and these changes have a significant effect on bone mass density and body fat distribution.[34] Strong evidence supports the hypothesis that the decline in estrogen levels with menopause may play a role in muscle mass loss in postmenopausal women.[35] In truth, estrogen has a direct anabolic action on the skeletal muscle that contains estrogenic receptors.[36] Notably, RT is an important stimulator of anabolic hormones. For instance, estradiol responses to RT appear to depend on the exercise intensity and stage of the menstrual cycle,[37] and occur mainly during the workout.[38] Furthermore, RT can result in 25 to 100%, or more, strength gains in older adults through muscle hypertrophy and, presumably, increased motor unit recruitment.[22,39] These improvements in muscle strength appear to be proportional to the intensity of the RT exercise.[11] Nevertheless, only 27% of the US population is estimated to participate in leisure-time RT exercise, and these rates are substantially less for individuals over the age of 50 years.[40] Thus, the main purpose of this review is to discuss the effects of RT on bone and muscle mass in older postmenopausal women, as a starting point for developing future intervention programs that help to maintain a healthy bone and muscle mass and a higher QOL.

EFFECTS OF RESISTANCE TRAINING ON BONE MASS

The studies that evaluated the role of RT on BMD in postmenopausal women have obtained mixed results. Some authors described increased mineralization,[41,42] others reported attenuated demineralization,[41,43] while still others indicated no effect[44,45] following RT. Nevertheless, RT is still one of the most recurrent types of exercise applied in order to improve bone mass in elderly individuals; especially in preventing bone loss among postmenopausal women.[21,46] Previous studies have reported that RT is able to prevent bone demineralization in older women.[47,48] For instance, the study by de Matos, et al.[48] reported that 12 weeks of weight training, among postmenopausal women with osteoporosis or osteopenia, did not significantly improve BMD (1.17%) at the lumbar spine in the exercise group (n=30). However, the control group (n=29) showed a significant loss in the spine BMD (2.26%). Further, Bocalini, et al.[47] evaluated the effects of RT on the BMD of postmenopausal women without Hormone Replacement Therapy (HRT). These investigators reported that following 24 weeks of training, untrained women exhibited a significant percentage decrease in BMD at the lumbar spine and femoral neck. Interestingly, BMD was maintained in trained women at both sites. Another 6-month exercise program study (n=125, 52-72 years old)[49] reported no significant change

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in the BMD of the femoral neck, lumbar spine, and ultra-distal and proximal radius; but they did note an increase in the density of the cortical component of the ultra-distal radius. Clearly, these previous studies seem to indicate that site-specific moderate physical exercises have very little effect on bone mass.

On the other hand, long-term RT programs (i.e, >1 year) reported significant effects of RT in postmenopausal women. Certainly, Nelson, et al.[41] revealed that 1 year of high-intensity RT was able to enhance BMD by 1% at the femoral neck and lumbar spine; while in the control group, women lost 2.5% and 1.8% at these sites, respectively. Another 1 year RT study of 56 postmenopausal women[50] reported that bone mass, in the exercise group, increased significantly at the trochanteric and intertrochanteric hip site, at Ward's triangle and at the ultra-distal radial site compared with the control group. This study concluded that postmenopausal bone mass can be significantly increased by RT, particularly when high-load low repetitions were used.[50] Finally, it has been reported that a significant effect of RT in postmenopausal women (mean age, 60 +/- 5 years) over 2 years at the clinically important intertrochanter hip site (+1.1%).[46] Remarkably, the maximum change in BMD occurred in the first year of the intervention. There was lative decline in the rate of change during the second year; however, BMD remained more than a 3% difference between the exercise and control group after 2 years.

Importantly, exercise intensity and duration, and continuous training are key components when prescribing RT programs. In regards to the exercise intensity, the majority of studies have determined that high intensity RT programs (70% to 90% of one repetition maximum; 1RM) had an osteogenic effect on the BMD in postmenopausal women by either increasing or preventing further bone loss as compared to the control group.[8,50-52] Really, it has been reported that the skeleton adapts to the increasing load applied by progressive RT in postmenopausal women by increasing BMD.[50] Similarly, the study by Nelson et al,[41] established that high intensity (i.e, 80% of 1RM) RT had a positive effect on the femoral neck BMD and lumbar BMD in postmenopausal women. Further, regular high intensity RT seems to be appropriate exercise therapy in maintaining lumbar spine BMD among postmenopausal women although the inclusion of other weight bearing activities may also be necessary to best augment hip BMD without other therapeutic agents.[52] Remarkably, for BMD improvement, the magnitude of the stimuli seems to be more important than the frequency of the stimuli.[53,54] Accordingly, RT has been more effective in increasing or maintaining BMD when compared to running, an already known osteogenic factor.[55] This positive effect occurs especially in anatomical sites where both activities produce mechanical stress, such as in the femur neck. Noticeably, the previous evidence appears to indicate that greater improvements could be achieved through RT of high-loading intensities with 3 sessions per week. It is imperative to emphasize that bone mass undergoes a never-ceasing process of formation and resorption and responds to the constantly changing mechanical forces impacting on its surfaces.[56] In regards to exercise duration, RT programs that last over 12 months appear to be responsible for a positive effect on bone mass. Although significant effects on BMD can be observed after 4 or 6 months in some locations of the body; the efficacy of the RT seems to be greater when the exercise programs lengthens for at least 1 year. Definitely, RT should last 12 to 18 months to ensure the training effect on BMD can be measured in an equilibrium state.[57] Further, when comparing pre- and postmenopausal women, the later require longer periods of intervention and higher loads because they are in a period of accelerated bone loss.[58] Lastly, the RT effects appear to disappear after the training is finished, as BMD decreased after the completion of the program.[56,59] For instance, Sinaki, et al.[59] reported changes in BMD continued 8 years after cessation of the 2-year RT program. The back exercise group had a loss in BMD, but the loss was significantly less in the back exercise group than in the control group. Clearly, RT helps prevent bone loss among postmenopausal women. It seems that the increased mechanical stress on the bone, provided by RT, is the causal factor of osteogenesis.[41] Furthermore, RT studies suggested that muscle contraction can also increase BMD by stimulating tissue remodeling,[45] bone formation,[60] or even augmentation of bone formation associated with an inhibition of reabsorption.[61]

Interestingly, it has been reported that high-frequency mechanical strain (i.e, vibration loading) might also have potential for preventing and treating osteoporosis. Really, Rubin, et al.[62] provided evidence in an animal model that low-risk, high-frequency mechanical accelerations may have a strong osteogenic effect. These investigators observed a dramatic increase of the quality and quantity of trabecular bone in sheep when exposed to low-level, high-frequency mechanical stimuli. Moreover, a high-frequency loading regimen applied to ovariectomized rats was effective in preventing early post-ovariectomy bone loss.[63] Further, Whole Body Vibration (WBV) training uses high frequency mechanical stimuli, which are generated by a vibrating platform and transmitted through the body where they load the bone and stimulate sensory receptors. Based on this background, a 6-month randomized controlled trial was aimed to study the effect of WBV on hip density in postmenopausal women.[64] The WBV participants (n=25, mean age=65 years) trained 3 times per week, performing static and dynamic knee-extensor exercises on a vibration platform, which mechanically loaded the bone and evoked reflexive muscle contractions. Importantly, no vibration-related side effects were observed; and BMD of the hip increased significantly (+0.93%) after vibration training.

In summary, the majority of studies cited previously seemed to indicate that RT promotes high-intensity loading force that are effective in increasing BMD in postmenopausal women. Thus, RT should be recommended as an adjunct lifestyle approach to osteoporosis prevention or in combination with other treatments in this group of women.

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EFFECTS OF RESISTANCE TRAINING ON MUSCLE MASS

Physical activity guidelines for older adults, men and women, have been developed byACSM and American Heart Association.[65] Indeed, muscle-strengthening activity should be performed, at least, 2 or more non-consecutive days per week, using a single set of 8-10 resistance exercises for the whole body, and at a moderate to high level of effort that allows 10-15 repetitions.[65] Additionally, RT is considered to be a safe and effective method for increasing strength and lean muscle tissue, and attenuating age-related muscle loss.[66-68] Interestingly, a 2004 systematic review of randomized controlled trials (n=28) on postmenopausal women (2646 participants, aged 50 to 65 years), reported that only 11 studies focused on muscular strength or endurance.[69] Additionally, a 12-week exercise program was conducted to determine the effects of RT and detraining on muscle mass in postmenopausal women (aged>50 years).[70] The intervention consisted of 3 sets of 10 repetitions; 3 times a week. The results showed that RT was sufficient to enhance strength of postmenopausal women. In addition, a 4-week detraining period had an adverse effect on muscle strength; however, the strength was greater in the RT group compared to the baseline values and the control group. The study by Charett, et al.[71] was aimed at determining whether increases in muscle strength were associated with changes in cross-sectional fiber area in older women (mean age=69 years). These investigators reported that the cross-sectional area of type II muscle fibers significantly increased in the exercise group (20.1 +/- 6.8%), after 12 weeks, compared with baseline. In contrast, no significant change in type II fiber area was observed in the controls.[71] A 16-week RT program promoted an increase on muscle mass and muscle strength in sedentary postmenopausal women (n=22, mean age=58 years).[72] The program targeted upper and lower body, 3 times per week in three series of 8-12 repetitions (60-80% 1RM). The exercise group gained 1.8 kg of muscle mass (10%) than the control group. Similar results were reported by Bonganha et al,[73] after a 16-week RT program. Postmenopausal women were randomized into exercise (n=16) and control (n=16) groups. RT was performed 3 times per week at 70 to 85% of 1RM. Their findings demonstrated that RT promoted a significant increase in muscle strength for leg press, bench press and curl. Moreover, after a 21-week progressive RT, performed twice a week,[74] maximal force increased by 37% and 1-RM by 29% of the leg extensors in older women (aged 64 years). Similarly, the cross-sectional area of the quadriceps increased after training. Holviala, et al.[75] studied the effects of 21-week heavy RT, twice a week, in 48 postmenopausal women (mean age=59 years). The study reported large increases in maximal and explosive strength, and in walking speed, as well as an improvement in dynamic balance test performance. These results indicate that total heavy RT may be applied in rehabilitation or preventive exercise protocols to improve balance capabilities in aging women. Additionally, studies reported similar results. For instance, Humphries, et al.[76] examining the effects of 24-week high intensity RT on muscular strength among postmenopausal women (n=34), either taking HRT or not taking HRT. RT was performed twice weekly (60-90% 1RM). Maximal bench press and squat strength improved significantly (25% and 37%, respectively), directly depending on the time and intensity of training.

On the other hand, long-term programs (i.e, >1 year) have also reported significant effects of RT on muscle mass. Indeed, Sipila et al.[77] examined the effects of a 12-month HRT combined with RT in postmenopausal women. The participants (n=80, aged 50-57 years) were randomized into four different groups; (a) RT only (2 sessions per week); (b) HRT only; (c) RT combined with HRT (2 sessions per week); and (d) control group. The results showed that those performing RT combined with HRT or receiving HRT alone significantly increased quadriceps cross-sectional area (+7.1% and +6.3%, respectively) compared to RT only group (+2.2%) or the controls (+0.7%). These investigators concluded that, in postmenopausal women, muscle performance, muscle mass and muscle composition are improved by HRT. Importantly, the beneficial effects of HRT combined with high-impact RT may exceed those of HRT alone.[77] Likewise, Teixeira, et al.[78] studied the impact of a 1-yr RT on body composition and muscle strength in postmenopausal women (40-66 years). Participants who were already users or non-users of HRT were randomly assigned to exercise (n=117; 60-75 min per day, 3 days per week) or non-exercise (n=116) groups. Significant gains in lean body mass were observed for women who exercised, regardless of HRT status, whereas women who did not exercise lost lean mass. The exercise group showed a mean increase of 0.9 kg in DXA-measured muscle mass that depended on the volume of training. Clearly, the results demonstrated that RT had a significant and positive impact on the total and regional body composition of postmenopausal women, independent of HRT.[78]

Lastly, Fjeldstad, et al.[79] studied the effects of 8-month RT with and without WBV on body composition in sedentary postmenopausal women. Participants (aged 60-75 years) were assigned to RT only (n=22), WBV+RT (n=21) or non-exercising control (n=12) groups. RT (3 sets 10 repetitions 80% 1RM) was performed using isotonic weight training equipment, and the WBV was done with the use of the power plate; both 3 times per week. Both, the RT and WBV+RT groups showed significant increases in arm bone free lean tissue mass, and in trunk bone free lean tissue mass. Likewise, in healthy postmenopausal women (n=25, mean age=65 years) a 24-week WBV program, 3 times per week, is feasible and able to modify muscle strength.[80] Indeed, WBV improved isometric and dynamic muscle strength (+15% and + 16%, respectively) compared to control subjects.

In summary, RT seems to be a safe and effective intervention for reversing the loss of muscle function and the deterioration of muscle structure by increasing muscle mass and strength in postmenopausal women. In addition, RT improves the functional status and levels of physical activity inpost menopausal women bringing about gains in speed, balance and general spontaneous activities. Thus, RT should be recommended to counteract sarcopenia and muscle weakness in postmenopausal women.

CONCLUSION

High intensity RT which places heavy loads on the skeleton during a training session, is effective at increasing BMD, muscle strength and muscle mass in postmenopausal women compared with control groups. The gradual decrease in strength has a potential for leading to disability and functional impairment in ADLs. In addition, the increased incidence of falls and hip fractures is feasibly the result of age-related atrophy in muscle mass. Indeed, sarcopenia, frequently observed in the elderly, contributes significantly to decreased QOL. Whenever physical exercise is stopped (i.e, detraining), the body may lose its beneficial adaptations, which is a response to diminished physiological demand. Postmenopausal women should continue to train and minimize detraining periods, as increased physical activity levels are essential for the protection of neuromuscular function, bone and muscle mass, and functional performance. Thus, progressive RT exercise programs should be targeted to obtain long lasting effects on bone and muscle mass.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

A.A.A.E.: Conception and drafting of the manuscript. J.E.B.: Drafting of the manuscript. The authors were involved in revising the manuscript, providing intellectual content, and approving the final version.

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