Comparison of Strength-Training Adaptations in Early and Older Postmenopausal Women

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Aging generally results in muscle and bone atrophy, with accelerated loss in the first few years after menopause contributing to decline in strength, balance, and mobility. This investigation compared the effects of 1 year periodized high-intensity strength training on a group of less-than-5-years (LF) postmenopausal women (n = 10, mean age 51 years) with its effects on a more-than-10-years (MT) postmenopausal group (n = 11, mean age 60 years). Mean lean body mass, strength, and balance increased over the intervention period for both groups, with no significant intergroup differences. Mean total fat mass significantly decreased for both groups, with no significant difference between groups. Total and regional bone density and mineral content did not significantly change in either group. These results indicate that even during the accelerated muscle-loss period after menopause, women can gain muscle and strength with resistance training to a similar extent as older women.

Key Words: body composition, resistance exercise, aging, physical activity

In the absence of intervention, menopausal and age-linked changes generally result in a loss of bone density and lean body mass (LBM) and a gain in fat mass in older women. The extreme wasting of muscle mass observed in the frail elderly is termed sarcopenia (Evans, 1991; Frontera, Huges, Lutz, & Evans, 1991). There is a particularly accelerated period of bone and muscle loss in the first few years after menopause as a response to altered hormonal status (Aloia, McGowan, Vaswani, Ross, & Cohn, 1991; Poehlman & Tchernof, 1998). Longitudinal studies show that central adiposity is also increased with menopause (Borkan, Hults, Gerzof, Robbins, & Silbert, 1983; Poehlman & Tchernof; Van Pelt et al., 1998). Sarcopenia is considered a critical factor in aging because it contributes to the lowering of strength and basal metabolic rate and is closely correlated with reduced bone density (Evans; Shephard, 1997). These changes in turn can result in increased fat deposition, especially among sedentary people (Evans & Cyr-Campbell, 1997), and coupled with strength decline, particularly in the legs (Vandervoort et al., 1992), result in poor balance and increased risk of falls. Women tend to lose strength earlier than men do and at a greater rate, especially during early menopause (Greeves, Cable,
Reilly, & Kingsland, 1999; Phillips, Rook, Siddle, Bruce, & Woledge, 1993). Because of weaker bones, falls contribute to a greater incidence of fractures (Nelson et al., 1994; Work, 1989).

It remains unclear how large a proportion of the total loss of muscle mass is a result of aging, per se, and how much reflects a decrease of habitual physical activity with aging (Adams, O'Shea, & OShea, 1999; Lexell, 1993). Studies of master athletes (Kavanagh, Mertens, Matosevic, Shephard, & Evans, 1989; Pollock, Foster, Knap, Rod, & Schmidt, 1987) show that the lean-tissue mass of an active person is well conserved to the seventh decade of life.

Strengthening exercise, often called resistance training, reduces the rate of atrophy and can increase muscle mass and strength even in the very old (Fiatarone & Evans, 1993). More investigation is needed, however, to determine the relative effectiveness of strength training and the best types of exercise for people of different ages. Considering the fact that accelerated losses of muscle and bone occur during early postmenopause, this might be a particularly appropriate time to provide preventive therapy. Accordingly, hormone-replacement therapy is often started during this period (Nelson et al., 1994). Perhaps older women have a slower rate of tissue atrophy than early postmenopausal women do because their tissues have had more time to adapt to their reduced estrogen levels. Early postmenopausal women might not respond as well as older women to an anabolic stimulus such as resistance training because they are losing bone and muscle at a faster rate. The relative responses of early and late postmenopausal women to strength training, however, had not been investigated until the present study. In the research presented here, the effects (body composition, strength, balance) of varied resistance training in recently menopausal women (less than 5 years since menopause; LF) were compared with their effects on an older cohort (more than 10 years after menopause; MT). It was hoped that this research would provide some guidance for older women about when to begin a resistance-training program to offset age- and menopause-related bone, muscle, and strength loss.

Method

PARTICIPANTS

In answer to advertisements in the local paper and from distributed leaflets, 32 postmenopausal women (between 47 and 69 years of age) volunteered to participate in this study. The inclusion criteria were as follows: (a) They had to be postmenopausal by at least 1 year as diagnosed by their doctor. They also had to be either less than 5 years or more than 10 years postmenopausal. (b) They must not have participated in strength training during the preceding 12 months. (c) They had medical approval (no chronic medical conditions that would preclude them from strength training) to participate from their regular physician or one assigned by the investigators. (d) They had to be willing to train three times a week at the Royal Melbourne Institute of Technology gym in Bundoora. (e) They had to agree not to change their diet (not analyzed) or exercise (none performed structured regular exercise) habits apart from the research intervention. None of the women smoked or took any medications that would interfere with the results, except 3 in the MT and
1 in the LF who were undergoing hormone-replacement therapy. After a meeting at which the aims and objectives of the program were discussed, 32 actually began the yearlong program. All participants gave their informed consent to participate, and the RMIT human ethics committee approved the research.

RESEARCH DESIGN

Participants who were accepted in the study were placed into two groups: LF (n = 16) and MT (n = 16). Women who were between 5 and 10 years postmenopausal were not included in the results of this study. The LF group had a mean age of 51 years (range 47–55), and those in the MT had a mean age of 60 years (range 55–69). The groups were well matched on body-composition variables before the intervention (see Table 1 and Figure 1). All participants were given a complete battery of dependent-variable tests both before and after they participated in the resistance-training intervention. They were given 3 days of complete rest from training before each testing period, and they were tested at the same time of day (midmorning) on each day of testing.

DEPENDENT-VARIABLE TESTING

Before and immediately after the yearlong training period all the participants were tested for a number of dependent variables. This included estimating their body composition by dual X-ray absorptiometry (DEXA, Hologic QDR-2000, S/N 2486). Total and regional bone density, bone mass, fat mass, and fat-free mass were also evaluated using this procedure. Maximal-strength tests were carried out after 4 weeks of preliminary training. The participants were taught to perform the exercises correctly, and any existing injuries were treated in this preliminary period before testing. In the strength tests, the 10-repetition-maximum (RM) resistance, or the maximum weight that could be lifted 10 times with good technique, was determined for the squat, bench press, and dead lift.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Time since menopause (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF</td>
<td>10</td>
<td>51 (3.2)</td>
<td>63.9 (9.2)</td>
<td>3 (1.7)</td>
</tr>
<tr>
<td>MT</td>
<td>11</td>
<td>60 (4.1)</td>
<td>67.3 (9.9)</td>
<td>12 (1.3)</td>
</tr>
</tbody>
</table>

*Note.* Numbers are means and standard deviations in parentheses. LF = less than 5 years postmenopausal; MT = more than 10 years postmenopausal.
The functional-ability tests were a timed stair climb to assess leg power and a timed backward toe-to-heel walk over 6 m as a test of dynamic balance. A floor-to-feet test, in which participants were timed as they went from a supine lying position to an upright standing position, was used to estimate agility. Participants were asked not to practice these movements between pre- and posttests so that learning effects would be eliminated. In this way it was possible to judge the effectiveness of strength training to improve on these tasks that resemble activities of daily living. Resting recumbent blood pressure was also assessed after 30 min of rest, using an automated sphygmomanometer (Dinamap Vital Signs Monitor, Model 8100). After these pretests all participants carried out the yearlong strength-training program, described in the next section, under our supervision.

**STRENGTH-TRAINING INTERVENTION**

The strength training was performed three times per week for a year. Each session lasted about 1 hr. The exercises used for leg strength included back squats, step-ups, leg extensions, leg press, leg curls, heel raises, lunges, and jump squats. For the arms and torso, exercises included dead lifts, latissimus pull-downs, bench press (flat, incline, and decline), press behind neck, dumbbell press, arm curls (normal and reverse), pulls, shrug pulls, “good mornings,” sit-ups, back arches, neck harness,
and wrist roll. Usually about six of the exercises mentioned were performed each session, including at least one exercise for each major muscle group. The sets and repetitions were varied according to the training emphases at different times during the year.

Throughout the program, trained instructors closely monitored the progress of each participant every session and updated her training resistances every 2 weeks to ensure optimal strength improvement. Most of the exercises were performed with free weights (dumbbells and bars) and some on a Universal multistation apparatus. The participants stretched all major muscle groups and did a light aerobic warm-up on an exercise bicycle before and after each resistance-training session. For exercises such as the squat, dead lift, and bench press a specific warm-up was used wherein one or two sets using lighter weights were performed before the RM resistances.

The yearlong program was divided into seven phases (periodized), each with the specific training emphasis and approach as follows:

1. Learning technique, rehabilitation, gym etiquette
2. Hypertrophy
3. Strength development
4. Power development
5. Eccentric-strength development in preparation for plyometric training
6. Plyometric training
7. Maintenance of strength/hypertrophy and fat reduction

In the 8-week first phase the emphasis was on learning the correct way to perform the basic exercises, starting with very light resistance (10 repetitions with only the weight-lifting bar and collars). This was also when participants were taught gym etiquette, with the intention of preventing accidents. Existing injuries were rehabilitated during this period. A large proportion of the participants had some problem, most in the shoulder, hip, or knees. At this early stage a considerable amount of massage and stretching was done to enable the more inflexible to attain the positions required and to overcome muscle soreness. Whenever a participant’s condition permitted, each session began and ended with an exercise such the squat or dead lift involving the larger muscles in the body. When, for example, a preexisting injury prevented a participant from carrying out a particular exercise, an alternative or modified activity was prescribed.

The 2-week second phase involved standard hypertrophy training in which three sets of 8- to 12RM were employed. There were some lighter (15- to 20RM) and harder (3- to 6RM) sessions included, as well, however. In the lighter sessions, new exercises or modifications of basic exercises such as the incline press or flat bench press were introduced.

In the 6-week third phase, pure strength development was emphasized with the performance of three sets of 5- to 8RM resistances. Participants were encouraged to train a bit harder (1- to 4RM) in some weeks, but recovery sessions (very light resistance and low repetitions) usually followed these more intense sessions. The fourth phase, lasting 6 weeks, involved sessions in which the participants used several types of training including forced repetitions. The emphasis was on performing fast, powerful movements.
For the 6-week fifth phase, more eccentric training (in which muscles stretch while tensed) was included in the program. In the sixth phase, of approximately 8 weeks, plyometric training (bouncing or impact exercises with body weight or added resistance) was mixed with eccentric and hypertrophy training. The plyometric exercise used was low-intensity bounding (squat jumps and toe jumps), but no high-intensity depth jumps or arm drops were included. The seventh phase, 12 weeks long, involved maintaining strength/hypertrophy and circuit training for fat reduction.

This type of varied and periodized program was used in this study because it has been shown to produce better performance gains than do unvaried regimes with younger people (Fleck, 1999; Fleck & Kraemer, 1996).

Statistical Methods

Data were analyzed with Statview 512+ software (Brainpower, Inc., Calabasas, CA). A 2 x 2 (Age x Time) analysis of variance with repeated measures across times was used to interpret the effects of strength training on the dependent variables. Pearson product–moment correlation coefficients between age and pre–post differences in the dependent variables were also calculated. The significance level was set at .05. The statistical power to detect differences in this study was calculated using the G.Power (Trier, Germany) statistical program, using an alpha level of .05. The power to detect Type II errors varied from .2 to .4.

Results

Of the 32 postmenopausal women who commenced training, 21 completed the 12-month program. Ten of these were postmenopausal by less than 5 years (M = 3 years) and 11 by more than 10 years (M = 12 years). In Table 2 and Figures 1 and 2 the pre- and postintervention test results for the dependent variables are presented for both groups. In all of these figures the error bars are standard errors (SE), and the line- or bar-chart values are means. The two groups were closely matched on lean body and fat mass (see Table 2) and strength (see Figure 2) before the intervention.

BODY COMPOSITION

Changes in body composition as estimated by DEXA scans are presented in Table 2. The intertest reliability of these measurements was 1%. The LBM increased by 4.25% (1.7 kg) in the MT group and by 2.7% (1.02 kg) in the LF group, and the intergroup difference was not significant. The MT group’s mean percentage fat mass (see Table 2) decreased by 5.9% (2.4 kg), and the LF mean decreased 3.9% (1.56 kg), but the intergroup difference was not significant (p = .91). There was no significant change in whole-body bone-mineral density (Table 2) or bone-mineral content for either group or a significant between-groups difference. Mean bone density and bone-mineral content of the hip, lumbar spine, and forearm also did not significantly change for either group over time, nor were there any significant differences between the groups. The mean bone-mineral density (p = .11) and
Figure 2. Change in leg power (LP), dynamic balance (DB), and agility (AG) of the LF (<5 years postmenopausal) and MT (>10 years postmenopausal) groups over the year’s training. All these tests are measured in seconds, and reduced time to accomplish a test indicates improvement in the parameter. Both groups significantly, $F(1, 19) = 51.1$, ***$p = .0001$, improved their leg power, balance, $F(1, 19) = 48.6$, ***$p = .0001$, and agility, $F(1, 19) = 38.25$, *$p = .008$, over the training period. There were no differences in mean improvement between the groups, and the MT group performed significantly better than the LF group did on leg power in both the pre- and posttests.
content ($p = .09$) of the younger group, however, were generally but not significantly higher in both pre- and posttests. There were no significant Age $\times$ Time interactions in the body-composition variables assessed. Pearson product–moment correlation coefficients calculated between age and changes in the dependent variables over time were all nonsignificant, confirming the ANOVA results.

**BODY STRENGTH**

The means and standard errors for the strength tests are shown in Figure 1. The mean percentage increases in strength for the whole group (LF and MT combined) over the year were 250% for the squat, 140% for the bench press, and 177% for the bench press. The intertest reliability of the strength tests was about 5%.

**LEG POWER, DYNAMIC BALANCE, AND AGILITY**

The results of these functional tests are presented in Figure 2. The intertest reliabilities for these tests were 3.3% for leg power, 4% for dynamic balance, and 4.5% for agility.

**BLOOD PRESSURE**

The MT group reduced their mean resting systolic blood pressure from 125.6 to 120.0, and the LF group decreased theirs from 155.2 to 114.7. The mean resting diastolic blood pressure for the MT group decreased from 70.9 to 65.3 and for the LF group increased from 64.6 to 66. There were no significant differences between the two groups for these changes, however. The intertest reliability for blood-pressure measurements was about 5%.

**COMPLIANCE**

Despite the strategies used to promote compliance, there were factors that had not been envisaged, and 11 of the 32 participants dropped out at various stages of the program. The main reason given by the women who dropped out was that they did not have enough time during the week to train, given their other commitments. Two participants moved interstate, and some felt that the activity did not suit them. Overall, the participants who completed the year’s training attended about 95% of the training sessions.

**Discussion**

The main finding from this study was that there were no significant differences (see Table 2 and Figures 1 and 2) in the resistance-training-induced improvements in strength and LBM between early postmenopausal women and those further removed from menopause. This finding is important because it indicates that even though early postmenopausal women have accelerated loss of bone and muscle compared with older women (Aloia et al., 1991), they gain muscle and strength at a similar rate in response to strength training. Nonetheless, the mean total, hip,
lumbar, and forearm bone-mineral density and content remained similar to pretraining levels for both groups of women.

These results support those found in similar previous resistance-training studies with postmenopausal women (Nelson et al., 1994; Nichols, Omizo, Peterson, & Nelson, 1993). In Nelson et al.’s study, in which women trained for a year as they did in the present study, the mean LBM gained by the postmenopausal women (age 50–70 years) was 1.2 kg. The over-60-year-old women in Nichols et al.’s (1993) investigation gained 1.5 kg in only 24 weeks. Whereas the women in the present study used periodized and varied resistance training with predominantly free-weight exercises, Nelson et al.’s participants used hydraulic resistance machines and Nichols et al.’s (1993) used Polaris machines. LBM changes were assessed with DEXA in the present investigation, whereas Nelson et al. used urinary creatinine excretion as their LBM index. The similarity in magnitude of the LBM improvements observed in these three studies, even though the methods used were quite different, strongly suggests that properly conducted resistance training is an appropriate way to reverse age- or menopause-related sarcopenia. Considering the fact that women lose up to 3 kg of LBM for every decade of life after menopause (Evans, 1991; Westcott & Baechle, 1997), the mean gain of 1.69 kg found in this study is a recovery of what would have been lost during the preceding 5 years.

In particular, the present study demonstrated that even women who typically have accelerated LBM loss (first 3 years after menopause) gained LBM. Aloia et al. (1991) indicated that LBM loss accelerates in the first 3 years after menopause and then continues with aging but at a slower rate. Consequently, the gains made by the LF group in the present study indicate that resistance training can reverse the accelerated catabolism in the first few years postmenopause. This might be a particularly important time for women to consider resistance training in order to avoid rapidly losing valuable LBM. The physiological mechanisms for resistance-training-induced muscle and bone growth in postmenopausal women are still unclear. Unlike younger women, their older counterparts do not seem to have an exercise-induced secretion of anabolic hormones such as growth hormone (Kraemer, Fleck, & Evans, 1996). The strength-training anabolism might be caused by yet-undiscovered paracrine and autocrine factors.

In contrast to the gain of LBM, the women in the present investigation significantly decreased their total fat mass irrespective of their age and the number of years since menopause. The MT group lost a mean of 2.38 kg of fat mass, compared with the LF group, who lost 1.66, but the intergroup mean difference was not significant. Some investigators (Gleim, 1993) have suggested that although there is sufficient evidence to show that exercise, particularly resistance training, induces fat loss in men, there is little or no evidence of exercise-induced fat loss with women. They claimed that women cannot lose body fat with exercise unless they also restrict their diet. The women in the present study, however, did not modify their diet in any way all through the program and still achieved a significant fat loss. In Nichols et al.’s (1993) study, the participants lost a mean of 0.9 kg fat mass with strength training over 24 weeks. In a 16-week study, Treuth et al. (1995) showed a nonsignificant 0.7-kg reduction in fat mass.

There was no significant change in the mean total or regional bone-mineral density of either group. In the normal course of events, postmenopausal women tend
to suffer the most substantial loss of muscle and bone in their life during the first 3–5 years after menopause (Aloia et al., 1991). In the present study, even the women who had fairly recently completed menopause did not significantly lose bone density or bone mass. Nonetheless, these results support those of several other studies that show that, in the short term at least, strength training does not increase bone density at skeletal sites that are vulnerable to bone fracture (Nichols, Nelson, Peterson, & Sartorius, 1995; Pruitt, Taaffe, & Marcus, 1995), but it might help delay bone loss.

The participants in the present study did not supplement their diet with calcium during the program as some authors have suggested might be needed (Bemben & Fetters, 2000; Nordin & Need, 1988). It could be worthwhile to conduct further studies of longer duration in which the diet of the participants is supplemented to bring their calcium intake up to the 1,800 mg recommended for postmenopausal women by health authorities. Nordstrom, Nordstrom, and Lorentzon (1998) suggested that the part played by plyometric training is another aspect that needs to be examined. It has been shown that plyometric training can result in increased bone density, and although the present study did incorporate plyometric training, it was only a small element of the overall program and was not intense.

The use of hormone-replacement therapy (HRT) is another factor to be considered. A study comparing two groups of surgically postmenopausal women who were on HRT had one group also using resistance training while the other acted as a control (Notelovitz et al., 1991). The resistance-trained group increased bone-mineral density of the spine by 8% in 2 years, whereas there was no significant change in the group who used HRT alone. Only 4 women in the present study were using HRT, 3 in the MT and 1 in the LF group. These women did not seem to make greater improvements than the other women did, but it is impossible to reliably conclude whether HRT influenced the results of the present study.

In the present study, the strength gained by the MT group was at least as much as if not more than that gained by the LF group (see Figure 1). These results support those of many previous studies that indicate that older women of any age can improve their strength with resistance training. Unlike most studies previously conducted with older women, the women in the present study trained with squats, bench press, and dead lifts and used a periodized program. The mean strength gained in the squats was 150%, the bench-press gain was 40%, and dead lift, 77%. These gains compared well with those of Nelson et al. (1994), which were 35–75%, and Treuth et al. (1995), ranging from 51% to 65%, with women of similar ages. The gains made in the present study would have been even greater in comparison, because the pretests were held after 4 weeks of conditioning. In contrast, most previous investigators tested strength before training commenced or after only a couple of training sessions. Presumably there would have been an increase in strength over the first 4 weeks, but it was considered safer to teach the squat and dead-lift techniques before testing maximal strength. Although the changes in strength were recorded each month, the rate of strength change for all participants in each group was not statistically analyzed. Nonetheless, the monthly strength tests of 3 participants indicated that there was a gradual improvement of strength throughout the year. Perhaps the variation in training used in this investigation helped overcome the strength plateaus often encountered with unvaried programs.
Leg power was assessed by a timed run up a flight of stairs. Both groups made a significant improvement in their performance, but again intergroup difference was not significant. Skelton, Young, Greig, and Malbut (1995) conducted a study to evaluate the effects of resistance training on the functional ability of women over 75. The exercises chosen were designed to strengthen the muscles relevant to the functional test but not to mimic the movement. In the 12-week program no significant improvement was noted in the stair-climb test. Both groups in the present study also made significant improvement in the floor-to-feet test, but the difference between the two groups was not significant. Skelton et al. also tested their participants in a “rise from lying on floor” test in which no improvement was noted.

Both groups made significant improvements in balance, but the intergroup difference was not significant. In a similar study (Nelson et al., 1994), the percentage improvement in timing for the same balance test was 14.3%, whereas in the present study the improvement was 34%. The greater improvement made by the women in the present study might be the result of the greater emphasis on leg strengthening with free weights (squats, dead lifts, leg presses, toe raises). The participants in Nelson et al.'s study only performed leg extensions on a machine. Because the squat and dead lifts are freestanding exercises that strengthen many muscles in a coordinated way, they might be better balance-training exercises than seated leg extension is. It was interesting to note that the participant who could not squat at the beginning of the training also could not complete the backward-walk test. After completing training, however, she was able to do both. Considering the importance of developing optimal strength-training programs to improve balance and prevent falls in older adults, future research comparing machine-based resistance exercises with free-weight closed-chain activities would be interesting.

References


