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Effects of Long-Term Resistance Training and Detraining on Strength and Physical Activity in Older Women

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Resistance training (RT) increases strength in older adults, but there have been few studies of long-term RT or detraining in older adults. Postmenopausal participants (51–71 years of age) were randomized to RT or a control group for Year 1. For Year 2, participants chose whether to resistance train or not. Three groups emerged: train/train ($n = 8$; 60 ± 4 years), train/no train ($n = 11$; 62 ± 3 years), or controls ($n = 17$; 58 ± 6 years). Both training groups increased strength ($p < .05$) in Year 1. In Year 2, train/train maintained strength, whereas train/no train lost strength for knee extension ($p < .001$) but not for arm pull-down. Controls did not change. Reported physical activity levels were significantly increased in trainers in Year 1 and remained high regardless of RT in Year 2 ($p < .05$). Therefore, sustained changes in strength and physical activity behavior might be possible even if RT is discontinued.

Key Words: aging, weight training, neurological

High-intensity resistance training is known to increase strength and have other beneficial effects for older adults (Porter & Vandervoort, 1995), but most studies have trained participants for only 2–3 months to look at adaptations to training or detraining. In one of the longest-running studies, participants strength trained over 2 years, with a short detraining period at midpoint (McCartney, Hicks, Martin, & Webber, 1996). That study found that participants continued to increase strength and muscle size in Year 2 (McCartney et al., 1996). In another 2-year study, involving lower intensity training, cardiovascular fitness and flexibility improved, but strength was not influenced (Morey et al., 1991).

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In older adults, detraining has lead to only partial losses in strength from gains made during high-intensity resistance training (Lemmer et al., 1997; Lexell, Downham, Larsson, Bruhn, & Morsing, 1995; McCartney et al., 1996; Sforzo, McManis, Black, Luniewski, & Scriber, 1995; Taaffe & Marcus, 1997). The detraining periods in these studies ranged from 5 weeks (Sforzo et al.) to 27 weeks (Lexell et al.), with most being 8–12 weeks (Lemmer et al.; McCartney et al., 1996; Sforzo et al.; Taaffe & Marcus). Neural adaptations have been proposed to account for the relative maintenance of strength, because muscle-fiber size returned to pretraining values (Taaffe & Marcus). In contrast, however, strength declined very rapidly in 4 weeks (Fiatarone et al., 1990) in very old nursing-home residents after they had made impressive increases in strength, which probably reflected the severity of detraining because of the lack of almost any habitual physical activity of these participants. In another study of nursing-home residents, a year of detraining lead to a 70% decline in strength, as well as losses in physical-performance measures of function (Connelly & Vandervoort, 1997). It has been suggested that physical activity other than resistance training might in fact help pre-serve strength during detraining from resistance training (Taaffe & Marcus).

The purpose of the present study was to determine whether strength can be maintained after a long-term training study and how much strength is lost in postmenopausal women who do not continue to train, as compared with control participants who did not strength train at all over the 2-year duration of the study. Also, long-term influences on physical activity patterns in addition to prescribed exercise were investigated.

Methods

PARTICIPANTS

Thirty-nine Caucasian women were initially recruited to take part in a randomized clinical trial designed to investigate the effects of 1 year of high-intensity resistance training on strength (Morganti et al., 1995; Nelson et al., 1994), as well as bone density and body composition (Nelson et al., 1996). The protocol was approved by the Human Investigation Review Committee at Tufts University, and each participant signed an informed-consent form. All women were at least 5 years postmenopausal but were less than 71 years of age before the initial year of the study. No participant was involved in a regular exercise program or strength training, and all participants were less than 130% of ideal body weight (Andres, Elahi, Tobin, Muller, & Brant, 1985). During Year 1 of the study no participant was on hormone replacements. Over the course of Year 2, 4 participants started hormone-replacement therapy (2 in train/train for 1 year and 7 months, and 2 in train/no train, both for 1 month).

INTERVENTION

The first year of the study has been described in detail elsewhere (Morganti et al., 1995; Nelson et al., 1994) but is briefly described here. Participants randomized to the strength-training group visited the laboratory two times a week for the year. Five exercises to train the limbs and trunk were performed under direct supervision of a research assistant and included knee extension (KE), lat pull-down (LPD; pull a bar down from above the head), double-leg press, abdominal curl, and back extension. Three sets of eight repetitions were done at 80% of one-repetition maximum (1RM), and 1RMs were tested every 4 weeks to allow progression. The control participants were asked to maintain their current physical activity levels and not start strength training. There were no significant differences at baseline in women randomized to experimental and control conditions except in their history of smoking.

After the first year of the study the women provided written informed consent to be followed for an additional year. They were given the following options: continuing the strength training (for those initially randomized to the strength-training group), starting strength training (for those initially randomized to the control group), or no strength training (for either controls or strength trainers).

At the end of the follow-up year, Year 2, all participants were interviewed about their strength-training activity to determine whether they could be considered strength trainers or not. The following groups emerged: train/train (initially randomized to strength training and continued to strength train in Year 2), train/no train (initially randomized to strength training and did not continue to strength train in Year 2), and controls (initially randomized to the control group and did not start strength training in Year 2). For those who reported any strength training during the follow-up year, detailed questions were asked about the frequency of training on average. Participants were considered to be strength training if they had trained consistently throughout the year. No participant from the non-strength-training groups reported any strength training during Year 2. Strength training was done with little or no investigator supervision, depending on where the training occurred. All participants who reported strength training in Year 2 either lifted free weights at home or used weight-training equipment at a fitness facility or the laboratory from the original study. Those who continued strength training were instructed that they did not need to increase the weight lifted because they were already at a high absolute-intensity level. The median strength-training frequency for those who were strength training in Year 2 was 2 days a week (range 1–3). Although participants had kept a training log during the initial year of training, they were not required to do so in Year 2, and logs that might have been kept were not reviewed for the follow-up period.

MEASUREMENTS

Strength Testing. The 1RM test was done for KE and LPD at all three time points (start, Year 1, and Year 2) on pneumatic resistance machines (Keiser Sports Health Equipment, Inc., Fresno, CA; Nelson et al., 1994). There are no data for other 1RM tests because of changes in equipment available in the laboratory in Year 2.

Physical Activity Patterns. Habitual physical activity was assessed using the Harvard Alumni Questionnaire (Paffenbarger, Wing, & Hyde, 1978). Kilocalories of activity per week were used as the outcome variable. Strength-training participation was not included in the habitual physical activity levels of the participants.

STATISTICAL ANALYSIS

Repeated-measures analyses of variance (ANOVAs) were performed for all variables (strength, body composition, and activity). Bonferroni post hoc comparisons were performed to determine differences between groups (train/train, train/no train, and control).

Results

Participant characteristics are shown in Table 1 for participants who completed the total study period of 2 years. Twenty-one women were initially randomized, 20 completed the strength-training portion, and 19 were randomized to the control group (Nelson et al., 1994). Thirty-seven participants completed strength testing at all three time points (baseline, 1 year, and 2 years). Of the women who were initially randomly assigned to the strength-training group, 8 continued strength training and 11 did not strength train in Year 2. Only 1 participant from the control group started strength training, so her data were not analyzed with the group data. Two participants did not have retesting done at Year 2—1 strength trainer as a result of family issues and 1 control because of illness. Two participants did not have complete strength data at Year 2 because of joint problems (one for KE, one for LPD). One participant did not have LPD data at Year 1. The data for these 3 participants were only included in the analysis for the exercise for which they were tested, but they were included in the physical activity analyses.

Lat Pull-Down Strength. There were no significant baseline differences between the groups (Figure 1). There was a significant effect of time point, however, $F(2,65) = 22.07$, $p < .001$, and an interaction between group and time point, $F(4,65) = 7.10$, $p < .001$, with the group effect almost reaching significance,

Table 1 Characteristics of the Participants ($M \pm SD$) at Baseline and at Year 2

Characteristic	Train /Train ($n = 8$)	Train /No train ($n = 11$)	Controls ($n = 17$)
Age (years)	60 ± 4	62 ± 3	58 ± 6[a]
Baseline height (cm)	166.0 ± 7.2	160.7 ± 5.0	164.6 ± 7.9
Year-2 height (cm)	165.4 ± 7.4*	159.7 ± 4.8*	163.3 ± 8.0*
Baseline weight (kg)	65.2 ± 9.7	64.0 ± 6.7	62.4 ± 8.8
Year-2 weight (kg)	65.7 ± 9.9	65.9 ± 7.1	64.6 ± 9.2
Baseline BMI (kg/m^2)	23.6 ± 2.5	24.8 ± 2.5	23.0 ± 2.2
Year-2 BMI (kg/m^2)	23.9 ± 2.7*	25.3 ± 2.4*	24.2 ± 2.4*

Note. Participants who strength trained in both the first and second years are labeled Train/Train, and those who strength trained in the first year but not in the second are labeled Train/No train. BMI = body-mass index. No significant differences were found between groups for baseline characteristics ($p > .05$). All groups showed a small significant decline in height from baseline to Year 2, and therefore there was a significant increase in BMI.

[a]For age, p value = .09.

*$p < .05$.

$F(2,33) = 3.14$, $p = .056$. The train/train group demonstrated significant gains in strength from baseline to Year 1 ($p < .001$) but did not change strength in Year 2 ($p > .05$). Train/no train had greater strength at both Year 1 and Year 2 compared with baseline ($p < .01$), with no significant difference between Year-1 and Year-2 strength ($p > .05$). The controls showed no differences between any of the time points ($p > .05$). The percentage changes in LPD for all groups are shown in Tables 2a and 2b. After Year 1 both training groups were significantly stronger than controls ($p < .05$). At the Year-2 time point, train/train was still stronger than the controls, but train/no train was not. The train/train group was not significantly stronger than train/no train after 2 years ($p = .085$).

Knee-Extension Strength. As with LPD, there were no significant baseline differences in KE between groups (Figure 2), but there was a significant effect of time point, $F(2,64) = 28.94$, $p < .001$, and an interaction between time point and

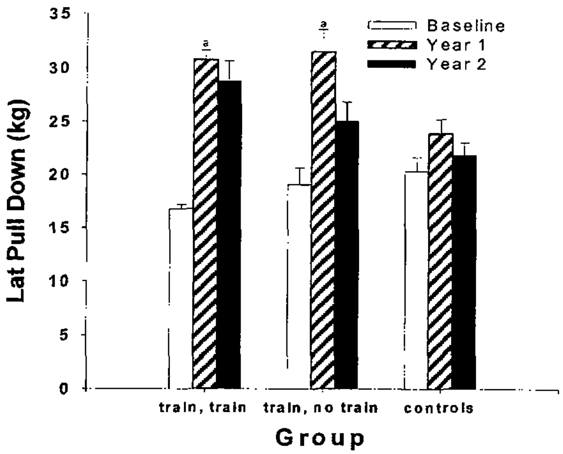

Figure 1. Lateral-pull-down one-repetition-maximum strength ($M \pm SE$) at baseline and 1 and 2 years. [a]Significant increase from baseline to Year 1 ($p < .01$).

Table 2a Percentage Change in Strength From Baseline to Year 1 (Year 1) and Year 1 to Year 2 (Year 2) for All Groups of Participants for Lat Pull-Down (LPD) and Knee Extension (KE)

Group	LPD Year 1	LPD Year 2	KE Year 1	KE Year 2
Train/Train	+ 83%	– 7%	+ 77%	– 9%
Train/No train	+ 65%	– 20%	+ 35%	– 24%
Controls	+ 19%	– 7%	+ 9%	– 11%

Table 2b Percentage Change in Strength From Baseline to End of Year 2 for Lat Pull-Down (LPD) and Knee Extension (KE)

Group	LPD	KE
Train/Train	+ 70%	+ 61%
Train/No train	+ 31%	+ 3%
Controls	+ 10%	+ 3%

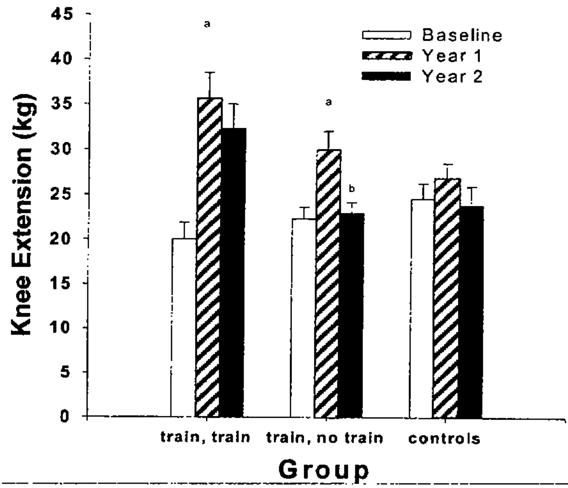

Figure 2. Knee-extension one-repetition-maximum strength ($M \pm SE$) at baseline and 1 and 2 years. [a]Significant increase from baseline to Year 1 ($p < .05$). [b]Significant loss in strength from Year 1 to Year 2 ($p < .001$).

group, $F(4,64) = 8.76$, $p < .01$. Train/train gained strength from baseline to Year 1 ($p = .005$), but there was no change in Year 2 ($p > .05$). Train/no train gained strength in Year 1 ($p = .012$) but lost strength in Year 2 ($p < .001$). The controls did not show any changes in strength ($p > .05$). Tables 2a and 2b show the percentage changes in strength for KE for all groups. At Year 1, train/train was stronger than controls ($p < .05$), but there were no other group differences. At Year 2 train/train was stronger than train/no train and controls, and there was no difference between KE strength for controls and train/no train.

Body Composition. There were no significant changes in weight over the 2 years, but height declined significantly in all three groups by Year 2 (Table 1). As a result, BMI showed a significant increase from baseline to Year 2 (Table 1).

Habitual Physical Activity. Physical activity levels for the groups at all time points are shown in Figure 3. There were no significant differences between the

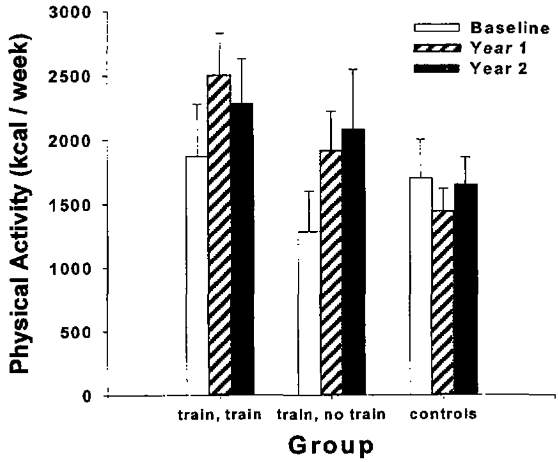

Figure 3. Habitual physical activity levels of the participants in kcal/week ($M \pm SE$) as determined by the Harvard Alumni Questionnaire (Paffenbarger et al., 1978).

three groups, $F(2,33) = p > .27$, but there were tendencies for the effects of time point, $F(2,66) = 2.80$, $p = .068$, and the group-by-time-point interaction, $F(4,66) = 2.13$, $p = .087$, although these did not reach significance. The power was reduced, however, by the small numbers of participants in the trained groups. When the train/train and train/no train groups were combined and compared with controls, there were significant differences at Year 1 ($p < .01$) and Year 2 ($p < .05$) but not at baseline ($p = .66$). The trained group increased their physical activity level in Year 1 ($p = .012$) and maintained this level in Year 2. The controls did not change their physical activity patterns significantly ($p > .05$) over the 2 years.

Discussion

The main findings of the present study are that participants who continued to strength train for 2 years (train/train) maintained their strength gains, whereas those who stopped strength training (train/no train) lost strength for knee extension, and that neither training group significantly lost strength in Year 2 for lat pull-down. Also, both groups of strength trainers increased their physical activity levels in Year 1 and maintained these levels in Year 2. The train/train group increased strength by an average of 80% in Year 1 of strength training and only lost 8% in Year 2 after a year of unsupervised nonprogressive strength training.

The results from Year 1 of this study are quite similar to those of other long-term training studies (McCartney, Hicks, Martin, & Webber, 1995; Pyka, Lindenberger, Charette, & Marcus, 1994; Taaffe, Pruitt, Reim, Butterfield, & Marcus, 1995). The results of Year 2 are different, however, from those of McCartney et al. (1996), who saw strength increase over the whole 2-year period. The percentage increase in strength from baseline to Year 2 was very similar to what was found in that same study, though (McCartney et al., 1996). The fact that participants in that study (McCartney et al., 1996) had a 2-month detraining phase at the end of Year 1 might partially explain their continued increase in strength through Year 2. More important, though, was the difference in supervision—the intensity or progression of training was probably the major factor explaining the continuous increase in strength in their study. Participants in the present study trained in an unsupervised manner in the second year and were not en-couraged to progressively increase their training loads. The fact that the train/train group maintained their strength to a greater extent than did the train/no train group, however, indicates that their training was sufficiently intensive to retain strength.

Previously, it has been speculated that nontraining physical activity can contribute to the preservation of strength after detraining, although regular strength testing could have played a larger role. Taaffe et al. (1997) suggested that neural adaptations were responsible for almost maintaining strength, because muscle-fiber size reverted to baseline levels in their older male participants (Taaffe et al., 1997). Strength testing, which was performed every 2 weeks during the short-term detraining phase in that study, might have been sufficient to affect such neural factors (Taaffe et al., 1997).

In the present study, 1 year of detraining lead to a return to pretraining strength for KE, but not LPD, in the train/no train group. It is difficult to explain this discrepancy between the upper and lower body response to detraining in this small sample, but one observation of note is that the initial training response was greater for LPD than for KE. Other detraining studies in older adults have found that strength was almost completely maintained even up to 27 weeks after 11 weeks of resistance training (Lexell et al., 1995). The losses were on average less than 10% (Lexell et al.). Again, it has been suggested that other physical activity or even periodic strength testing played a role in this maintenance of strength (Lexell et al.). In the present study, with a longer detraining phase, more of a loss of strength would be expected, particularly because no strength testing occurred in the interim. It is possible that in these older women, the large gains in upper body strength during Year 1 led them to increase particular activities of daily living requiring upper body strength (e.g., carrying loads, lifting groceries, heavy housework, yard work) that they might have previously avoided. The Harvard Alumni Questionnaire does not capture most of these items, because it focuses on stair climbing, walking, and discreet recreational pursuits, so we were unable to directly assess such potential contributions to the partial maintenance of upper body strength in our detrainers. Nonetheless, both training groups increased their overall physical activity in Year 1 and maintained it into Year 2, whereas the control group did not change.

A limitation of the present study is the lack of randomization of participants in Year 2. Initially the participants were randomized to control and strength-training groups, with the promise to the controls that they could receive instruction on strength training after the year of no training. Only 1 control participant (of 19) chose to strength train in Year 2, compared with 8 of 20 trainers from Year 1. The reasons for not continuing training were predominantly logistic (i.e., getting to the laboratory or strength-training facility) or family responsibilities. Control participants were not questioned as to why they did not choose to start strength training.

At Year 1, when train/train participants were compared with train/no train participants, there were no significant differences except that KE strength tended to have increased to a greater extent in the train/train group. It could be speculated that the participants who gained more strength continued to train. Other authors have found that, among other things, women with greater strength and those who had greater self-reported improvements in strength were more likely to continue a low-intensity exercise program designed to improve balance, coordination, strength, and cardiorespiratory fitness after a year of training (Williams & Lord, 1995). Research on adherence to predominantly cardiorespiratory exercise programs in older adults has suggested that a complex mixture of physiologic and psychological factors affects continuation of exercise programs (Emery, Hauck, & Blumenthal, 1992; McAuley, 1993; McAuley, Lox, & Duncan, 1993; Williams & Lord).

A further limitation of the study was a potential reporting bias. Because levels of habitual physical activity were obtained through self-reported questionnaires, the training groups could have been more aware of the benefits of high levels of habitual physical activity. Therefore, overreporting of physical activity could have occurred in the two groups that had participated in the initial year of strength training. Without objective monitoring of physical activity, this is a limitation of the present study that requires further research.

In summary, the results of this study demonstrate that continued unsupervised strength training can maintain strength after a year of progressive resistance training, whereas a year of detraining leads to losses that approach pretraining strength, particularly in the lower extremity. Also, strength training appears to have an influence on habitual physical activity, such that both groups that initially strength trained were more active than controls at Year 2. Both maintaining strength and increasing habitual physical activity could have important health benefits and act to preserve independence in these older women (American College of Sports Medicine, 1998).

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