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EFFECTS OF SINGLE- VS. MULTIPLE-SET RESISTANCE TRAINING ON MAXIMUM STRENGTH AND BODY COMPOSITION IN TRAINED POSTMENOPAUSAL WOMEN

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ABSTRACT. Kemmler, W.K., D. Lauber, K. Engelke, and J. Weineck. Effects of single- vs. multiple-set resistance training on maximum strength and body composition in trained postmenopausal women. *J. Strength Cond. Res. 18(4):000–000. 2004.*—The purpose of this study was to examine the effect of a single- vs. a multiple-set resistance training protocol in well-trained early postmenopausal women. Subjects ($N = 71$) were randomly assigned to begin either with 12 weeks of the single-set or 12 weeks of the multiple-set protocol. After another 5 weeks of regenerational resistance training, the subgroup performing the single-set protocol during the first 12 weeks crossed over to the 12-week multiple-set protocol and vice versa. Neither exercise type nor exercise intensity, degree of fatigue, rest periods, speed of movement, training sessions per week, compliance and attendance, or periodization strategy differed between exercise protocols. Body mass, body composition, and 1 repetition maximum (1RM) values for leg press, bench press, rowing, and leg adduction were measured at baseline and after each period. Multiple-set training resulted in significant increases (3.5–5.5%) for all 4 strength measurements, whereas single-set training resulted in significant decreases (−1.1 to −2.0%). Body mass and body composition did not change during the study. The results show that, in pretrained subjects, multiple-set protocols are superior to single-set protocols in increasing maximum strength.

KEY WORDS. 1RM changes, training volume, pretrained women, prevention

INTRODUCTION

Estrogen decline during menopause affects various organs and increases the risk of many diseases. Adequate physical training should simultaneously increase strength, endurance, flexibility, and balance. Obviously, the consideration of all of these aspects could easily expand the necessary training time beyond the amount of time that normal postmenopausal women are willing to invest. Thus, optimizing training efficacy is of high interest. With respect to the improvement of strength, many programs focus on multiple-set resistance training. From the standpoint of time, single-set instead of multiple-set training schemes would free time for exercises targeting the other aspects mentioned above.

The question of multiple- vs. single-set training has been extensively reviewed (4, 7, 8, 12, 20, 33, 35–37, 42, 45), but still there is no unequivocal vote. Results in the literature range from a nonsignificant finding of superiority of single-set training (44) to a significant finding of superiority of a multiple-set regimen (3, 25). Unfortunately, this question is difficult to resolve, because a large variety of causes may contribute to the discrepancy.

Exercise studies comparing single- and multiple-set protocols differ not only with respect to training volume but also with respect to the equipment used for the measurements (9, 25, 31, 41), exercise intensity (6, 30, 31, 34), exercise mode (i.e., velocity [30, 39, 41]), periodization strategy (28, 30, 41), work until failure or not (22), and muscle groups (32, 38). Also, the training experiences of the subjects investigated in these studies were very heterogeneous, ranging from untrained subjects to top-division footballers (25). Further, all studies were carried out with young or middle-aged men and women. Data for postmenopausal women do not exist, with the exception of the study of Ryan et al. (38), who interindividually assessed a multiple-set regime for the lower extremities vs. a single-set regime for the upper body. Finally, with some exceptions (3, 11, 28, 30, 44), all studies were shorter than 6 months in duration.

Each of these factors may affect the strength development elicited by the exercise regime and must be therefore controlled or deleted to avoid confounding influences (35). In this study, we stringently focus on comparable conditions in both (single-set vs. multiple-set) subgroups to clarify the issue which training strategy is more effective in trained older subjects.

METHODS

Experimental Approach to the Problem

The current study was conducted to compare the effect of a single-set vs. a multiple-set exercise training protocol (3) on the dependent variables of 1 repetition maximum (1RM) and anthropometry in well-trained postmenopausal women, using a crossover design in which each subject serves as its own control. Despite the crossover design and the stringent exclusion criteria of the Erlangen Fitness Osteoporosis Prevention Study (EFOPS) (17, 18), both exercise subgroups (beginning with either the single-set or the multiple-set protocol) were well matched with respect to age, menopausal status, muscle strength (except leg press), anthropometric variables, and nutritional intake at baseline. Also, with the exception of the number of sets per exercise, exercise and measurement conditions were identical for both groups.

Subjects

In this investigation, 71 subjects from the training arm of EFOPS participated. EFOPS is a controlled 5-year exercise trial in early postmenopausal women (1–8 years after menopause) with osteopenia ($-1 >$ DXA T-Score > -2.5) at the lumbar spine or the total proximal femur. EFOPS exclusion criteria were intake of medication af-

TABLE 1. Strength training exercises during the joint training sessions.

Exercises	Session 1	Session 2
Legs		
Horizontal leg press	X	
Wide-stance dead lift		X
Leg curls	X	
Leg adduction	X	
Leg abduction	X	
Leg extension	X	
Back		
Rowing	X	
1-arm dumbbell rowing		X
Latissimus dorsi pull	X	
Back extension	X	
Chest		
Wide-grip bench press		X
Seated bench press	X	
Abdomen		
Abdominal flexion	X	
Shoulder		
Shoulder raises	X	

fecting bone metabolism (with the exception of Ca and vitamin D) within the last 2 years, known osteoporotic fractures, acute vertebral disk problems, inflammatory disease, history of cardiovascular disease, maximal cycle ergometry load of less than 75 W, and athletic activity during the 2 decades prior to the beginning of the study. EFOPS was approved by the ethics committee of the University of Erlangen (Ethik Antrag 905), the Bundesamt für Strahlenschutz (S9108-202/97/1, S21-22112-81-00) and the Bayerische Landesamt für Strahlenschutz (13B/3443-4/5/98). All study participants gave written informed consent.

The study reported here began 18 months after the start of the EFOPS study; thus, all 71 participants were well trained. As detailed below, study participants exercised in 6 different training groups. For the purpose of this study, the training groups were randomly divided into 2 study groups, group 1 and group 2. Group 1 encompassed 3 training groups that started with a multiple-set protocol and crossed over to the single-set regime. Group 2, which encompassed the other 3 training groups, started with a single-set protocol and crossed over to the multiple-set regime.

Testing and Procedures

Attendance and compliance were assessed using subject-specific training logs and attendance lists kept by the trainers. Only subjects who, in both high-intensity periods, participated in at least 20 joint training sessions each were included in the analysis. Given a maximum of 24 joint training sessions, this corresponds to a training attendance of 83%.

The anthropometric parameters of height, weight, and body composition were measured parallel to the 1RM tests. Body composition was assessed using the bioelectrical impedance analysis (BIA; Tanita BF 305, Tokyo, Japan).

1RM tests of horizontal leg press, seated bench press, rowing, and leg adduction were performed according to the protocol used by Kraemer (27). Research assistants controlled proper conduct and maximum effort during the tests. Reproducibility of our 1RM protocol was tested after 6 and 26 months of the EFOPS study. Coefficient of variation was ≤5.9% for all test exercises for the first test and ≤3.8% for the second test. The 1RM tests were always performed in the last and first sessions of the low-intensity training periods bracketing the high-intensity periods. It must be remembered that the study reported here was embedded in the periodized EFOPS training regimen.

Training Program

EFOPS is a general purpose exercise program with emphasis on strength training, and has already been extensively described (17, 18). The exercise program was organized in 2 weekly joint training sessions (60–70 minutes) of approximately 9–12 participants each, and 2 additional home training sessions (25 minutes). The strength training portion was spread out over the 2 joint training sessions. Session 1 was performed on machines (Technogym, Gambettola, Italy) designed for multiple joint exercises (Table 1). Movements were performed in a 2-second (concentric), 1-second (static), 2-second (eccentric) mode. The second part of the strength training was carried out during joint session 2 and consisted of dumbbell and weighted vest exercises (Table 1).

As mentioned above, the investigation reported here started 18 months after the EFOPS baseline visit. To clarify the prestudy training status of the subjects, we will briefly describe the initial 18 months of the EFOPS program. During the first months, the intensity of the training was increased slowly to minimize injury risks and to allow the participants to adjust slowly to the various sequences. The intensity of the resistance training was controlled and adjusted every 12 weeks using 1RM tests. After 8 months, the exercise regimen was changed and periodization was introduced. Twelve weeks of periodized high-intensity resistance training were interleaved with 4–6 weeks of lower intensity (19).

After the 18 months that are regarded as baseline for the investigation reported here, the differentiation of single- vs. multiple-set schemes shown in Table 2 was introduced. Group 1 exercised with the multiple-set and group

TABLE 2. Study design.

	Period 1 (weeks 1–12)	Weeks 13–17	Period 2 (weeks 18–29)
Group 1 ($n = 29$)	Periodized High intensity Multiple-set regime	Non-periodized Low-intensity training	Periodized High intensity Single-set regime
Group 2 ($n = 21$)	Periodized High intensity Single-set regime	Nonperiodized Low-intensity training	Periodized High intensity Multiple-set regime

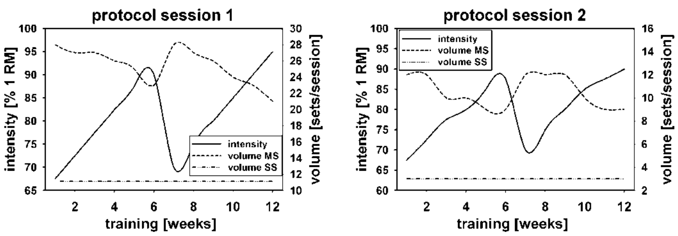

FIGURE 1. Intensity as percentage of 1RM and volume in sets per session of the strength training portion of the exercise regimen. The periodization effect of the training is clearly shown. Session 1 was carried out on machines; session 2 consisted of dumbbell and weighted vests exercises (see Table 1).

TABLE 3. Baseline data for anthropometric parameters and 1 RM values.†

Parameter	Group 1 (n = 29)	Group 2 (n = 21)	p
Age (y)	56.7 ± 3.0	56.5 ± 3.1	n.s.
Height (cm)	163.8 ± 6.5	164.4 ± 6.5	n.s.
Weight (kg)	66.3 ± 8.5	68.4 ± 8.5	n.s.
Body fat (%)	36.0 ± 5.6	36.7 ± 5.6	n.s.
LBM (kg)	41.6 ± 3.6	43.5 ± 3.6	n.s.
Energy intake (kJ/d)	7,650 ± 1,283	7,752 ± 1,317	n.s.
Leg press (kg)	163.1 ± 22.1	182.6 ± 19.7	*
Bench press (kg)	45.2 ± 5.7	47.0 ± 5.7	n.s.
Rowing (kg)	45.0 ± 5.1	45.5 ± 5.1	n.s.
Leg adduction (kg)	41.3 ± 7.9	44.8 ± 7.9	n.s.

† 1RM = 1 repetition maximum; n.s. = not significant.
* $p = <0.05$.

2 with the single-set protocol. Within 29 weeks, the crossover design was realized with a low-intensity training period in between 2 high-intensity periods. In the single-set mode, 1 set per exercise of the protocol outlined in Table 1 was carried out, with 90 seconds of rest between the exercises. In contrast, the multiple-set mode consisted of 2–4 sets per exercise with 90 seconds of rest. Both the single and the multiple-set training were linearly periodized between 65 and 90% of 1RM (Figure 1). During the low-intensity training (weeks 13–17), 2 sets of 11 exercises with 20 reps at 50–55% of 1RM were carried out. Two to three sessions during this period were lost because of holidays. In neither the low- nor the high-intensity periods did we maximize the number of repetitions to achieve complete exhaustion of the participants.

Statistical Analyses

All measured values are reported as mean ± *SD*. The Kolgomorov-Smirnov test was used to check for normal distribution. For normally distributed variables, differences within and between groups were assessed with paired t-tests. Otherwise, the Wilcoxon test was used. All tests were 2-tailed, and a 5% probability level was considered significant. We used SPSS 11.5 (SPSS Inc., Chicago, IL) for statistical analysis.

RESULTS

None of the participants dropped out of the study, but only 50 of 71 subjects fulfilled the 20 out of 24 sessions training attendance criterion in both the single- and the multiple-set periods. Table 3 shows baseline values for anthropometric parameters and 1RM for study groups 1 and 2. With the exception of leg press, there were no significant intergroup differences for any of the parameters shown in Table 3.

Neither significant changes nor between-group differences were observed for any of the anthropometric parameters investigated in the study. Figure 2 shows the development of the 1RM measurements for leg press, bench press, rowing, and leg adduction for both study groups. During the first period, we observed significant (3–5%) increases in 1RM for group 1, the study group performing the multiple-set training. In group 2, we observed decreases of 1–2%. These decreases continued during the low-intensity training period. In period 2, group 2 performed the multiple-set training, and 1RM values increased relative to the start point of period 2 by 3.5 to 5.5%, similar to the increase seen for group 1 during period 1. After the gain during period 1 for group 1, the 1RM values significantly decreased in the low-intensity training phase as well as in the single-set high-intensity training during period 2. Altogether, after 29 weeks for group 1 the net effect was around 0.

In Figure 3, we calculated average changes from both study groups for single- and multiple-set training using the results from the high-intensity periods 1 and 2.

DISCUSSION

The background of our study was pragmatic. Under the premise that early postmenopausal women with a variety of estrogen depletion–related risk factors but without severe complaints are unwilling to spend a large amount of time for prevention, the available time should be used most effectively. Single-set training regimens would save time (31) that could be spent for other relevant training contents. However, with respect to strength, our results clearly demonstrate the superiority of the multiple-set approach. Concerning body mass and body composition after 18 months of pretraining, anthropometric variables were affected neither by the single- nor by the multiple-set regimen.

Our study possesses several strengths: (a) We specifically targeted a homogeneous group of early postmenopausal woman who had already trained for 18 months. (b) Factors that might have affected results, such as medication, diseases, nutrition, and lifestyle changes, were strictly controlled throughout the study. (c) In the crossover design, subjects served as their own controls. Therefore, group differences should not have affected our results. (d) The training protocols for both study groups differed only in the timing of the single- and multiple-set training. Group 1 started with multiple-set and group 2 with single-set training. (e) Only subjects with high compliance and attendance were included in the analysis. (f) The number of 50 included subjects was high enough that relevant differences between the 2 protocols could be detected.

In Figure 3, we calculated average results of our study. This is certainly justified for the multiple-set training, because here the increases in both groups were comparable (Figure 2). With respect to the single-set training, it may be argued that the decrease in group 1 was higher than the decrease in group 2. This is true, but it must be considered that group 1 underwent the multiple-set training first, and thus it can be expected that losses were higher because the attained absolute strength values

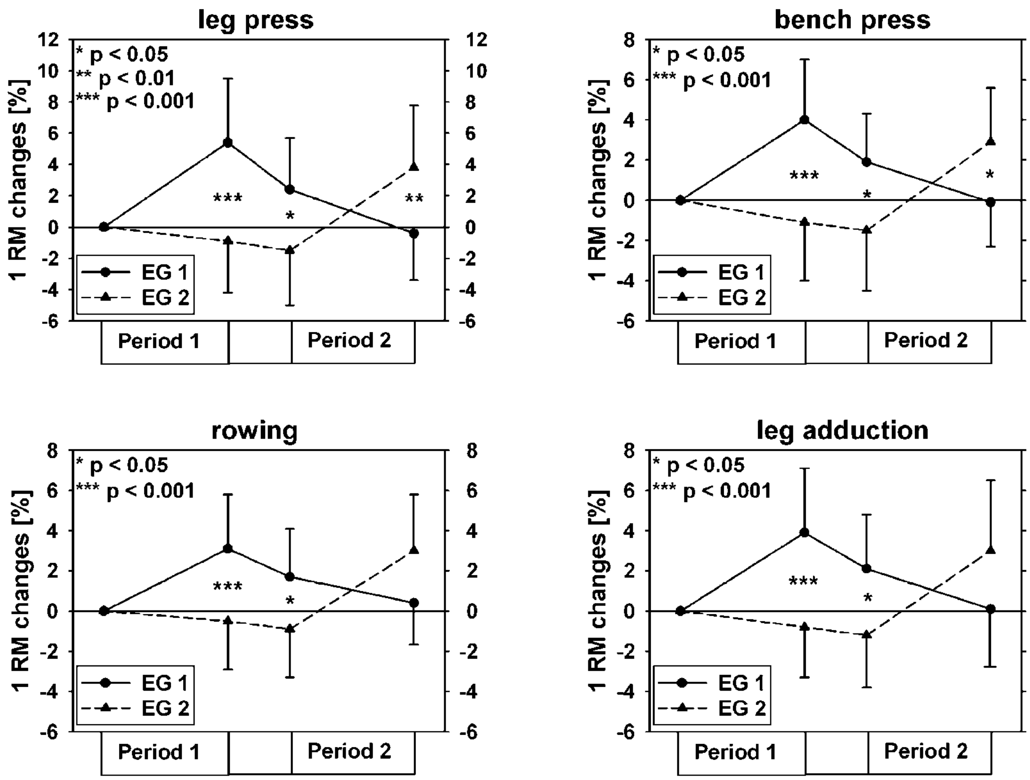

FIGURE 2. 1RM changes for groups 1 and 2 during the 29 study weeks. Group 1 started with the multiple-set and group 2 with the single-set regime.

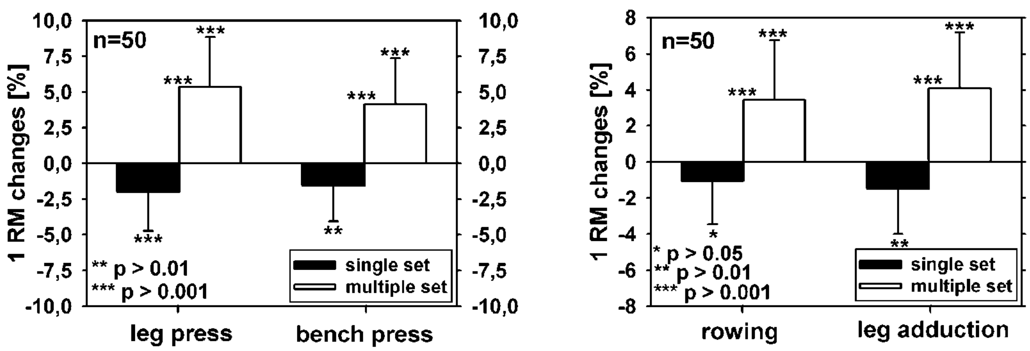

FIGURE 3. Average changes in the two periods for multiple-set and single-set training.

were higher. Also, given the size of the standard deviation, we abstained from more sophisticated analyses.

Of course a few limitations that may also impact on our results must be mentioned: The EFOPS training, and therefore the training used in this study, did not focus exclusively on resistance training. Because the primary endpoint of the EFOPS study was bone mineral density, 20–25 minutes of endurance training (low- and high-impact aerobics) and multidirectional jumps were performed before the resistance sequence. However, we do not believe that this training regimen had a large impact on the generalization of the results reported here.

Further, we investigated only early postmenopausal women who had been pretrained using multiple-set regimens for 18 months, including 6 months of periodized high-resistance training. To achieve further gains, trained subjects need greater training stimuli than untrained subjects (42). It is well known that in untrained subjects, maximum strength increases during the first training months are caused mostly by neuronal effects. After the initial months, muscle hypertrophy is the dominant factor in strength gain (14, 15, 21). Therefore, in untrained subjects, the impact of training volume on strength increases may be negligible (5, 28, 45), despite the fact that in their meta-analysis, Rhea et al. demonstrated the significant superiority of multiple-set regimens independent of training status (37). Nevertheless, in untrained subjects, significant advantages of a multiple-set protocol have been observed in only a few studies (2, 3, 30, 43). However, in the study of Marx et al. (30), only the multiple-set training protocol was periodized, and it contained explosive movement speed, which may be the main reason for the differences. In the study of Stowers et al. (43), 1RM for the squat was significantly different between single-set training and "periodization" (with no significant differences for the bench press) but not between single-set and multiple-set training after 7 weeks of training.

In accordance with our results, differences between single- and multiple-set regimens are far more obvious in trained subjects or athletes (25, 28, 29, 35, 40, 45).

In exercise programs for the elderly, in addition to strength increases, the optimization of body composition is another important endpoint. For example, it was suggested that increases of lean body mass were the main reason for strength gains in trained subjects (1). Some studies indeed showed training-related changes in body composition (25, 28, 30). However, like others (9, 16, 34, 35), we cannot confirm these results. Perhaps in well-trained subjects body composition changes in particular cannot be expected in a relatively short time period.

In conclusion, we favor the use of a multiple-set training regimen. In untrained elderly people, it is advisable to slowly increase the training amount and intensity; thus, single-set training may be an alternative during the initial training months. However, when strength is a training focus later on, single-set exercises should be replaced by a multiple-set regimen.

PRACTICAL APPLICATIONS

The decision as to whether to use a single- or multiple-set training regimen must be taken in accordance with the status of the subject and the main goals of the training program. For untrained subjects, a single-set regimen may be a alternative to time-consuming multiple-set regimen. However, strength development after the initial adaptation phase was "suboptimal" (22, 28, 45) in single-set programs. Further, other relevant endpoints of resistance training (i.e., body composition changes, and anabolic hormonal releases [3, 10, 13, 23, 24, 26]) seemed to be much more affected by a multiple-set training program.

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