Effects of Modified Pyramid System on Muscular Strength and Hypertrophy in Older Women

Authors
Leandro dos Santos[1], Alex S. Ribeiro[2], Edilaine F. Cavalcante[1], Hellen C. Nabuco[1], Melissa Antunes[1], Brad J. Schoenfeld[3], Edilson S. Cyrino[1]

Affiliations
1 Study and Research Group in Metabolism, Nutrition, and Exercise, Londrina State University, Londrina, Paraná, Brazil
2 Center for Research in Health Sciences. University of Northern Paraná, Londrina, Brazil
3 Exercise Science Department, CUNY Lehman College, Bronx, New York

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Correspondence
Leandro dos Santos, PhD
Physical Education and Sports Center
Londrina University State
São Francisco Street, 476,
room 403 - 90620070 Porto Alegre
Rio Grande do Sul
Brazil
Tel.: +55/051/994238540
le_edfisica@hotmail.com

ABSTRACT

This study aimed to analyze the effects of a pyramid system performed with two repetition zones on muscular strength and skeletal muscle mass (SMM) in older women. Thirty-nine physically independent older women (67.8 ± 5.4 years) were randomly assigned into one of two of groups that performed an 8-week resistance training program in an ascending pyramid fashion. Both groups performed 3 sets: a narrow repetition zone (NPR, n = 20) with 12/10/8 repetitions, and a wide repetition zone (WPR, n = 19) with 15/10/5 repetitions. The program consisted of 8 whole-body exercises, performed 3 times a week. Dual-energy X-ray absorptiometry was used to measure SMM, and muscular strength was evaluated by one-repetition maximum (1RM). Both groups increased ($P < 0.05$) SMM (NPR = + 4.7 %, effect size = + 0.34; WPR = + 8.4 %, effect size = + 0.77), and total strength (NPR = + 11.3 %, effect size = + 0.80; WPR = + 13.8 %, effect size = 0.84), without statistical differences between them. Results suggest that both zones of repetitions in a pyramid system are effective strategies to improve muscular strength and muscle growth in older women.

Introduction

Reductions in muscular strength and skeletal muscle mass (SMM) are two of the main age-related impairments [3] that are associated with a decrease in performance of daily life activities and functional autonomy, thus having a negative effect on general health, quality of life and survival in older individuals [3, 4, 12, 16]. To counter these deleterious effects, resistance training (RT) has been recommended to older individuals given its well-established ability to elicit positive adaptations in muscular strength and muscle mass [1, 2, 6].

The muscular adaptations induced by RT are dependent on manipulating program variables, with training volume and intensity of load widely considered to be two of the most important variables [1, 17]. Training volume is affected by the number of sets, repetitions and exercises performed as well as training frequency [1], whereas intensity of load refers to the absolute or relative resistance used for a given exercise [1]. Accordingly, coaches and practitioners have proposed some training systems as a means to train with higher loads without a drastic reduction in volume. Among the training systems, the ascending pyramid system, due to its inherent characteristic of varying loads and number of repetitions, allows exercise performance at higher intensities of load without necessarily causing a drastic loss in the volume, thus maintaining a favorable anabolic environment for increasing strength and muscle hypertrophy.

A previous study from our laboratory [15] with another cohort of older women investigated the effect of the ascending pyramid system on muscular strength and hypertrophy, and it was observed that this load management system induced similar adaptations than when the load remained constant through the sets of a given exercise [15]. However, one possible reason for the lack of the superiority of the pyramid system may be because the repetition range applied in the pyramid condition (12/10/8 RM) was too narrow to promote different stresses compared to the constant (8–12 RM) condition and thus induce differential adaptations. It has been proposed that muscular adaptations are mediated by different mechanisms, including mechanical tension, which is maximized via heavier loading, and metabolic stress, which is maximized by lighter loads with longer set durations [17]. Therefore, we cannot rule out the possibility that a pyramid approach using a wide repetition zone, which allows a higher metabolic and mechanical stimulus, may induce superior results.

The purpose of the present study was to analyze the effects of two pyramid systems on muscular strength and skeletal muscle mass (SMM) in older women. We hypothesized that both pyramid systems would be effective to induce increases in strength and muscle mass, and that the pyramid performed in a wide zone of repetitions would elicit greater improvements compared to the narrow zone of repetition. The rationale for this hypothesis is based on a greater variation of the stimulus, thus allowing higher metabolic (in the first set) and mechanical stress (in the final set).

Methods

Participants

Thirty-nine older women, with a mean and standard deviation of 67.8 ± 5.4 years, 67.0 ± 11.2 kg, 155.2 ± 6.0 cm, 27.8 ± 4.5 kg/m^2, were selected for participation in this study. Recruitment was carried out through newspaper, television programs and radio advertisements, and home delivery of leaflets in the central area and residential neighborhoods. All participants completed health history questionnaires and met the following inclusion criteria: physically independent, free from cardiac dysfunction, not receiving hormonal replacement therapy, and not performing any regular physical exercise for more than once a week over the six months preceding the beginning of the study. Participants passed a diagnostic, graded exercise stress test with a 12-lead electrocardiogram reviewed by a cardiologist. They were then released with no restrictions for participation in this study. Adherence to the program was satisfactory, with all participants included in the analysis attending a minimum of 85 % of the total sessions. After meetings with volunteer groups, those with the necessary prerequisites completed an initial interview and signed the Informed Consent approved by the Ethics Committee of the local university. This investigation was conducted according to the Declaration of Helsinki and in accordance with the Ethical Standards in Sport and Exercise Science Research [7].

Experimental design

The study was carried out over a period of 12 weeks, with 8 weeks dedicated to the RT program, and 4 weeks for data collection. Pre- and post-intervention testing was carried out at weeks 1–2 and 11–12, respectively, and comprised anthropometric and body composition tests performed in the afternoon and maximal dynamic strength tests performed in the morning. The RT program was carried out during weeks 3–10. Physical education professionals supervised all sessions. Subjects were instructed not to perform any other type of physical exercise throughout the study period. Prior to baseline testing, the participants were randomly assigned to two groups of the pyramid training system: a narrow zone of repetitions (NPR, n = 20) in which participants performed 3 sets of 12/10/8 repetitions, or a wide zone of repetitions (WPR, n = 19) in which participants performed 3 sets of 15/10/5 repetitions.

Muscular strength

Maximal dynamic muscular strength was determined by the one repetition maximum test (1RM) on bench press (BP) knee extension (KE), and preacher curl (PC). Testing for these exercises was preceded by a warm-up set (6–10 repetitions) using approximately 50 % of the estimated load used in the first attempt of the 1RM test. This warm-up was also used to familiarize the subjects with the testing equipment and lifting technique to reduce the effects of learning and establish reproducibility in the exercise. The testing procedure was initiated 2 min after the warm-up. Participants were instructed to try to accomplish two repetitions with the imposed load in three attempts. A 3- to 5-min rest period was afforded between each attempt. The 1RM was recorded as the last load lifted in which the participant was able to complete only one single maximal repetition. Execution of each exercise was standardized and continuously monitored to ensure reliability. Experienced researchers supervised all 1RM testing sessions for greater participant safety and integrity. Verbal encouragement was given throughout each test. Three 1RM sessions were performed separated by 48 h. The highest load achieved among the 3 sessions was used for analysis in the exercise. The sum of the three exercises was considered total strength. The intraclass correlation coefficient (ICC) from our lab for these tests is ≥ 0.96 with a standard error of measurement (SEM) of ≤ 2.0 kg.

Body composition

Fat-free mass (FFM), lower limb muscle mass (LLMM), and upper limb muscle mass (ULMM) measurements were carried out using a dual-energy X-ray absorptiometry (DXA) scan (Lunar Prodigy, model NRL 41990, GE Lunar, Madison, WI, USA). Before scanning, participants were instructed to remove all objects containing metal. Calibration and scans were performed according to the manufacturer's instruction manual. Both calibration and analysis were carried out by a skilled laboratory technician. Analyses during the intervention were performed by the same technician, who was blinded to the intervention time point. The SMM was calculated from the appendicular lean soft tissue estimated by DXA using the model proposed by Kim et al. [8]. SMM = (1.13 x appendicular lean soft tissue) – (0.02 x age) + (0.61 x sex) + 0.97. Sex: female = 0. Previous test-retest scans of eight older women resulted in SEM of

0.6 kg and ICC of 0.99 for FFM and SEM of 0.7 kg and ICC of 0.99 for SMM.

Resistance training program

The RT program was performed three times a week, with an interval of 48 h between training sessions and was carried out over a period of 8 weeks. Training took place in the morning and was based on recommendations for RT in an older population to improve muscle hypertrophy and strength [1, 2]. Physical education professionals personally supervised all participants throughout each training session in order to reduce deviations from the study protocol and to ensure subject safety. Subjects performed RT using a combination of free weights and machines.

The RT protocol consisted of a whole-body program with 8 exercises performed in the following order: chest press, horizontal leg press, seated row, knee extension, preacher curl, leg curl, triceps pushdown, and seated calf raise. Participants performed either 3 sets of 12/10/8 repetitions (NRP) or 15/10/5 repetitions (WPR) with incrementally higher loads for each set (ascending pyramid). The participants were instructed to inspire during the eccentric phase and exhale during the concentric phase of the exercise and to maintain the velocity of movements at a ratio of 1:2 (concentric and eccentric phases, respectively). The rest interval ranged between 60–120 s for sets and exercises. The supervisors adjusted the loads of each exercise according to the subject's ability and improvements in exercise capacity throughout the study in order ensure that subjects were using as much resistance as possible while maintaining proper technique. The progression was planned so that when the upper limit of repetitions in each set was completed by two consecutive sessions, the load increased 2–5 % for the exercises of the upper limb and 5–10 % for the exercises of the lower limbs [1].

Statistical analysis

Analyses were performed with SPSS (v.22.0, 2013, SPSS Inc., Chicago, IL, USA). Data are presented as mean, standard deviations, z-scores, and percentage of changes. The Kolmogorov-Smirnov test was used to checked normality. The baseline comparisons were performed by paired Student's t-test. The 2-way ANOVA for repeated measures was conducted for comparisons between and within groups over time. Adjusted Greenhouse-Geisser corrections were used for any violations of sphericity by Mauchly's test. Bonferroni post-hoc test was conducted to identify the mean differences when the F-ratio was significant. The effect size (ES) was calculated to verify the magnitude of the differences by Cohen's d where an ES of ≥ 0.20–0.49 was considered as small, 0.50–0.79 as moderate and ≥ 0.80 as large [5]. The differences between pre- to post-training were calculated, transformed into z-scores, and means for each variable compared by independent t-test. For all statistical analyses, significance was established at $P < 0.05$.

Results

▶ **Fig. 1** depicts the baseline and post-intervention scores and percentage changes from pre- to post-training for FFM, SMM, LLMM and ULMM by group. A significant increase was observed for FFM (NPR = + 1.9 % [+ 0.7 kg], WPR = + 3.2 % [+ 1.2 kg]); SMM (NPR = + 4.7 % [+ 0.8 kg], WPR = + 8.4 % [+ 1.5 kg]); LLMM (NPR = + 4.7 % [+ 0.6 kg], WPR = + 6.2 % [+ 0.7 kg]); and ULMM (NPR = + 4.4 % [+ 0.2 kg], WPR = + 5.3 % [+ 0.2 kg]); and no significant differences between groups were observed for any variable ($P > 0.05$).

The muscular strength values at pre- and post-intervention according to groups are presented in ▶ **Fig. 2**. A significant increase was observed ($P < 0.05$) for chest press (NPR = + 9.4 % [+ 3.3 kg], WPR = + 11.5 % [+ 4.7 kg]); knee extension (NPR = + 13.1 % [+ 5.2 kg], WPR = + 14.1 % [+ 6.2 kg]); preacher curl (NPR = + 11.4 % [+ 2.3 kg], WPR = + 17.9 % [+ 3.3 kg]); and total strength (NPR = + 11.3 % [+ 10.6 kg], WPR = + 13.8 % [+ 14.2 kg]). Both groups presented similar changes in their scores, without significant differences between groups ($P > 0.05$).

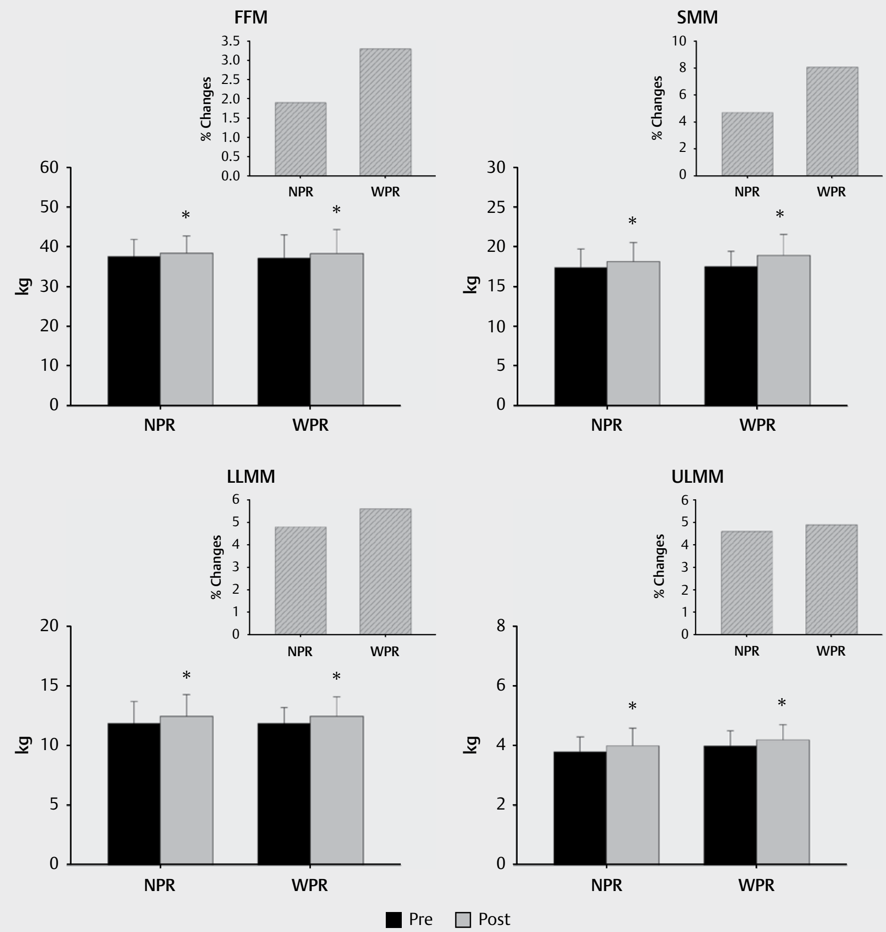
▶ **Table 1** presents the effect size and values for groups as well as the difference between groups. A difference of small magnitude was observed for SMM, LLMM, and PC, favoring the WPR. For the other parameters investigated, the differences between groups did not reach meaningful values.

The z-scores of the percentage changes from pre- to post-training for each parameter investigated are presented in ▶ **Table 2**. The WPR group presented the highest positive variation means for all outcomes analyzed, but the differences from NPR were statistically significant for SMM ($P > 0.05$).

Discussion

To the authors' knowledge, this is the first study to compare muscular adaptations in RT pyramid systems using a narrow versus wide range of repetitions. The novel results of our study showed that both pyramid systems produced significant increases, with statistically similar changes between WPR and NPR noted in all outcomes studied. However, there were several differences identified between conditions that, although not rising to a level of predetermined statistical probability, nevertheless may be considered meaningful from a practical standpoint.

With respect to changes in body composition, increases in SMM for WPR were almost double that for NPR (1.5 kg versus 0.8 kg, respectively), although results did not reach statistical significance. The relative ES difference for this outcome was 0.43, which borders a small to moderate effect. Moreover, these differences were primarily the result of greater increases in lower limb muscle mass, where the relative ES difference was 0.25. Although no previous studies have directly compared pyramid systems of differing repetition ranges, several studies have used a daily undulating periodized (DUP) protocol to investigate the effects of training with wide versus narrow repetition ranges. In a cohort of female collegiate tennis players, Kraemer et al. [9] found that wide repetition range (4–6RM on Day 1, 8–10RM on Day 2, 12–15RM on Day 3) produced significantly greater absolute increases in FFM compared to a narrow repetition range (8–10RM) as assessed by the 3-site skinfold technique over a 9-month study period (3.3 kg vs.1.6 kg, respectively). Recently, Schoenfeld et al. [18] randomized young, resistance-trained men to train with either a narrow repetition range (8–12RM) or a wide repetition range (2–4RM per set on Day 1, 8–12RM per set on Day 2, 20–30RM on Day 3). Although similar statistical increases were shown for muscle thickness for the biceps, triceps,

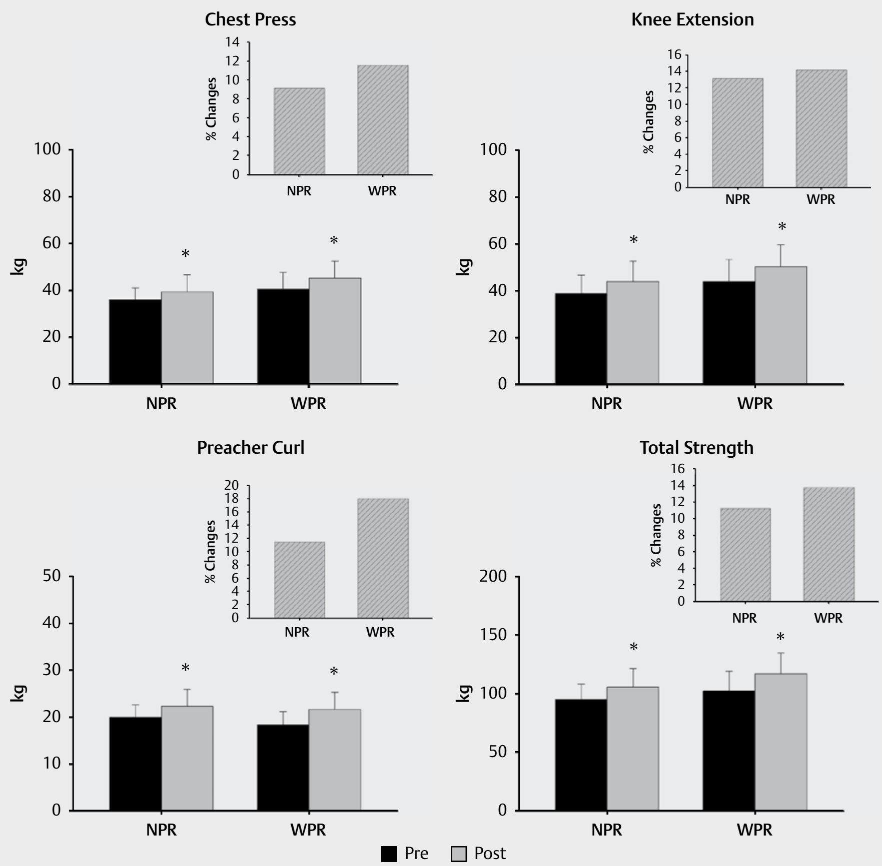


▶ **Fig. 1** Pre- to post-training scores and percentage changes of fat-free mass (FFM), skeletal muscle mass (SMM), lower limb muscle mass (LLMM), and upper limb muscle mass (ULMM) by group (NPR, narrow zone repetition, and WPR, wide zone of repetition). There were no significant group vs. time interactions for any variables ($P>0.05$). * $P<0.05$ vs. pre-training.

and quadriceps as measured by B-mode ultrasound, the ES for the upper limbs indicated a potential hypertrophic superiority for the group using a wider repetition range. Results of these studies are difficult to reconcile given the wide-ranging differences in populations and methods between studies, but the totality of findings would seem to indicate a potential benefit from wider variations in repetition ranges in order to maximally increase muscle mass. Emerging research indicates that lighter load training promotes greater increases in type I muscle fibers, whereas heavier load training promotes greater increases in type II muscle fibers [13, 14, 19]. The benefits from a wider repetition range may be related to more complete development across fiber types. This hypothesis warrants further study.

Total strength changes across exercises tested for 1RM were similar between training conditions, with WPR producing a 13.8 % increase and NPR producing an 11.3 % increase. These results can be largely attributed to greater increases in 1RM for the preacher curl favoring WPR compared to NPR (17.9 % vs 11.4 %, respectively), with a small relative ES difference of 0.25. As mentioned, no previous studies have compared muscular adaptations using different pyramid loading schemes. However, several studies have investigated strength outcomes in wide versus narrow repetition ranges using a DUP approach. In the study by Kraemer et al. [9], the wider repetition range produced greater increases in the leg press, bench press, and shoulder press. Alternatively, Schoenfeld et al. [18] found similar strength-related changes between wide and narrow repetition ranges, although the ES favored the wider range in the bench press. Despite somewhat equivocal evidence, the totality of findings suggests a potential strength-related benefit to employing a wide repetition range.

The study had several limitations that are worthy of note. First, the study period of 8 weeks was of rather short duration. It remains to be determined whether results would differ over a longer period. Second, despite the fact that subjects were instructed to adhere to their usual and customary nutritional regimen, there was no attempt to monitor dietary intake. Thus, alterations in diet during the course of the study unbeknown to the research staff may have confounded results. Third, the use of DXA, although well-established as a valid instrument to estimate body composition, lacks the sensitivity to detect subtle changes in muscle mass compared to direct imaging modalities such as computed tomography and magnetic resonance image [10, 11]. For greater clarity, future stud-



▶ **Fig. 2** Pre- to post-training scores and percentage changes of muscle strength of chest press, knee extension, preacher curl and total strength by group (NPR, narrow zone repetition, and WPR, wide zone of repetition). There were no significant group vs. time interactions for any variables (P>0.05). * P<0.05 vs. pre-training.

▶ **Table 1** Effect size values according to groups.

	NPR (n=20)	WPR (n=19)	Differences
Fat free mass	0.17	0.20	−0.03
Skeletal muscle mass	0.34	0.77	−0.43
Lower limb muscle mass	0.31	0.56	−0.25
Upper limb muscle mass	0.34	0.42	−0.08
Chest press	0.67	0.64	0.03
Knee extension	0.65	0.66	−0.01
Preacher curl	0.88	1.13	−0.25
Total strength	0.80	0.84	−0.04

Note: NPR, narrow repetition zone. WPR, wide repetition zone. Differences = NPR – WPR.

▶ **Table 2** Z-scores of the percentage changes from pre- to post-training period (8 weeks) according to group. Data are expressed as mean and standard deviation.

	NPR (n=20)	WPR (n=19)	P-value
Fat free mass	0.24±0.6	0.66±1.1	0.16
Skeletal muscle mass	0.25±0.3	0.59±1.4	0.05
Lower limb muscle mass	0.16±0.3	0.54±1.5	0.08
Upper limb muscle mass	0.45±0.7	0.49±0.6	0.47
Chest press	0.31±0.8	0.64±0.9	0.70
Knee extension	0.50±0.6	0.60±0.6	0.60
Preacher curl	0.34±0.5	0.76±0.8	0.24
Total strength	0.47±0.5	0.73±0.6	0.79
Composite z-score	0.39±0.4	0.67±0.8	0.17

Note: NPR, narrow repetition zone. WPR, wide repetition zone. * P<0.05 vs. control. Composite z-score = (skeletal muscle mass z-score + total strength z-score)/2.

ies should endeavor to investigate the topic using direct imaging modalities. Finally, the study is specific to untrained, older women and results cannot be generalized to other populations including children, young adults, men, and those with resistance training experience.

In conclusion, the study showed that pyramid system employing both a wide and narrow repetition range are effective in promoting increases in strength and muscle mass. Although no statistically significant differences were noted between systems, the underlying analysis suggests a potential benefit to performing a wider range of repetitions. The implications of our data suggest that different load schemes and set durations may have synergistic, additive effects on enhancing muscle growth. Future studies should attempt to investigate whether outcomes may be mechanistically altered by differences in fiber-type adaptations across repetition ranges.

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Conflict of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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