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Effects of Resistance Training with Different Pyramid Systems on Bioimpedance Vector Patterns, Body Composition, and Cellular Health in Older Women: A Randomized Controlled Trial

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Received: 20 July 2020; Accepted: 16 August 2020; Published: 18 August 2020

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Abstract: Bioelectrical impedance vector analysis (BIVA) and phase angle (PhA) have been widely used to monitor changes in health-related parameters in older adults, while resistance training (RT) is one of the potential strategies to mitigate the adverse effects of aging. The purpose of this study was to compare the effects of the crescent pyramid RT system with two repetition zones on BIVA patterns and PhA. Fifty-five older women (≥60 years) were randomly assigned into three groups: control (CON, n = 18), narrow pyramid (NPR, n = 19), and wide pyramid (WPR, n = 18). The RT was performed for eight weeks, three times per week, in eight exercises for the whole body with three sets of 12/10/8 (NPR) or 15/10/5 repetitions (WPR). Bioimpedance spectroscopy (50 kHz frequency) was assessed. After the intervention period, both training groups showed significant changes in BIVA patterns compared to CON ($p < 0.001$); resistance decreased and reactance increased, which resulted in a BIVA-vector displacement over time ($p < 0.001$). Changes in PhA were greater for WPR ($\Delta\% = 10.6$; effect size [ES] = 0.64) compared to NPR ($\Delta\% = 5.3$; ES = 0.41) and CON ($\Delta\% = -6.4$; ES = −0.40). The results suggest that the crescent pyramid RT system with both repetition zones (WPR and NPR) is effective for inducing improvements in BIVA patterns and PhA in older women, although WPR elicits greater increases in PhA than NPR.

Keywords: aging; BIVA; bioelectrical impedance analysis; body composition; elderly; strength training; dose-response

1. Introduction

Aging is associated with a variety of adverse changes to older adults [1–4]. Sarcopenia, described as the loss of muscle mass and function, is one of the main health problems in aging and has been associated with increased risk of falls, injuries, and hospitalizations [1]. The cost of care and treatment for the elderly who suffer fatal and nonfatal falls is high and burdens health systems [1,2]. Therefore, implementing strategies to improve functionality and body composition in older adults such as physical exercises are deemed of primary importance to lead a healthy life [1,3], and may mitigate socioeconomic impacts by reducing health care costs [1,2]. In this way, analyzing and monitoring body composition is an essential topic when discussing the benefits of leading an active lifestyle.

Among the several tools to estimate body composition, the bioelectrical impedance analysis (BIA) is a non-invasive, inexpensive, and simple method to do it in different populations [5]. Recent studies have opted to use the interpretation of the raw parameters obtained from BIA, like bioelectrical impedance vector analysis (BIVA) and phase angle (PhA), to infer regarding body composition, instead of using prediction equations to avoid errors associated with them [6]. Through the BIVA approach, the bioelectric parameters of resistance (R) and reactance (Xc) are interpreted together as a vector within an R-Xc graph. Since R and Xc reflect body fluid content and cell density, respectively, the position of the bioimpedance vector provides essential information on body composition [5]. Additionally, the vector inclination determines the bioelectrical PhA, which represents the relationship between the intra- (ICW) and extracellular fluids (ECW) [7].

The aging-associated alterations in body composition, manifested by reduction of skeletal muscle mass and increased body fat, may influence BIVA parameters resulting in PhA decreases [8–12]. In contrast, exercise practice promotes positive changes in BIVA and PhA, followed by benefits on psychological, cognitive, and physical aspects, hydration, nutritional status, muscle function, and quality of life in the elderly [11–20]. Resistance training (RT) is one of the potential strategies to reverse the adverse effects of aging on cellular integrity and function, improve BIA parameters, and induce changes in the cellular volume of skeletal muscle tissue and cell membrane potential [8–13]. However, despite some recent and preliminary results [11,21–23], the dose–response relationship regarding specific RT variables (e.g., training period, frequency, intensity, volume, training system) on bioelectrical parameters is unclear.

In this regard, the pyramid training system is an RT strategy applied to increase muscular strength and muscle mass, whereby loads are progressively increased (crescent pyramid) or decreased (reverse pyramid) inversely to the number of repetitions for successive sets of a given exercise [24,25]. The traditional crescent pyramid system adopts a narrow repetition zone (e.g., 12, 10, and 8 repetitions, respectively) with ~5% load increases for each set [24]. However, due to the muscular strength to be reduced with the aging process, older adults have shown difficulty in increasing the exercise loads throughout the sets in the proper manner [24]. Thus, both traditional and crescent pyramid systems tend to result in similar adaptative responses to RT in older adults [24]. Therefore, it seems that an alternative for this population can be the use of a wider repetition zone such as 15, 10, and 5 repetitions, respectively, for each set [25]. From a wider repetition zone, it would be possible for progressive increases of the weight to allow an appropriate combination of metabolic and mechanic stimuli, which might result in additional benefits. This hypothesis was confirmed in a recent study that found a better hypertrophic response in older women submitted to a crescent pyramid RT system with a wider variety of training loads than a narrower loading range [25].

Therefore, considering the correlation between muscular strength and muscle mass with PhA in older men and women [13,26], it seems logical that a crescent pyramid RT system using a more extensive repetition zone would also induce more significant changes in both BIVA patterns and PhA. Thus, the purpose of the present study was to compare the effects of the crescent pyramid system performed with a wide versus a narrow repetition zone on the most informative bioimpedance parameters in older women. It was hypothesized that training would be adequate to induce changes in BIVA vector displacements and increases in PhA and that the crescent pyramid system performed in a wide repetition zone would elicit more significant improvements compared to the narrow zone.

2. Materials and Methods

2.1. Experimental Design

The present study is part of a longitudinal research project named "Active Aging Longitudinal Study", initiated in 2012, whose purpose is to analyze the effects of supervised, structured, and progressive RT program on neuromuscular, morphological, physiological, and metabolic outcomes in older women [25]. A randomized controlled trial was carried out over 12 weeks, with eight weeks dedicated to the RT program, and four weeks for data collection. Pre- and post-intervention testing was carried out at weeks 1–2 and 11–12, respectively. The RT program was carried out during weeks 3–10. Adherence to the RT program was established as >85% of the total sessions. Participants were instructed not to perform any other type of physical exercise throughout the study period. The procedures were conducted according to the Declaration of Helsinki, and the Londrina State University Ethics Committee approved this investigation (committee opinion number: 1.306.507). No adverse event occurred during the intervention period.

2.2. Subjects

Recruitment was carried out through the newspaper, television programs, radio advertisings, and home delivery of leaflets in the central area and residential neighborhoods. Interested individuals completed detailed health history and physical activity questionnaires. Participants were subsequently admitted to the study if they met specific inclusion criteria: female, ≥60 years old, 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 test by a cardiologist (resting 12-lead electrocardiogram test, personal interview, and treadmill stress test when deemed necessary). All were released with no restrictions for participation in this study. Fifty-nine physically independent older women (67.3 ± 4.4 years, 66.5 ± 12.6 kg, 1.55 ± 0.1 m, 27.6 ± 5.0 $kg \cdot m^{-2}$) were selected and randomly assigned to one of three groups: nonexercise control group (CON, n = 19); pyramid RT system with narrow repetition zone (NPR, n = 20), in which participants performed three sets of 12/10/8 repetitions per exercise, respectively; or pyramid RT system with wider repetition zone (WPR, n = 20), in which participants performed three sets of 15/10/5 repetitions per exercise, respectively. This final number of subjects reached the necessary criteria for this experiment, according to the sample size calculation (repeated measures, moderate effect size = 0.50, $\alpha = 0.05$, power = 0.80). Written informed consent was obtained from all participants after a detailed description of study procedures was provided.

2.3. Bioimpedance Spectroscopy

A phase-sensitive BIA (Xitron Hydra, model 4200, Xitron Technologies, San Diego, CA, USA) was used to obtain whole-body R and Xc at a single frequency at 50 kHz. PhA was calculated as arc-tangent (Xc/R) × 180°/π. Classic BIVA values were calculated relative to height (R/H and Xc/H). Fat-free mass (FFM), fat mass (FM), total body water (TBW), and its fractions ECW and ICW, were assessed by equations on the software device. Before each test, the analyzer was calibrated by measuring, modeling, and computing volume using a module provided by the manufacturer. The calibration test result is based on the default ECW and ICW resistivity coefficients. Participants were instructed to lie in a supine position for approximately 10 min (serving as an equilibration period). After cleaning the skin with alcohol, four electrodes were positioned on the surface of the right hand and right foot, according to conventional procedures established in the literature [27]. Participants were instructed to urinate about 30 min before the measures, refrain from ingesting food or drink in the last four hours, avoid strenuous physical exercise for at least 24 h, refrain from the consumption of alcoholic and caffeinated beverages for at least 48 h, and avoid the use of diuretics at least during seven days prior to each assessment. The BIA device was calibrated each day according to the manufacturer's recommendations. The exams were performed by the same professional in the pre- and post-intervention periods. The intraclass correlation coefficient (ICC) and standard error of measurement (SEM) were = [ECW: (SEM = 0.32 L, ICC = 0.98), ICW: (SEM = 0.19 L, ICC = 0.99), TBW: (SEM = 0.38 L, ICC = 0.98), R: (SEM = 15.6 ohms, ICC = 0.95), Xc: (SEM = 3.5 ohms, ICC = 0.96), PhA: (SEM = 0.21 degrees, ICC = 0.96)].

2.4. Resistance Training Program

A schematic representation of how RT was prescribed is displayed in Table 1. The training program was performed in the morning hours on Mondays, Wednesdays, and Fridays for eight weeks. It was based on recommendations for RT in an older population to improve muscle hypertrophy and muscular strength [28]. Physical Education professionals personally supervised (1–2 supervisors per exercise) all training sessions to reduce deviations from the study protocol and ensure safety. The RT protocol consisted of eight exercises for the whole body (as shown in Table 1), performed in either three sets of 12/10/8 RM (NPR) or 15/10/5 RM (WPR) with incrementally higher loads for each set (crescent pyramid system) [24,25]. The supervisors adjusted exercise loads according to the participant's ability and improvements in exercise capacity throughout the study to ensure that they used adequate resistance while maintaining proper technique.

Table 1. Resistance training program performed by the older women for eight weeks.

	Narrow Repetition Zone Training	**Wide Repetition Zone Training**
Exercises performed	chest press, horizontal leg press, seated low-row, leg extension, barbell preacher curl, lying leg curl, triceps pushdown, seated calf raise	
Number of sets × repetitions	3 × 12/10/8	3 × 15/10/5
Intensity	12/10/8 RM-load	15/10/5 RM-load
Load progression	2–5% and 5–10% per week for upper- and lower-body exercises, respectively	
Execution velocity	1 s and 2 s for concentric and eccentric movement phases, respectively	
Rest intervals	1–2 min and 2–3 min between sets and exercises, respectively	

Note. RM = repetitions-maximum.

The loads and the number of repetitions performed during each set of the eight exercises were individually recorded for each training session. The volume for each set of all exercises was calculated by multiplying the load by the number of repetitions. The volume of each exercise per session was calculated as the sum of the volume of all three sets for each exercise. The total volume-load per session was calculated as the sum of all eight exercises. The weekly volume-load (WVL) was calculated by summing the three training sessions performed in one week. Increases in WVL throughout the RT program were calculated as the WVL of the eighth week minus the WVL of the first week.

2.5. Dietary Intake

Food intake was assessed by the 24-h dietary recall method applied on two nonconsecutive days of the week, with the aid of a photographic record taken during an interview. Dietary intake was monitored in the first two and the last two weeks of the intervention period. The homemade measurements of the nutritional values of food were converted into grams and milliliters by the online software Virtual Nutri Plus (Keeple®, Rio de Janeiro, RJ, Brazil) for diet analysis. Some foods were not found in the program database, and therefore these items were added from food tables.

2.6. Statistical Analyses

The Shapiro–Wilk test was used to analyze the distribution of data. Generalized estimated equations (GEE) analyses were applied to investigate the effects of intervention over time within and between groups. Bonferroni post hoc test was adopted when significant effects on group, time, or interaction were confirmed. The paired one-sample Hotelling T^2-test [29] was used to evaluate if the changes in the mean group vectors (measured before and after the intervention period) were significantly different from zero (null vector); a 95% confidence ellipse excluding the null vector indicated a significant vector displacement. Cohen's effect size (ES) was calculated as post-training mean minus pre-training mean divided by the pooled pre-training standard deviation [30]. An ES of 0.00–0.19 was considered as trivial, 0.20–0.49 was considered as small, 0.50–0.79 as moderate, and ≥0.80 as large [30]. For all statistical analyses, statistical significance was established at $p < 0.05$. The data were stored and analyzed using IBM SPSS Statistics, v. 22.0 (IBM Corp., Armonk, NY, USA).

3. Results

Data from 55 participants were considered for final analysis (CON = 18, NPR = 19, and WPR = 18). Sample losses were due to personal reasons (CON = 1) and adherence lower than 85% (NPR = 1 and WPR = 2). A significantly greater increase in WVL was observed ($p < 0.001$) for WPR compared to NPR (+135.2 ± 15.7 kg versus +123.6 ± 17.5 kg, respectively). There were no significant differences ($p > 0.05$) in daily relative energy and macronutrients intra- and inter-groups over time (Table 2).

Table 2. Dietary intake at pre- and post-intervention according to the group.

		Control (n = 18)	Narrow Repetition Zone (n = 19)	Wide Repetition Zone (n = 18)	Interaction *p*-Value
Carbohydrate (g·kg·d^{-1})	Pre	3.4 ± 1.1	3.0 ± 1.0	3.0 ± 1.0	
	Post	3.4 ± 1.3	3.0 ± 1.0	3.1 ± 0.9	0.548
Protein (g·kg·d^{-1})	Pre	1.1 ± 0.3	0.9 ± 0.4	1.0 ± 0.2	
	Post	1.0 ± 0.3	1.0 ± 0.4	0.9 ± 0.2	0.091
Lipid (g·kg·d^{-1})	Pre	0.7 ± 0.2	0.7 ± 0.3	0.7 ± 0.2	
	Post	0.7 ± 0.2	0.6 ± 0.3	0.7 ± 0.2	0.632
Energy (kcal·kg·d^{-1})	Pre	25.4 ± 7.8	21.4 ± 7.6	21.9 ± 5.7	
	Post	24.3 ± 6.9	20.9 ± 8.0	22.2 ± 5.5	0.376

Note. Data are expressed as mean ± standard deviation.

Table 3 depicts the baseline and post-intervention scores, percentage changes and effect-sizes for body composition, and BIA variables by group. Both training groups had significantly ($p < 0.05$) greater increases compared to CON for FM (NPR = −0.5 kg; WPR = −0.6 kg; CON = +0.2 kg), FFM (NPR = +0.5 kg; WPR = +0.7 kg; CON = −0.2 kg), ECW (NPR = −0.3 L; WPR = −0.7 L; CON = +0.2 L), ICW (NPR = +0.7 L; WPR = +1.2 L; CON = −0.8 L), R (NPR = −8.6 ohm; WPR = −25.3 ohm; CON = +15.1 ohm), R/H (NPR = −5.4 ohm/m; WPR = −16.5 ohm/m; CON = +9.8 ohm/m), Xc/H (NPR = +1.3 ohm/m; WPR = +2.2 ohm/m; CON = −1.6 ohm/m), and Z/H (NPR = −5.8 ohm/m; WPR = −16.4 ohm/m; CON = +9.8 ohm/m) with no statistically significant differences between experimental groups ($p > 0.05$).

Figure 1 depicts the pre- to post-intervention percentage change on PhA by the group. There was a significantly higher post-study increase in PhA ($p < 0.05$) in WPR compared to NPR and CON (+10.6%, 5.3%, and −6.4%, respectively). The mean differences in R/H and Xc/H vectors with 95% confidence ellipses by groups are depicted in Figure 2. A significant change was observed for CON ($T^2 = 42.0$), NPR ($T^2 = 29.4$), and WPR ($T^2 = 57.9$), in which the 95% confidence ellipses did not cross the origin. Figure 3 presents the mean impedance vectors with 95% confidence ellipses baseline to post-intervention by groups. The vector change was statistically significant only in the WPR group ($T^2 = 8.1$; $p = 0.03$).

Table 3. Participant's scores at pre- and post-intervention according to the groups.

		Control (n = 18)	Narrow Repetition Zone (n = 19)	Wide Repetition Zone (n = 18)	Interaction *p*-Value
Fat mass (kg)	Pre	25.8 ± 9.8	27.4 ± 8.9	28.7 ± 8.0	<0.001
	Post	26.0 ± 10.0 *	26.9 ± 9.1 *	28.1 ± 8.1 *	
	Δ%	+0.77	−1.82	−2.09	
	ES	0.02	−0.05	−0.07	
Fat-free mass (kg)	Pre	38.1 ± 5.4	37.6 ± 4.7	37.5 ± 4.7	<0.001
	Post	37.9 ± 5.4 *	38.1 ± 4.8 *	38.2 ± 4.6 *	
	Δ%	−0.52	1.33	1.05	
	ES	−0.04	0.11	0.09	
TBW (L)	Pre	28.9 ± 5.4	29.3 ± 3.7	28.0 ± 3.6	0.029
	Post	28.5 ± 5.1	29.6 ± 3.6	28.4 ± 3.6 *	
	Δ%	−1.38	1.02	1.43	
	ES	−0.07	0.08	0.11	
ECW (L)	Pre	13.2 ± 2.0	12.9 ± 1.4	13.2 ± 1.6	<0.001
	Post	13.4 ± 2.0 *	12.6 ± 1.2 *	12.5 ± 1.7 *	
	Δ%	1.51	−2.33	−5.30	
	ES	0.10	−0.21	−0.44	
ICW (L)	Pre	15.6 ± 3.5	16.4 ± 2.5	14.7 ± 2.3	<0.001
	Post	14.8 ± 2.7 *	17.1 ± 2.6 *	15.9 ± 2.2 *	
	Δ%	−5.13	4.27	8.16	
	ES	−0.23	0.28	0.52	
Resistance (ohm)	Pre	572.1 ± 72.3	564.0 ± 44.8	574.5 ± 55.8	0.007
	Post	587.2 ± 75.7 *	555.4 ± 51.2 *	549.2 ± 60.5 *	
	Δ%	2.64	−1.52	−4.40	
	ES	0.21	−0.19	−0.45	
Reactance (ohm)	Pre	54.7 ± 5.0	53.6 ± 5.1	54.5 ± 6.8	0.240
	Post	53.6 ± 7.0	55.7 ± 5.9	57.8 ± 5.4 *	
	Δ%	−2.01	3.92	6.05	
	ES	−0.22	0.41	0.48	
Phase angle (degree)	Pre	5.61 ± 0.9	5.46 ± 0.7	5.48 ± 0.9	<0.001
	Post	5.25 ± 0.6	5.75 ± 0.6 *	6.06 ± 0.7 *	
	Δ%	−6.42	5.31	10.60	
	ES	−0.40	0.41	0.64	
R/H (ohm/m)	Pre	366.3 ± 40.1	366.7 ± 23.4	367.4 ± 32.0	<0.001
	Post	376.1 ± 43.1 *	361.3 ± 28.6 *	350.9 ± 35.9 *	
	Δ%	2.68	−1.47	−4.49	
	ES	0.24	−0.23	−0.51	
Xc/H (ohm/m)	Pre	36.0 ± 4.2	34.9 ± 3.1	35.0 ± 3.1	<0.001
	Post	34.4 ± 4.4 *	36.2 ± 3.7 *	37.2 ± 3.6 *	
	Δ%	−4.44	3.72	6.29	
	ES	−0.38	0.42	0.71	
Z/H (ohm/m)	Pre	366.4 ± 9.2	366.8 ± 5.2	367.4 ± 7.3	<0.001
	Post	376.2 ± 9.9 *	361.4 ± 6.3 *	351.0 ± 8.2 *	
	Δ%	2.67	−1.47	−4.46	
	ES	1.06	−1.03	−2.19	

Notes. TBW: total body water; ECW: extracellular water; ICW: intracellular water; R/H: resistance by height; Xc/H: reactance by height; Z/H: impedance by height; ES: effect size. Data are expressed as mean ± standard deviation. * $p < 0.05$ versus pre-intervention.

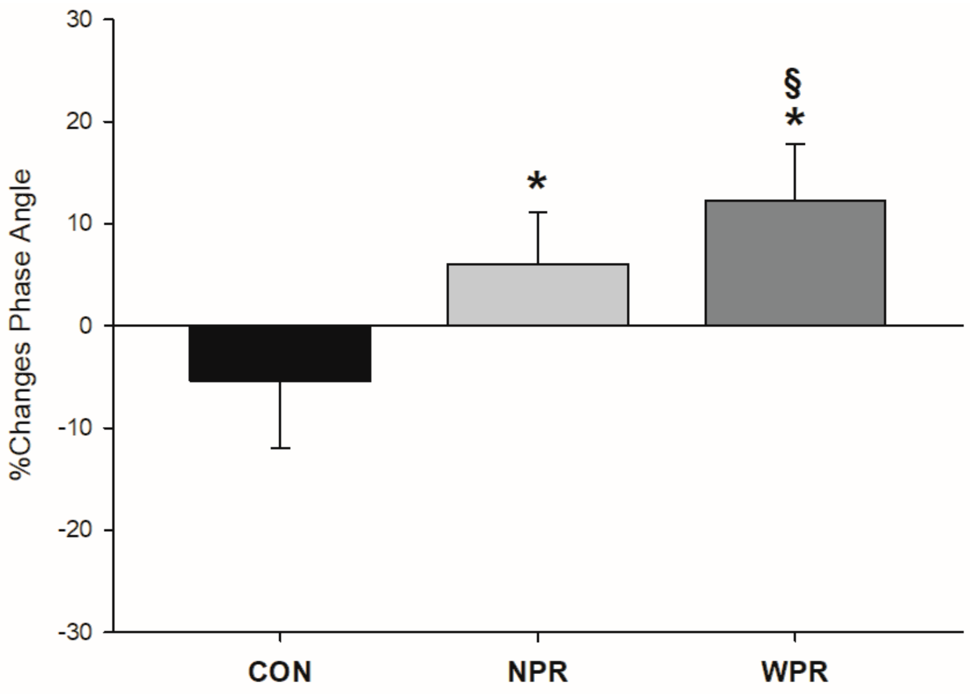

Figure 1. Percentage changes on phase angle after intervention for control (CON, n = 18), narrow pyramid (NPR, n = 19), and wide pyramid (WPR, n = 18) groups. * $p < 0.05$ versus CON. § $p < 0.05$ versus NPR.

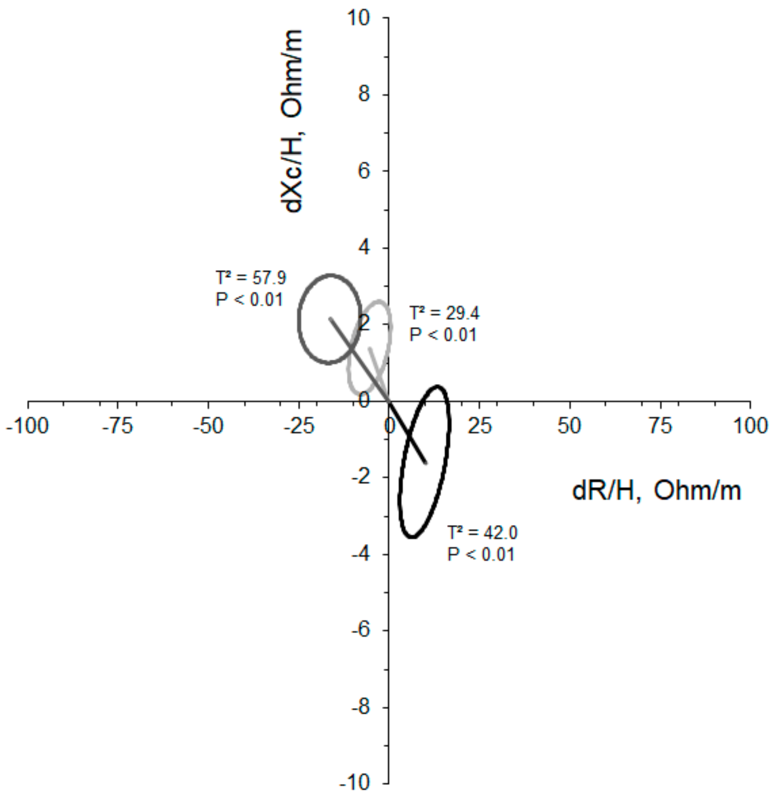

Figure 2. Mean difference vector displacement with the 95% confidence ellipses of the differences for control (black), narrow pyramid (light grey), and wide pyramid (dark grey) groups.

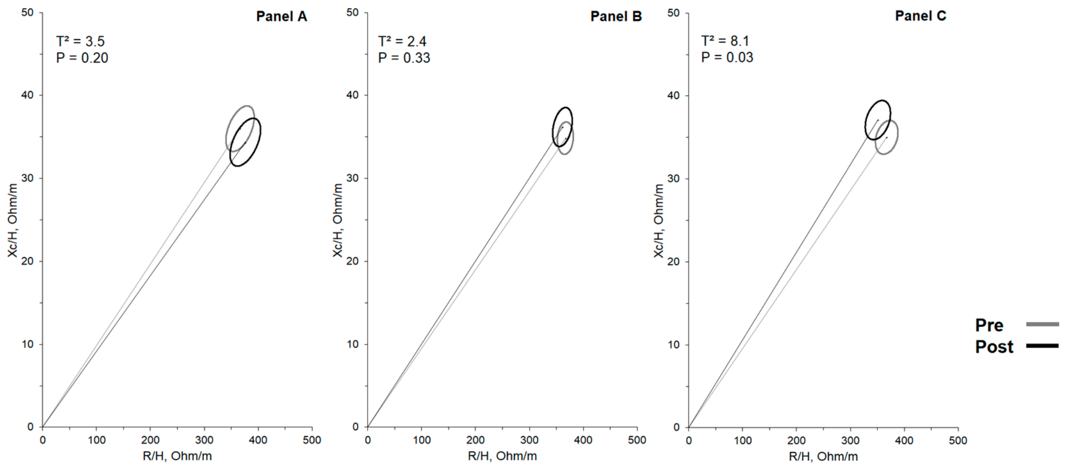

Figure 3. Mean impedance vectors with 95% confidence ellipses for control (**Panel A**), narrow pyramid (**Panel B**), and wide pyramid (**Panel C**) groups at pre- and post-intervention.

4. Discussion

To our knowledge, this is the first investigation comparing the effects of different RT systems on BIA and BIVA parameters in older women. The main finding of the current study was that a crescent-pyramid system performed with narrow or wide repetition zones was effective to improve markers of cellular integrity and function as assessed by changes in BIA outcomes. In particular, the vector displacements measured in the two intervention groups have shown how exercise has counteracted the aging effects while preserving muscle mass and cellular health. On the contrary, in the control group, the results presented an opposite trend where R increased and Xc decreased, indicating a reduction in fluid content and cellular density, respectively. As a consequence of these physiological changes and the effects of exercise, PhA increased in the training groups and decreased in the control group after the 8-week intervention period. In fact, in parallel with the bioimpedance changes, an increase in FFM was measured in the training groups versus a reduction in the control group. Also, the magnitude of the effect was influenced by the width of the repetition zone, with a wider zone inducing superior changes. Therefore, our hypothesis that RT performed with WPR would result in better improvements was confirmed.

The results of the present study indicate that performing a crescent PR system with a wider range of repetitions may maximize the metabolic response in the initial sets and the mechanical effects in the latter sets, thereby heightening anabolism [31]. Our results may be, at least in part, explained by the higher WVL verified for WPR. RT-associated muscle hypertrophy appears to be volume-dependent [32,33]. Therefore, due to its relation with muscle hypertrophy, it is possible to believe that a greater WVL elicits improvement in the BIA and BIVA parameters.

Fukuda et al. [8] reported that RT improved BIVA parameters in older women. Our findings revealed a similar change in the BIVA vectors in both training groups, indicating that increases were not influenced by different schemes of the pyramid RT system. However, for both CON and NPR groups, the R/H and Xc/H components contributed equally to the BIVA vector displacement. In contrast, for the WPR group, the change occurred due to the more significant reduction of the R/H component. Also, RT performed in the WPR system resulted in superior effect-sizes in Xc/H and ICW (ES = 0.71 and 0.52, respectively) compared to NPR (ES = 0.42 and 0.28, respectively) and Z/H (ES = 2.19 versus 1.03, respectively). These changes indicate a possible improvement in the integrity of the cell membrane, increasing the capacitance of the cells [7,12]. It has been postulated that cellular swelling in response to RT may induce an increased pressure on the cell membrane, which, in turn, threatens the cell's integrity and thus leads to increased anabolic signaling and processes to enhance the cell's ultrastructure [31].

While improvements in cell integrity, structure, and function may reflect changes in PhA, aging per se results in losses in cellular integrity and functions [8,12], reflecting reductions in PhA values, as verified in the present study (−6.4%). The PhA changes highlighted in this study are in line with the results of other studies in which the PhA increased in the intervention groups and decreased in the older women who were not involved in the physical activity program [9,10]. In healthy older women, the reference values for PhA are between 5 and 6 degrees [34]. The PhA of our sample was within the population mean in all groups (CON = 5.61 degrees, NPR = 5.46 degrees, and WPR = 5.48 degrees). Besides, our analysis revealed that in both training groups, the increases in PhA were significantly higher than the CON group. However, the rise in WPR was statistically superior to NPR ($p < 0.05$; ES = 0.64 versus 0.41, respectively), indicating that performing a wider repetition range may promote additional effects on cellularity, cell size, and integrity of cell membrane. It is not clear whether alterations in metabolic stress may have contributed to the differences found in PhA between groups; therefore, further studies are needed to determine potential explanatory mechanisms.

The alterations found for PhA of the pre- to post-intervention were higher than SEM from our lab in 83% for CON and WPR, and 89% for NPR. Our results are consistent with previous studies from our group in other cohorts of older women, which show that RT interventions lasting 8 to 12 weeks result in increments between 0.2 and 0.4 degrees (+3% to +17%) [10,11,13,21,22]. The analysis of vector displacement in each group revealed that there were increments relating to cellularity and soft tissue only in the RT groups, while in the CON group, changes were towards cachexia, fluid increase, and soft tissue reduction (Figure 2). Complementary analysis of the pre- to post-intervention vector difference showed significant differences only in the NPR group ($T^2 = 8.1$, $p = 0.03$), with a bias in favor of increased cell membrane integrity and cellularity. A clinical effect was evident (ES = 2.19) in the Z/H analysis (Table 3).

Although RT is an intervention frequently used to improve the health of women, further research is needed to reveal optimal dose–response relationships following RT in healthy older women [28]. In this regard, our results contribute significantly to practitioners, along with trainers and exercise professionals who work with older women, aiding in more scientific evidence-based exercise conduct. Different RT systems over the training mesocycles may be used as a strategy to avoid a plateau of adaptations, to increase the motivation, or still to reduce the monotony of the training sessions. Thus, the use of the crescent pyramid RT system with a wide repetition zone seems to be a feasible alternative and more appropriate for older women than the traditional pyramid system with a narrow repetition zone since it allows a higher load progression and, consequently, a better combination of metabolic and mechanic stimuli. Therefore, the crescent pyramid RT system with a wide repetition zone may promote additional benefits associated with increasing of PhA, which ultimately can mitigate the risks of falls, fractures, and reduce the number of hospitalizations, enabling greater sustainability of public health systems.

Our study has some limitations that should be addressed. First, our findings are applicable to single-frequency bioimpedance equipment. In fact, different results in measuring R and Xc values are obtained using devices that work on single- or multi-frequency [35]. Additionally, eight weeks of intervention can be considered as a relatively short period. Therefore, it is necessary to determine whether results would differ over a longer timeframe. Another aspect concerns the sample size, which included untrained older women. Thus, results should not be generalized to other populations with different age and physical fitness, as various adaptative responses to RT may be influenced by such factors. Moreover, the absence of biomarkers of lipid peroxidation, protein oxidation, and metabolic stress limit the understanding of possible mechanisms associated with the observed results. Finally, physical activity and sedentary behavior were not monitored during the experiment, hindering our ability to determine whether these factors influenced changes found in this investigation. On the other hand, it is essential to highlight the strengths of our study. All training sessions were supervised by professionals with RT experience to ensure participant safety, quality of execution of the movement, and effectiveness. The importance of supervised RT in older adults has been reported in several studies [36]. Moreover, the load adjustments were continuous and based on the participants' progress throughout the RT sessions, which permitted the maintenance of the intensity throughout the intervention. In addition, the monitoring of food consumption of the participants allowed a more consistent analysis of RT effects.

5. Conclusions

The impact of physical activity and healthy habits on body composition are particularly important in the elderly. Our findings suggest that the crescent PR system performed with narrow or wide repetition zones is effective in improving cellular integrity, function, and health (BIVA patterns and PhA). However, while the beneficial effect of physical activity in contrasting the aging process has been confirmed, WPR seems to promote superior increases in PhA in untrained older women.

Author Contributions: Conceptualization, L.d.S., A.S.R., L.A.G., J.P.N., P.M.C., F.C., S.T., B.J.S., L.B.S. and E.S.C.; data curation, L.d.S.; formal analysis, L.d.S. and L.A.G.; funding acquisition, L.B.S. and E.S.C.; investigation, L.d.S., A.S.R., J.P.N. and P.M.S.; methodology, L.d.S., A.S.R., L.B.S. and E.S.C.; project administration, L.d.S., A.S.R., J.P.N. and P.M.S.; resources, E.S.C.; supervision, L.d.S., A.S.R., J.P.N. and P.M.S.; writing—original draft, L.d.S.; writing—review and editing, L.d.S., A.S.R., L.A.G., J.P.N., P.M.S., F.C., S.T., B.J.S., L.B.S. and E.S.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors would like to express thanks to all the participants for their engagement in this study, the Coordination of Improvement of Higher Education Personnel (CAPES/Brazil) for the scholarship conferred to J.P.N. (master), L.d.S., and P.M.C. (doctoral), and the National Council of Technological and Scientific Development (CNPq/Brazil) for the grants conceded to E.S.C. This study was partially supported by the Ministry of Education (MEC/Brazil) and CNPq/Brazil.

Conflicts of Interest: The authors declare no conflict of interest.

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