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Article *in* International Journal of Sports Medicine · January 2017

DOI: 10.1055/s-0042-102788

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Hypertrophy-type Resistance Training Improves Phase Angle in Young Adult Men and Women

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Key words

strength training, phase angle skeletal muscle, cellular hydration, spectral bioimpedance

accepted after revision 26.01.2016

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DOI http://dx.doi.org/10.1055/s-0042-102788
Published online: October 28, 2016 | Int J Sports Med 2017; 38: 35–40

ISSN 0172-4622

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ABSTRACT

The main purpose of the present study was to investigate the effect of a hypertrophy-type resistance training protocol on phase angle, an indicator of cellular integrity, in young adult men and women. 28 men (22.2 ± 4.3 years, 67.8 ± 9.0 kg and 174.2 ± 6.8 cm) and 31 women (23.2 ± 4.1 years, 58.7 ± 12.1 kg and 162.7 ± 6.4 cm) underwent a progressive RT for 16 weeks (2 phases, 8 weeks each), 3 times per week, consisting of 10 to 12 whole body exercises with 3 sets of 8–12 repetitions maximum. Phase angle, resistance, reactance and total body water (intra and extracellular water compartments) were assessed by bioimpedance spectroscopy (Xitron 4200 Bioimpedance Spectrum Analyzer). Total body water, intracellular water and phase angle increased significantly ($P<0.05$) in men (7.8, 8.3, and 4.3 %, respectively) and women (7.6, 11.7, and 5.8 % respectively), with no significant difference between sexes ($P>0.05$). Bioimpedance resistance decreased ($P<0.05$) similarly in both sex (men = −4.8 %, women = −3.8 %). The results suggest that regardless of sex, progressive RT induces an increase in phase angle and a rise in cellular hydration.

Introduction

Phase angle (PhA) is an angular derived bioelectrical impedance (BIA) parameter from resistance (R) and reactance (Xc) that has been widely used in different populations as an objective indicator of cellular health with higher values reflecting better cellularity, cell membrane integrity and cell function [9, 23]. PhA is considered a valuable alternative for predicting functionality [5, 23], nutritional status [38], disease prognosis [35] and mortality risk [24, 37].

Values of PhA have been proposed as a muscle fitness index expressing both the amount and quality of soft tissue [23]. Given this information, resistance training (RT) can conceivably play an important role on PhA improvements, since RT is a well-recognized method of exercise for eliciting increases in muscle growth and remodeling [1]. A cross-sectional study comparing the PhA of healthy young adult males and bodybuilders showed higher PhA scores for those who engaged in regular RT [26]. Due to the premise of reverse causality, however, cross-sectional studies provide limited utility for drawing robust conclusions about the influence of the chronic adaptations induced by RT on PhA. Thus, it is important to determine whether an RT program designed to promote hypertrophy results in long-term changes in PhA.

Factors such as age, body mass index and sex are primary determinants of the PhA [3, 6]. Men generally present higher PhA values than women, which may be related to their higher amount of skeletal muscle mass (SMM) [6] and because the R and Xc – the electrical properties that determine PhA – differ between sexes [6].

Considering the abovementioned information, we cannot rule out the possibility that men and women may present different chronic adaptations in PhA pursuant to resistance exercise. Therefore, the purpose of the present study was to investigate the effect of a hypertrophy-type RT on PhA in young adult men and women.

Methods

Experimental design

The study was carried out over a period of 22 weeks, with 16 weeks dedicated to the RT program and 6 weeks to measurements and evaluations. Anthropometric and body compositions measurements were performed at weeks 1–2, 11–12 and 21–22. The first measurement took place one week before the intervention (Monday and Tuesday). The second and third evaluations were performed on the following Monday and Tuesday after the end of each training phase (Friday). With this procedure, there was a 48–72 h period between the last training session and the bioimpedance analysis. The supervised progressive RT was performed between weeks 3–10, 13–20. Subjects were instructed to maintain their normal level of physical activity and were specifically asked not to start a new exercise regimen during study period.

Participants

Participants were recruited from a university population and though a local advertisement. All volunteers (47 women and 42 men) completed a detailed health history questionnaire. Inclusion criteria were the following: no signs or symptoms of any disease and orthopedic injuries, insufficiently inactive (defined as performing physical activity less than twice a week), and no participation on any RT for at least 6 months before the beginning of the study. 28 men and 31 women finished the study and therefore were included in the final analysis. The reasons for the dropouts included insufficient attendance to training sessions (< 85 % of the total sessions) and voluntary abandonment for different reasons.

All women included in the analysis were in the same phase of their menstrual cycle at the 3 time-points designated for evaluation. 19 women were at the follicular phase, and 12 women were at the luteal phase when body water was assessed. The follicular phase was assumed as the first day of menstruation until the fourteenth day, and the luteal phase was considered as half of the cycle (fifteenth day) until the day that precedes menstruation. In addition, all women were not assessed in the last week of the luteal phase or during the days they were menstruating.

Written informed consent was obtained from the participants after a detailed description of all procedures was provided. The study was conducted in accordance with accepted ethical standards [12] and was approved by the Research Ethics Committee of the local University.

Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, PR, Brazil), with the participants wearing light workout clothing and no shoes. Height was measured with a stadiometer attached on the scale to the nearest 0.1 cm with participants standing without shoes. Body mass index was calculated as body mass in kilograms divided by the square of height in meters.

Body composition

Bioimpedance spetroscopy (BIS) (Xitron Hydra, model 4200, Xitron Technologies, San Diego, CA, USA) was used to determine the total body water (TBW), intracellular water (ICW) and extracellular water (ECW) content, resistance (R), and reactance (Xc), and subsequently PhA was calculated by arc-tangent (Xc/R) x 180 °/π. SMM was estimated by the predictive equation developed by Janssen et al. [15]:

$$SMM\,(kg) = [(Ht^2/R \times 0.401) + (sex \times 3.825) + (age \times -0.071)] + 5.102$$

where Ht is height in cm; R is BIA resistance in ohms; for sex, men = 1 and women = 0; age is in years. A frequency of 50 kHz was used to calculate SMM.

Before BIS measurement participants were instructed to remove all objects containing metal. Measurements were performed on a table that was isolated from electrical conductors, with subjects lying supine along the table's longitudinal centerline axis, legs abducted at an angle of 45 °, and hands pronated. After cleaning the skin with alcohol, 2 electrodes were placed on the surface of the right hand and 2 on the right foot in accordance with procedures described by Sardinha et al. [31]. Participants were instructed to urinate about 30 min before the measures, refrain from ingesting food or drink in the last 4 h, avoid strenuous physical exercise for at least 24 h, refrain consumption of alcoholic and caffeinated beverages for at least 48 h, and avoid the use of diuretics during 7 days prior each assessment. Before each measurement day, the BIS equipment was calibrated as per the manufacturer's recommendations. Based on the test-retest procedure measured 24 h apart, it was found SEM of 0.32 L and ICC = 0.98 for ECW, SEM of 0.19 L and ICC = 0.99 for ICW, and SEM of 0.38 L and ICC = 0.98 for TBW, SEM of 15.6 ohms and ICC = 0.95 for R, SEM of 3.5 ohms and ICC = 0.96 for Xc, SEM of 0.21 degrees and ICC = 0.96 for PhA, SEM of 0.40 kg and ICC = 0.99 for SMM.

Dietary intake

Participants were instructed by a nutritionist to complete a food record on 3 nonconsecutive days (2 week days and one weekend day) at weeks 1–2, and 21–22. Participants were given specific instructions regarding the recording of portion sizes and quantities to identify all food and fluid intake. Total dietary energy, protein, carbohydrate and fat content were calculated using nutrition analysis software (Avanutri Processor Nutrition Software, Rio de Janeiro, Brazil; Version 3.1.4). All participants were asked to maintain their normal diet throughout the study period.

Resistance training program

A supervised progressive RT program designed to induce muscular hypertrophy [1] was performed in two 8-week phases with training performed 3 times per week on Monday, Wednesday and Friday. Exercise physiologists supervised all training sessions during which the designed exercise protocol and related safety were assured. The progressive RT program in the first 8-week phase consisted of 9 exercises selected to stress the major muscle groups in the following order: bench press, 45 °-angle leg press, wide-grip behind-the-neck pull-down, leg extension, side lateral raise, lying leg curl, triceps pushdown, calf raise and arm curl.

In the second 8-week training phase, the RT program was redesigned, and 11 exercises were performed in the following order: bench press, incline dumbbell fly, wide-grip behind-the-neck pull-down, seated cable rows, military press, triceps press, arm curl, leg extension, 45 °-angle leg press, lying leg curl and seated calf raise. At the end of all training sessions, 3 sets of the abdominal crunch exercise were performed lying on the floor. In both training phases, participants were encouraged to total between 50–100 repetitions in the 3 sets of crunches.

For both training phases, all participants performed 3 sets of 8–12 maximum repetitions for all the exercises except calf exercises (3 sets of 15–20 maximum repetitions) and were instructed to perform each repetition with a concentric-to-eccentric phase ratio of 1:2. The rest period between sets was 60–90 s with a 2–3 min interval between each exercise. The training load was consistent with the prescribed number of repetitions for the 3 sets of each exercise. The load was adjusted weekly using the weight test for repetition maximums [27], which consisted of executing the first and second sets at the lower end of the repetition zone (8 repetitions), and as many repetitions as possible until voluntary exhaustion in the third set. The same load was used to perform all 3 sets of an exercise. Adjustments in the resistance load were made on a weekly basis using the following equations:

Upper limb exercises: FW = WT + RE/2

Lower limb exercises: FW = WT + RE

where FW = final weight (kg) used in training; WT = weight used in the test (kg); RE = maximum number of repetitions performed that exceeded the lower limit (8 repetitions) in the third set.

To determine the load used in the first week of training a repetition maximum test was performed in the first training session of the first week of training. The load used for this test for repetition maximums was set according to the perception and experience of the researchers. In the last session of the first week of training a second repetition maximum test was performed to determine the load used in the second week of training. The load used for this test was the one used in training. In the last training session of all other training weeks, a repetition maximum test was performed in the last training session of the week using the load used in training for each exercise. The results of these tests were used to determine the load to be used during the following week.

Statistical analysis

Normality was checked by the Shapiro-Wilk's test. Levene's test was used to analyze the homogeneity of variances. The independent t-test indicated baseline differences between sexes for all dependent variables analyzed. For this reason, the 2-way analysis of covariance (ANCOVA) for repeated measures was used for comparisons, with baseline scores used as covariate. 2-way analysis of variance (ANOVA) for repeated measures was used for nutritional comparisons. In variables where sphericity was violated as indicated by Mauchly's test, the analyses were adjusted using a Greenhouse-Geisser correction. When F-ratio was significant, Bonferroni's post hoc test was employed to identify the mean differences. For all statistical analyses, significance was accepted at $P < 0.05$. The data were stored and analyzed using STATISTICA software version 10.0 (StatSoft Inc, Tulsa, OK, USA).

Results

The anthropometric characteristics of the participants are presented in ▶ **Table 1**. As expected, men were taller (+11.5 cm) compared to women ($P < 0.001$).

Total energy and macronutrients daily intake at pre- and post-training are shown in ▶ **Table 2**. There were no significant main effects or interactions ($P > 0.05$) for daily relative energy and macronutrients within and between groups over time.

Changes in body mass, SMM, TBW, ICW and ECW fractions, R, and Xc at the different time points of the study are presented in ▶ **Table 3**. There was no group by time interaction ($P > 0.05$) for any of the outcomes analyzed. A significant main effect of time ($P < 0.05$) was observed for body mass, SMM, TBW, ICW, R and PhA. The covariate means as well as the adjusted mid- and post-training scores are presented in ▶ **Table 4**.

▶ **Fig. 1** presents the box plot of relative changes (Panel A), as well as the individual changes (Panel B) from pre- to post-training (16 weeks) in PhA according to sex.

Discussion

The main and novel findings of the present study were that the hypertrophy-oriented RT produced significant increases in PhA, and these changes were not influenced by sex. To the best of the authors' knowledge, this is the first study to analyze the effects of RT on PhA in young men and women, providing unique insights into the topic. We had hypothesized that PhA would increase after 16 weeks of RT, and this adaptation would be influenced by the participants' sex. This hypothesis was partially confirmed since, contrary to our initial speculation, both men and women displayed similar increases in the PhA.

▶ **Table 1** General characteristics of the sample at baseline. Data are presented as mean and standard deviation.

	Men (n = 28)	**Women (n = 31)**	***P***
Age (years)	22.2 ± 4.3	23.2 ± 4.1	0.47
Height (cm)	174.2 ± 6.8	162.7 ± 6.4	< 0.001
Body mass index (kg/m²)	22.4 ± 2.4	22.0 ± 3.5	0.66

▶ **Table 2** Dietary intake of the participants at pre- and post-training. The results are presented as mean and standard deviation.

	Men (n = 28)	**Women (n = 31)**	**ANOVA Effects**	**F**	***P***
Carbohydrate (g/kg/d)			Sex	0.59	0.44
Pre-training	4.1 ± 1.8	4.2 ± 1.8	Time	3.80	0.08
Post-training	3.9 ± 1.3	4.0 ± 1.8	Interaction	1.06	0.30
Protein (g/kg/d)			Sex	0.44	0.50
Pre-training	1.5 ± 0.6	1.3 ± 0.5	Time	3.30	0.09
Post-training	1.3 ± 0.3	1.3 ± 0.6	Interaction	0.28	0.59
Fat (g/kg/d)			Sex	2.85	0.09
Pre-training	1.1 ± 0.4	1.2 ± 0.3	Time	3.36	0.09
Post-training	1.0 ± 0.3	1.2 ± 0.6	Interaction	0.64	0.42
Energy intake (kcal/kg/d)			Sex	0.75	0.38
Pre-training	31.9 ± 12.5	34.7 ± 11.8	Time	3.96	0.07
Post-training	29.7 ± 8.3	31.9 ± 14.4	Interaction	0.03	0.84

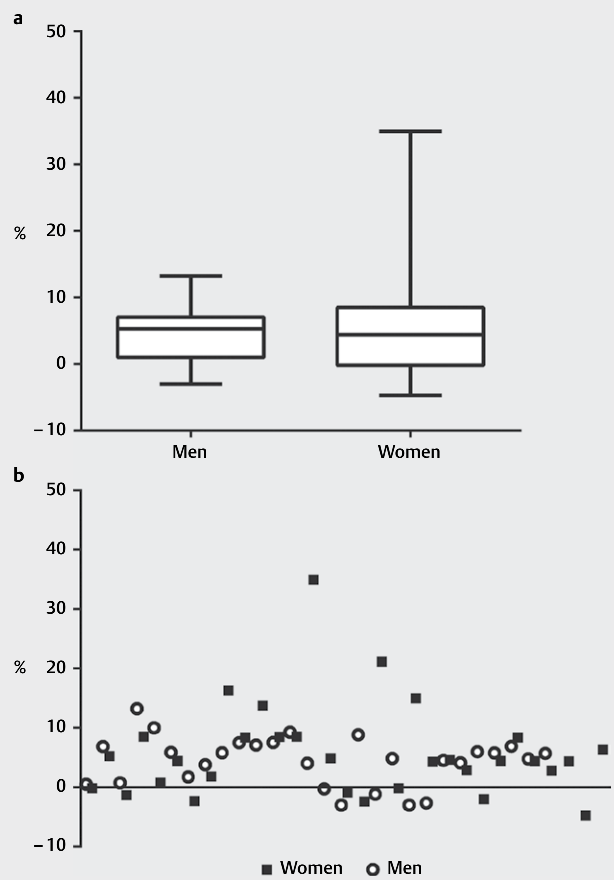
▶ **Table 3** Participant's scores at baseline (pre-training), after 8 weeks (mid-training), and 16 weeks (post-training) of resistance training. Data are expressed as mean and standard deviation.

	Men (n=28)	Women (n=31)	ANCOVA Effects	F	*P*
Body mass (kg)					
Pre-training	67.8±9.0	58.7±12.1	Group	0.23	0.64
Mid-training	68.8±8.4[a]	60.7±12.6[a]	Time	4.81	0.05
Post-training	70.0±8.1[a]	61.3±13.0[a]	Interaction	0.87	0.41
Skeletal muscle mass (kg)					
Pre-training	31.1±2.7	20.7±2.6	Group	0.18	0.66
Mid-training	31.9±2.7[a]	21.0±2.8[a]	Time	8.49	<0.01
Post-training	32.4±2.8[ab]	21.5±3.0[ab]	Interaction	0.47	0.62
Total body water (L)					
Pre-training	39.9±5.5	28.9±4.6	Group	0.92	0.25
Mid-training	41.6±4.6[a]	29.7±6.0[a]	Time	4.11	<0.05
Post-training	43.0±4.9[ab]	31.1±5.6[ab]	Interaction	3.02	0.10
Intracellular water (L)					
Pre-training	24.1±2.9	16.3±2.9	Group	0.04	0.83
Mid-training	24.8±3.3[a]	17.2±3.2[a]	Time	5.61	<0.05
Post-training	26.1±3.3[ab]	18.2±3.7[ab]	Interaction	0.46	0.62
Extracellular water (L)					
Pre-training	16.3±1.8	12.5±1.9	Group	0.32	0.56
Mid-training	16.7±1.8	12.9±2.8	Time	1.22	0.29
Post-training	16.8±1.9	12.9 ±2.1	Interaction	0.29	0.74
Resistance (ohms)					
Pre-training	515.2±45.6	625.5±68.7	Group	1.38	0.24
Mid-training	496.9±37.2[a]	615.2±75.9[a]	Time	4.99	0.05
Post-training	490.7±46.7[a]	601.6±75.9[a]	Interaction	1.73	0.18
Reactance (ohms)					
Pre-training	64.7±5.0	69.3±8.4	Group	2.42	0.12
Mid-training	64.6±5.6	70.4±10.2	Time	1.96	0.14
Post-training	64.3±5.3	70.4±9.3	Interaction	1.44	0.24
Phase angle (degrees)					
Pre-training	7.19±0.63	6.34±0.63	Group	1.21	0.27
Mid-training	7.42±0.59[a]	6.54±0.70[a]	Time	4.94	<0.01
Post-training	7.50±0.60[ab]	6.71±0.69[ab]	Interaction	0.60	0.54

[a]$P<0.05$ vs. pre-training and [b]$P<0.05$ vs. mid-training

▶ **Table 4** Covariate mean and the adjusted mean by ANCOVA to mid- and post-training.

	Covariate mean	Men (n=28)		Women (n=31)	
		Mean (95% CI)		Mean (95% CI)	
		Mid-training	Post-training	Mid-training	Post-training
Body mass (kg)	63.3	65.1 (64.5–68.8)	65.2 (64.4–66.1)	65.0 (64.4–65.6)	65.8 (65.0–66.6)
Skeletal muscle mass (kg)	25.6	26.4 (25.7–27.2)	26.7 (26.0–27.4)	25.9 (25.3–26.6)	26.7 (26.1–27.3)
Total body water (L)	34.1	37.0 (35.2–38.7)	37.6 (36.4–38.8)	35.9 (34.2–37.5)	36.9 (35.9–38.1)
Intracellular water (L)	20.0	21.1 (20.1–22.1)	21.8 (20.9–22.7)	20.6 (20.1–21.5)	22.1 (21.2–22.9)
Extracellular water (L)	14.3	14.9 (14.1–15.7)	14.8 (14.5–15.1)	14.7 (13.8–15.3)	14.7 (14.5–15.0)
Resistance (ohms)	573.2	549.9 (536.9–562.9)	547.2 (534.4–560.0)	567.4 (555.2–579.6)	550.5 (538.5–562.5)
Reactance (ohms)	67.1	66.9 (64.9–68.9)	66.3 (64.2–68.3)	67.3 (66.4–70.2)	67.7 (66.7–70.6)
Phase angle (degrees)	6.74	7.02 (6.88–7.16)	7.14 (6.96–7.32)	6.91 (6.78–7.04)	7.05 (6.86–7.20)



▶ **Fig. 1** Relative (%) group changes and individual changes (Panels **a** and **b**, respectively) on phase angle after 16 weeks of resistance training in young adult men (n = 28) and women (n = 31).

PhA is calculated as the arctangent of the ratio between R and Xc [4]. Xc describes the capacitive impedance of cell membranes that is based on the dielectric properties of cell membranes and tissue interfaces and is related to its structure and functionality, while R behavior is mainly dependent on the hydration of bodily tissues [16]. The human body R is inversely proportional to the intracellular fluids, which means that the higher the ICW the lower is the body's R [4]. Therefore, we can consider that the changes in hydration status were sufficient to affect the PhA changes. In the present investigation the PhA improvement was solely due to R reduction, considering that Xc did not change during the intervention in both men and women. Given the lack of change in Xc, it seems that cellularity, cell size and integrity of cell membrane are not influenced by resistive exercise. On the other hand, PhA increases may be associated with cellular hydration influencing the resistive behavior (R) of bodily tissues.

The increase in ICW content observed in the present investigation is in agreement with previous work from our laboratory that used the same RT protocol in a similar cohort of healthy young adult men and women [28]. Consistent RT can elicit cellular hydration by an increase in glycogen storage [19], since every gram of glycogen attracts 3 g of water [7]. Fast-twitch fibers are particularly sensitive to osmotic changes, presumably related to a high concentration of water transport channels called aquaporin-4 [11]. Considering that the number of fast-twitch fibers seems to be proportionally higher in men than in women [30, 32], and given that females have an impaired metabolism in glycogen degradation compared with males [36], it could be hypothesized that ICW change would be sex-dependent. Contrary to this hypothesis, the results of our investigation indicate that ICW content change occurred similarly in men and women.

Intracellular hydration may contribute to muscle hypertrophy by stimulating pathways that increase protein synthesis as well as those that diminish protein degradation [33, 34]. Moreover, it has been theorized that the stimulus associated with cell hydration status may trigger proliferation of satellite cells and facilitate their fusion to hypertrophying myofibers [8]. Increasing SMM is a primary goal of many recreational individuals of both sexes who are engaged in RT programs. To this end, our results indicate that the SMM gain observed after the RT program was not influenced by sex. Previous studies analyzing the effects of RT on fat-free mass in men and women also found no sex effect on the investigated outcomes [10, 17, 18]. On the other hand, other investigations found chronic adaptive differences in hypertrophic responses between sexes, with men showing higher hypertrophy than women [13, 14, 25, 29]. A conceivable explanation for these conflicting results may be related, at least in part, to the accuracy of the method used to determine the lean tissue, in which the investigation that employed more advanced and valid technological equipment, such as magnetic resonance imaging, ultrasound, and computed tomography, have detected differences between the sexes. Despite their greater accuracy, these procedures are expensive and have limited practical application.

This investigation has some limitations. SMM and the water pools were measured by BIS and not by the related gold standard methods, magnetic resonance imaging, and dilution methods. However, it has been shown that BIS has good validity to estimate SMM [15]. Moreover, BIS has been shown to be a valid tool for assessment of TBW and its various compartments when compared to a criterion method by deuterium or bromide dilution technique in both men and women across a wide array of populations [2, 20–22].

In conclusion, this investigation advances our understanding about RT adaptations related to sexual dimorphism. In young adult men and women a 16-week progressive hypertrophy-type RT increases PhA, TBW, ICW and SMM. PhA increase was found to be dependent on the resistive component (R) of the PhA and not on the capacitive behavior of tissues associated with Xc and related cellularity, cell size and integrative of cell membrane. These findings highlight the specific influence of hypertrophy-type RT exercise on the resistance component of PhA and shed light on the physiological changes that may influence this biophysical parameter.

Conflict of interest

The authors declare that they have no conflict of interest.

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