Effects of three water-based resistance trainings on maximal strength, rapid strength and muscular endurance of sedentary and trained older women

Thaís Reichert[1], Rodrigo S. Delevatti[1,2], Alexandre K.G. Prado[1,3], Natália C. Bagatini[1], Nicole M. Simmer[1], Andressa P. Meinerz[1], Bruna M. Barroso[1], Rochelle R. Costa[1], Ana C. Kanitz[1,4], Luiz F. M. Kruel[1]

[1]Federal University of Rio Grande do Sul. Physical Education School. Brasil. [2]Federal University of Santa Catarina. Physical Education School. Brasil. [3]Federal University of Mato Grosso. Physical Education School. Brasil. [4]Federal University of Uberlândia. College of Physical Education and Physiotherapy. Brasil.

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Summary

Water-based resistance training (WRT) increases strength in sedentary elderly. However, it is not known if this modality promotes strength gains in the trained elderly. In addition, as all the existing studies compared the WRT group with the control group, it is not yet known what the best WRT strategy to promote strength gains in the elderly. Therefore, the aim of this study was to compare the effects of three WRT on the maximal strength, rapid strength and muscular endurance of sedentary and trained elderly women. Twenty-six women were allocated in groups: simple set of 30 seconds (1x30s, 66±1 years), multiple sets of 10 seconds (3x10s, 67±2 years) and simple set of 10 seconds (1x10s, 65±1 years). Training lasted for 20 weeks (two weekly sessions). Assessments were performed after 12 and 20 weeks of training to assess sedentary and trained women, respectively. Maximal strength was assessed by the 1RM test in knee extension, knee flexion and elbow flexion exercises. In these same exercises, the muscular endurance was evaluated, for this, the individual should perform the maximal of repetitions with the load corresponding to 60% of 1RM. Finally, rapid force was assessed by the rate of force development during knee extension. After 12 weeks of training, all groups significantly increased the maximal strength, muscular endurance and rapid strength. However, the groups showed no increase in strength from week 12 to week 20. In conclusion, the three WRT promoted an improvement in strength of sedentary older women, however, they were not efficient in promoting adaptations in trained women.

Key words:
Exercise. Aging. Muscle strength.

Efectos de tres entrenamientos de fuerza en el medio acuático en la fuerza máxima, fuerza rápida y la resistencia muscular de mujeres mayores sedentarias y entrenadas

Resumen

El entrenamiento de fuerza en el medio acuático (WRT) aumenta la fuerza de mayores sedentarios. Sin embargo, no se sabe si esta modalidad promueve ganancias de fuerza en mayores entrenados. Además, como todos los estudios existentes compararon el grupo WRT con el grupo control, aún no se sabe cuál es la mejor estrategia WRT para promover ganancias de fuerza en los ancianos. Por lo tanto, el objetivo del presente estudio fue comparar los efectos de tres WRT en la fuerza máxima, fuerza rápida y resistencia muscular en mujeres mayores sedentarias y entrenadas. Veintiséis mujeres fueron distribuidas en los grupos: serie simple de 30 segundos (1x30s, 66±1 años), series múltiples de 10 segundos (3x10s, 67±2 años) y serie simple de 10 segundos (1x10s, 65±1 años). Los entrenamientos tuvieron una duración de 20 semanas (dos sesiones semanales). Las evaluaciones fueron realizadas después de 12 y 20 semanas de entrenamiento para evaluar mujeres sedentarias y entrenadas, respectivamente. La fuerza máxima se evaluó mediante la prueba de 1RM en ejercicios de extensión de rodilla, flexión de rodilla y flexión de codo. En estos mismos ejercicios, se evaluó la resistencia muscular, para ello, el individuo debe realizar el máximo de repeticiones con la carga correspondiente al 60% de 1RM. Finalmente, la fuerza rápida se evaluó por la tasa de desarrollo de la fuerza durante la extensión de la rodilla. Después de 12 semanas de entrenamiento, todos los grupos aumentaron significativamente la fuerza máxima, la resistencia muscular y la fuerza rápida. Sin embargo, los grupos no presentaron incremento en la fuerza de la semana 12 a la semana 20. En conclusión, los tres WRT promovieron incrementos en la fuerza de mujeres mayores sedentarias, sin embargo, no fueron efectivos en promover adaptaciones en mujeres entrenadas.

Palabras clave:
Ejercicio. Envejecimiento. Fuerza muscular.

Correspondencia: Thaís Reichert
E-mail: thais_reichert@hotmail.com

Introduction

Aging causes a decline in different manifestations of muscular strength (maximal strength, rapid strength and muscular endurance)[1-5], which is related to a decrease in functional independence[6-8], a higher risk of falls[9,10] and mortality[11]. Therefore, water-based resistance training (WRT) has been recommended for the elderly in order to soften the deleterious effects of advancing age[12]. The aquatic environment has beneficial characteristics for the training of this public, such as lower joint impact[13], less sympathetic activation and suppression of the renin angiotensin system[14], which reduces heart rate and blood pressure levels[14].

Currently, WRT has been prescribed, as a priority, for set execution time and exercises are performed at maximal execution speed[15-21]. In aquatic environment, the execution speed is the main determinant of the exercise intensity[22]. Thus, it is believed that the higher the execution speed, the greater the intensity of the exercise and, consequently, the greater the stimulus for the increase of muscle strength. In this sense, it is speculated that breaking a set of long duration in multiple sets of short duration will allow a greater speed during the exercise, due to the recovery interval, which can maximize the strength gains. However, this strategy increases the session time required for strength training and, currently, there is a tendency to identify time-efficient interventions because of the shorter time available for exercise. In this sense, it has already been demonstrated that performing one set promotes the same strength gains that perform three sets after 10 weeks of WRT[16,17].

Increases in muscle strength in the first weeks of training are primarily a result of neural factors, such as better recruitment of motor units, better intramuscular coordination and reduction in the coactivation of the antagonist muscles[23]. It is believed that, in the initial stage of training with sedentary individuals, low volume strength training promotes sufficient stimulation to improve these factors as well as high volume training[23]. For this reason, it seems that different training strategies promote the same increases in muscle strength due to the short intervention period and the initial conditioning of the individual, and this result can not be extrapolated to interventions with longer duration. In this sense, identifying the long-term response of a training in individuals already trained is fundamental, since this is the scenario of fitness clubs. However, no study was found comparing different training strategies after a period of more than 12 weeks. Thus, the objective of this study was to compare the effects of three WRT (1x30s, 3x10s, and 1x10s) on maximal strength, rapid strength and muscular endurance of elderly women after 12 and 20 weeks of training, corresponding to a previously sedentary and trained state, respectively.

Material and method

Experimental approach to the problem

This study is a quasi-experimental longitudinal study. To investigate the effects of different WRT on strength in older women, three trainings were performed. Fifteen individuals (67±1 years) were evaluated twice before the start of training (weeks –4 and 0, which served as control period) to test the stability and reliability of outcomes. During the four weeks control period, individuals were instructed to maintain their regular lifestyle habits and no intervention regarding the present study (ie, training session or assessments) was performed. This period served to test the stability and reproducibility of the dependent variables without the practice of physical exercise. All groups (i.e., 1x30s, 3x10s and 1x10s) trained during 20 weeks and each participant were evaluated before, after 12 and after 20 weeks (weeks 0, 13 and 21, respectively) the water-based resistance training. Participants completed all the evaluations within a week with an interval of 48 h between the tests. Each specific test at pre- and post-intervention was over seen by the same investigator (who was blinded to the training group of the subjects in maximal dynamic and muscular endurance tests) and was conducted on the same equipment with identical subject/equipment positioning. Throughout the training period, the water temperature was maintained at 31°C and the water depth in all individuals was fixed between the xiphoid process and shoulders.

Participants

Thirty women aged from 60 to 75 years old volunteered for the study. The participants volunteered for the present investigation following announcements in internet and in a widely read local newspaper. As inclusion criteria, women should not be practicing physical exercise for at least 3 months and present medical permission for exercise. The exclusion criteria included any history of neuromuscular, metabolic or hormonal diseases. The participants were not taking any medication that could influence their hormonal or neuromuscular metabolism and were advised to maintain their normal dietary intake throughout the study. The participants were residents of the city of Porto Alegre and metropolitan region. After pre-training evaluations, the participants were allocated by stratified randomization (randomization.com site) using a 1:1:1 ratio based on the maximum dynamic strength of knee extension to three groups: 30 seconds single set training group (1x30s; n=10), 10 seconds multiple set training group (3x10s; n=10) or 10 seconds single set training group (1x10s; n=10). The individuals were informed about the study and the possible risks and discomfort related to the procedures prior to signing an informed consent form. The study was conducted according to the Declaration of Helsinki and was approved by the research Ethics Committee at the Federal University of Rio Grande of Sul (protocol number 675.861).

After the training period, the 1x30s group showed no sample lost, three individuals were lost in 3x10s group (one due allergy problem, one because surgery was required and one due work) and one individual was lost in 1x10s group (due health problems). Therefore, twenty-six women completed the training: 10 in the 1x30s group, 7 in the 3x10s group and 9 in the 1x10s group.

Procedures

Physical characteristics

Heigth and body mass were measured using an Asimed stadiometer (resolution of 1mm) and Asimed analog scale (resolution of 0.1 kg), respectively. Body composition was assessed using the skinfold technique. A four-site skinfold equation was used to estimate body density[24] and body fat was subsequently calculated using the Siri equation[25].

Maximal dynamic strength (1RM)

Maximal dynamic strength was assessed using the one-repetition maximal test (1RM) on the bilateral knee extension (World-Esculptor, Porto Alegre, Brazil), knee flexion (Können Gym, Porto Alegre, Brazil) and elbow flexion (free weights). The order of the exercises was randomized, alternating upper and lower limbs exercise. The participants warmed up for 5 minutes on a cycle ergometer and performed specific movements for the exercise test. Each individual's maximal load was determined with no more than 5 attempts with a 5-min recovery between attempts. Performance time for each contraction (concentric and eccentric) was 2 seconds, controlled by a metronome (MA-30, KORG, Japan). The 1RM value was considered as the maximal load possible to exert at the concentric phase for a given exercise. Participants were familiarized with all procedures in two sessions one week prior to the test day. The test-retest reliability coefficient (intraclass correlation coefficient, ICC) was 0.93 for the knee extension 1RM, 0.90 for the knee flexion 1RM and 0.98 for the elbow flexion 1RM ($p<0.001$).

Muscular endurance

Muscular endurance was assessed during the bilateral knee extension, knee flexion and elbow flexion. In these test, the participants had to perform a maximum possible number of repetitions with a load equivalent to 60% of 1RM. Performance time for each contraction and the order of the tests was the same used in the 1RM test. In the post-training test, the same absolute load of the first evaluation was used.

Rate of force development

The rate of force development during isometric contraction of knee extension evaluated. The participants were positioned seated on a knee extension exercise machine (Taurus, Porto Alegre, Brazil) with 90° of hip flexion and 60° of knee flexion (0º to full extension) of the dominant member. Strength was evaluated using a load cell (ZX250 alpha) connected to a digital converter. The individuals were instructed to exert maximal strength possible as fast as was possible. Three attempts were performed, each lasting 5 seconds and with 3 minutes interval between them. During the tests, the researchers provided verbal encouragement so that the women would feel motivated to produce their maximal strength. Before the measurement session, a familiarization with the testing procedure was performed. The isometric force–time analysis on the absolute scale included the maximal rate of force development (RFD; N.s-1), defined as the greatest increase in the force (the largest increase in strength at fixed intervals of 20 milliseconds); and, the RFD at 50 and 100 ms, defined as the greatest increase in the force in the first period of 50 and 100 ms, respectively. The RFD variables were calculated from the force onset, which was considered the point that the force exceeded 2.5 times the standard deviations of the mean of the force signal at rest, and were determined using the MATLAB software. The ICC values were 0.95, 0.98 and 0.92 for maximal, 50 and 100 knee extension RFD.

Water-based resistance training

Before the start of the resistance training, individuals completed two familiarization sessions with the exercises they would further perform during the training period and with Borg Scale of Perceived Exertion (6-20). The trainings were performed twice a week, on nonconsecutive days, during 20 weeks. The resistance training was performed in circuit format: the pool was divided into 4 stations and in each station 3 exercises were performed, totalizing 12 exercises (Table 1). A passive interval of 2 minutes was conducted between stations. The participants performed each repetition at maximal effort (index 19 of Borg Scale of Perceived Exertion) and amplitude to achieve the greatest possible velocity of motion and, consequently, greater resistance. The difference between 3 groups was the amount of sets performed or time of execution by set: 1x30s group performed each exercise by 30 seconds once, 3x10s group performed three sets of each exercise for 10 seconds (with a passive interval of 2 minutes between sets) and 1x10s group performed each exercise during 10 seconds once. Verbal encouragement was provided by the instructor during all resistance exercises. Every session, women started training at a different station.

Table 1. Description of the exercises performed in each station.

Station 1	Unilateral hip flexion until 90° with knee extension and after hip extension with the knee extended (right leg) Unilateral hip flexion until 90° with knee extension and after hip extension with the knee extended (left leg) Flexion and extension horizontal of shoulders, simultaneous of both arms
Station 2	Simultaneous hip adduction and abduction of the 2 legs Unilateral elbow flexion and extension(right arm) Unilateral elbow flexion and extension (left arm)
Station 3	Unilateral knee flexion and extension (right leg) Unilateral knee flexion and extension (left leg) Flexion and extension of the shoulders simultaneous of both arms
Station 4	Unilateral hip adduction and abduction (right leg) Unilateral hip adduction and abduction (left leg) Flexion and extension of elbows with abducted shoulders, simultaneous of both arms

Each session was composed of a standard articular warm-up of 7 minutes, resistance training (13 minutes for 1x30s group, 28 minutes for 3x10s group and 9 minutes for 1x10s group) and final stretching (10min). In order to equalize 45 minutes session for the three groups, 1x30s and 1x10s groups performed a relaxation immersion after stretching. The same experienced instructor and monitor in practice of water-based exercises accompanied all the sessions for three groups.

Statistical analysis

To analyze the results, descriptive statistics were used (mean±standard error). Normal distribution and homogeneity parameters were checked using the Shapiro–Wilk and Levene tests, respectively. Baseline comparisons and training frequency were analyzed using one-way ANOVA. Statistical comparisons with the control period (from week – 4 to week 0) were performed using Student's paired t-test. The

ICC test was applied in order to verify the reliability of variables (test and retest) during control period. The training-related effects were assessed using Generalized Estimating Equation (GEE) and Bonferroni post hoc procedures were used to locate the pairwise differences. The adopted level of significance was α=0.05. The SPSS statistical software package was used to analyze all of the data.

Results

The physical characteristics of participants are shown in Table 2. Age, height, body mass, body mass index, fat mass and sum of skinfolds were similar between groups.

During the control period (i.e., between weeks –4 and 0), no significant differences were observed in all variables analyzed (Table 3). During the intervention, the training frequency showed no difference between groups (1x30s: 90.00±1.10%, 3x10s: 89.81±1.79%, 1x10s: 88.61±1.38%, p=0.471).

At baseline, there were no differences between groups in maximal dynamic strength (1RM). After 12 weeks of training, all groups similarly increased the knee extension 1RM (1x30s: 36.00 ± 2.94 to 46.2 ± 2.9 kg; 3x10s: 37.42 ± 3.49 to 43.71 ± 4.08 kg; 1x10s: 34.88 ± 2.99 to 46.00 ± 4.11 kg), knee flexion 1RM (1x30s: 33.80 ± 1.63 to 40.40 ± 2.76 kg; 3x10s: 34.85 ± 3.33 to 41.71 ± 3.04 kg; 1x10s: 33.88 ± 2.64 to 39.88 ±2.56 kg) and elbow flexion 1RM (1x30s: 16.90 ± 0.67 to 19.40 ± 0.83 kg; 3x10s: 15.71 ± 0.83 to 18.42 ± 0.90 kg; 1x10s: 16.66 ± 1.04 to 19.44 ± 1.10 kg). The results of 1RM at week 20 (knee extension: 1x30s: 48.2 ± 3.22 kg, 3x10s: 49.16 ± 3.91 kg, 1x10s: 48.55 ± 4.72; knee flexion: 1x30s: 43.00 ± 3.27 kg, 3x10s: 43.50 ± 2.73 kg, 1x10s: 40.00 ± 2.05 kg; elbow flexion: 1x30s: 19.60 ± 0.87 kg, 3x10s: 18.66 ± 0.45 kg, 1x10s: 20.66 ± 1.29 kg) were higher than pre-training, but did not differ from week 12. 1RM results are shown in Figure 1.

Table 3. Pre- and post-values during the control period (–4 and 0 weeks).

(n=15)	Week -4 Mean±SE	Week 0 Mean±SE	p
KE 1RM (kg)	35.86±2.40	34.93±2.18	0.280
KF 1RM (kg)	32.66±1.86	32.20±1.87	0.587
EF 1RM (kg)	15.86±0.56	15.73±0.51	0.164
KE ME (rep)	10±1	9±1	0.083
KF ME (rep)	11±1	10±1	0.950
EF ME (rep)	12±1	11±1	0.711
RFD 50 ms KE ($N.s^{-1}$)	96.22±35.78	98.18±35.99	0.778
RFD 100 ms KE ($N.s^{-1}$)	187.74±59.45	209.59±57.76	0.339
RFD maximal KE ($N.s^{-1}$)	736.15±191.49	680.55±201.60	0.339

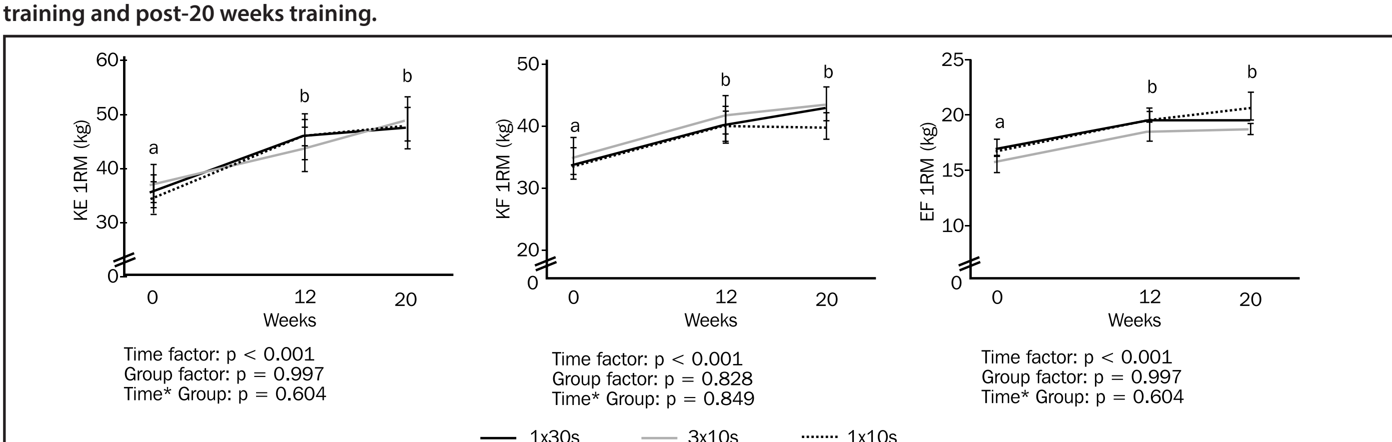
1RM: one maximal repetition, KE: knee extension, KF: knee flexion, EF: elbow flexion, ME: muscular endurance, rep: repetitions, RFD: rate of force development, ms: millisecond.

Table 2. Physical characteristics of participants.

	1x30s Group (n=10) Mean±SE	3x10s Group (n=7) Mean±SE	1x10s Group (n=9) Mean±SE	p
Age (years)	66 ± 1	67 ± 2	65 ± 1	0.683
Height (m)	1.57 ± 0.1	1.55 ± 0.01	1.61 ± 0.01	0.062
Body mass (kg)	68.36 ± 2.60	61.57 ± 3.20	71.08 ± 3.74	0.149
IMC ($kg.cm^{-2}$)	27.72 ± 1.25	25.36 ± 1.21	27.20 ± 1.41	0.463
Fat mass (%)	31.98 ± 1.40	30.68 ± 1.45	33.12 ± 1.18	0.491
∑ skinfolds (mm)	82.10 ± 4.25	77.30 ± 4.11	92.86 ± 6.17	0.212

∑: sum

Figure 1. Maximal dynamic strength of knee extension (KE 1RM), knee flexion (KF 1RM) and elbow flexion (EF 1RM) pre-, post-12 weeks training and post-20 weeks training.



Lowercase letters represent difference in the time factor.

Table 4. Rate of force development and muscular endurance pre-, post-12 weeks training and post-20 weeks training.

	Group (n)	Pre-training Mean±SE	Post-12 weeks Mean±SE	Post-20 weeks Mean±SE	Time	Group	Time* Group
KE RFD	1x30s (10)	136.10 ± 48.5[a]	376.91 ± 156.16[b]	401.15 ± 89.05[b]	<0.001	0.113	0.289
50ms	3x10s (07)	175.55 ± 127.14[a]	875.54 ± 306.60[b]	755.27 ± 212.44[b]			
($N.s^{-1}$)	1x10s (09)	154.75 ± 59.18[a]	275.32 ± 91.91[b]	391.29 ± 79.59[b]			
KE RFD	1x30s (10)	177.17 ± 59.18[a]	423.24 ± 124.61[b]	541.00 ± 100.57[b]	<0.001	0.093	0.240
100ms	3x10s (07)	312.99 ± 158.38[a]	967.57 ± 257.60[b]	769.07 ± 183.22[b]			
($N.s^{-1}$)	1x10s (09)	232.36 ± 83.43[a]	403.57 ± 136.42[b]	454.37 ± 77.37[b]			
KE RFD	1x30s (10)	858.40 ± 231.35[AB]	862.39 ± 162.62[AB]	1036.41 ± 177.90[AB]	0.317	0.015	0.284
max	3x10s (07)	1465.97 ± 367.24[B]	1721.85 ± 357.62[B]	1133.71 ± 201.50[B]			
($N.s^{-1}$)	1x10s (09)	548.09 ± 102.52[A]	719.46 ± 185.33[A]	618.18 ± 96.95[A]			
KE ME	1x30s (10)	9 ± 1[a]	12 ± 1[b]	13 ± 1[b]			
(rep)	3x10s (07)	12 ± 1[a]	19 ± 4[b]	14 ± 3[b]	0.001	0.218	0.752
	1x10s (09)	10 ± 1[a]	13 ± 2[b]	13 ± 1[b]			
KF ME	1x30s (10)	11 ± 2[a]	15 ± 1[b]	17 ± 1[b]			
(rep)	3x10s (07)	12 ± 1[a]	25 ± 8[b]	14 ± 1[b]	0.001	0.711	0.233
	1x10s (09)	13 ± 2[a]	16 ± 1[b]	15 ± 1[b]			
EF ME	1x30s (10)	12 ± 1[a]	19 ± 3[b]	19 ± 3[b]			
(rep)	3x10s (07)	12 ± 2[a]	20 ± 2[b]	21 ± 3[b]	<0.001	0.822	0.622
	1x10s (09)	13 ± 1[a]	19 ± 2[b]	17 ± 2[b]			

Note: KE: knee extension, RFD: rate of force development, ms: millisecond, ME: muscular endurance, KF: knee flexion, EF: elbow flexion, rep: repetitions. Lowercase letters represent difference in the time factor. Uppercase letters represent differences in the group factor.

Table 5. Percentages of significant increase observed in maximal strength, muscular endurance and rapid strength after 12 weeks of training.

	1 x 30 s	3 x 10 s	1 x 10 s
KE 1RM	28 %	17 %	32 %
KF 1RM	20 %	20 %	18 %
EF 1RM	15 %	17 %	17 %
KE RFD 50 ms	177 %	399 %	8 %
KE RFD 100 ms	139 %	209 %	4 %
KE ME	29 %	57 %	32 %
KF ME	40 %	115 %	30 %
EF ME	51 %	69 %	45 %

1RM: one maximal repetition, KE: knee extension, KF: knee flexion, EF: elbow flexion, ME: muscular endurance, rep: repetitions, RFD: rate of force development, ms: millisecond.

The results of RFD and muscular endurance are shown in Table 4. At baseline, there were no differences between groups in the RFD at 50 and 100 ms. There was a significant increase in the RFD at 50 and 100 ms in all groups after 12 weeks of training, and there was a maintenance of those values until the end of training. The maximal RFD showed no difference in the time factor and the 3x10 s group had higher values than the group 1x10 s during the intervention. Muscular endurance showed no difference between groups at baseline. After 12 weeks of training, knee extension, knee flexion and elbow flexion muscular endurance increased significantly in all groups and these values remained constant until the twentieth week of training.

Table 5 presents the percentages of significant increase observed in maximal strength, muscular endurance and rapid strength after 12 weeks of training.

Discussion

The main finding of the present study was that the three WRT promoted similar gains of maximal strength, muscular endurance and rapid strength after 12 weeks of training in previously sedentary older women. This result is important for the elderly population because the maximal strength is inversely associated with the risk of mortality whereas the improvement of the rapid strength and muscular endurance may reflect in a greater ability to perform activities of daily living, greater functional independence and lower risk of falls. However, no adaptation was observed from week 12 to 20, showing that WRT did not stimulate strength gains in previously trained older women.

The results of the present study after the initial 12 weeks of training corroborate other investigations that observed increases of maximal strength in elderly individuals after aquatic training[26-29]. The percentage increases observed in the present study are similar to the ones found by Tsourlou *et al.*[27] (knee extension 29%) after 24-weeks training and higher than those observed by Bento *et al.*[28] after 12-weeks training (knee extension 12 and knee flexion 13%). This divergence is possibly related to the fact that the aforementioned studies used submaximal velocities in WRT, which are not specific for the development of muscle strength, whereas the present study had always used the maximal velocity. In this way, Takeshima *et al*.[26] found increases in the maximal strength similar to the present study (knee flexion 13 to 40%, knee extension 8 to 27%) after a 12-weeks training performed always in maximal velocity. In addition, the maximal execution speed is essential to increase the RFD[30]. Only the study by Bento *et al*.[31] observed an increase in RFD of knee extension (11%), however, the observed increments are much lower than in the present study, which is also attributed to the submaximal velocity used in the cited study. The increment of the lower limbs RFD found in the present study could represent a better capacity of the elderly to perform their daily life activities, making them more independent and less susceptible to the care of others[31]. In addition, a greater capacity to produce strength in a short period of time could serve as a protective mechanism during a possible fall[10], since that the individuals would be able to restore balance more quickly[32].

To the best of our knowledge, this is the first study that investigated muscular endurance in elderly individuals after WRT. Schoenell *et al*.[16] found increases in muscular endurance of knee extension (9-13%), knee flexion (20-33%) and elbow flexion (33%) in young women after 10 weeks of WRT. These percentages of increases are lower than those observed in the present study, which could be attributed to the greater amplitude for improvement of the elderly population. The improvement of muscular endurance is of extreme importance for the older people, once it demonstrates a capacity to produce strength for a longer period and a better capacity to accomplish their daily life activities, like walking, climbing stairs and carrying objects, promoting functional independence to these individuals.

We believed that the 3x10 s group would perform the exercises at a higher execution speed when compared to the 1x30s group, due to the fractionation of the exercise in multiple sets and the recovery interval between them, which could promote greater strength gains. However, similar increments were observed after both WRT, suggesting that perhaps both groups performed the exercises at similar execution speeds, generating the same stimulus for strength development. Similar increases between the 3x10s and 1x10s groups after the initial 12 weeks of training were already expected and corroborate other studies with WRT[16,17].

The results of the present study also demonstrated that, surprisingly, no differences were observed in strength between week 12 and 20 of training. We believed that previously untrained older women who initiated a WRT would increase muscle strength, which would provide a higher execution speed during training in subsequent weeks. This higher execution speed would promote a greater training overload, generating new stimuli for increasing muscle strength. However, this hypothesis is not true, since no increase was observed in any investigated variable from week 12 to 20. However, this result should be interpreted with caution, since it does not mean that WRT does not promote strength increase in already trained individuals, but rather that the same periodization of training (ie, same volume and intensity) prescribed for untrained individuals is insufficient to promote increased muscle strength in trained individuals. Thus, it is speculated that there must be a progression of WRT after the initial weeks of intervention to promote strength gains in trained older women.

Possible limitations of the present study are the small n sample and the absence of neuromuscular and morphological evaluations. We highlight the strengths of the study methods such as randomizing participants between the groups, blinding of assessors to outcomes in maximal dynamic and muscular endurance tests, and description of losses and exclusions. Moreover, the main difference of the present study in relation to previous studies is the longer follow-up, which allowed to evaluate the effect of WRT in sedentary and trained elderly women, adding important information in the literature and contributing to a better prescription of WRT.

In conclusion, 1×30s, 3×10s, and 1×10s training models promote similar increments in maximal strength, rapid strength and muscular endurance after 12 weeks of intervention in previously sedentary older women. As a practical application, the results of the present study demonstrate that it is not necessary to fractionate a long duration set into multiple sets of shorter duration nor to perform multiple series to maximize the gains in strength of sedentary older women. However, after 12 weeks of intervention, the same prescription of volume and intensity in WRT do not promote strength improvements in trained women in already trained women, which shows the need to increase the training overload in this period.

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Conflict of interest

The authors do not declare a conflict of interest.

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