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ORIGINAL ARTICLE

Suspension training vs. traditional resistance training: effects on muscle mass, strength and functional performance in older adults

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Abstract

Purpose We compared the effects of suspension training (ST) with traditional resistance training (TRT) on muscle mass, strength and functional performance in older adults.

Methods Forty-two untrained older adults were randomized in TRT, ST (both performed 3 sets of whole body exercises to muscle failure) or control group (CON). Muscle thickness (MT) of biceps brachii (MT_{BB}) and vastus lateralis (MT_{VL}), maximal dynamic strength test (1RM) for biceps curl ($1RM_{BC}$) and leg extension exercises ($1RM_{LE}$), and functional performance tests (chair stand [CS], timed up and go [TUG] and maximal gait speed [MGS]) were performed before and after 12 weeks of training.

Results MT_{BB} increased significantly and similarly for all training groups (TRT 23.35%; ST 21.56%). MT_{VL} increased significantly and similarly for all training groups (TRT 13.03%; ST 14.07%). $1RM_{BC}$ increased significantly and similarly for all training groups (TRT 16.06%; ST 14.33%). $1RM_{LE}$ increased significantly and similarly for all training groups (TRT 14.89%; ST 18.06%). MGS increased significantly and similarly for all groups (TRT 6.26%; ST 5.99%; CON 2.87%). CS decreased significantly and similarly for all training groups (TRT −20.80%; ST −15.73%). TUG decreased significantly and similarly for all training groups (TRT −8.66%; ST −9.16%).

Conclusion Suspension training (ST) promotes similar muscle mass, strength and functional performance improvements compared to TRT in older adults.

Keywords TRX training · Instability resistance training · Muscle hypertrophy · Functionality · Aging

Abbreviations

1RM	Maximal dynamic strength test
$1RM_{BC}$	Biceps curl maximal dynamic strength test
$1RM_{LE}$	Leg extension maximal dynamic strength test
CON	Control group
CS	Chair Stand
CV	Coefficient of variation
ES	Effect sizes
MGS	Maximal gait speed
MT	Muscle thickness
MT_{BB}	Biceps brachii muscle thickness
MT_{VL}	Vastus lateralis muscle thickness
RT	Resistance training
ST	Suspension training
TE	Typical error
TRT	Traditional resistance training
TUG	Timed up and go

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Introduction

Muscle mass and strength declines at an annual rate of 1–2% and 1.5%, respectively, after the fifth decade of life and accelerates after the age of 60 (Morley et al. 2014; Zembroń-Łacny et al. 2014). This condition affects the functional performance (e.g., motor performance, control, mobility and balance) and autonomy in activities of daily living, increasing risk of falls, fractures and even death (Frontera et al. 2008; Morley et al. 2014; Marty et al. 2017; McGlory et al. 2019). Therefore, effective strategies to mitigate the decreases in muscle mass, strength and functional performance in older adults are required.

Resistance training (RT) performed at least twice weekly, with moderate to high loads and slow velocity (i.e., a RT mode named traditional RT [TRT]) has been widely recommended to maintain and/or increase muscle mass, strength and functional performance in older adults (Garber et al. 2011; Fragala et al. 2019). Nevertheless, a large body of literature shows that despite increases in muscle mass and strength, TRT produces a small effect on functional performance (Skelton et al. 1995; Miszko and Cress 2002; De Vreede et al. 2005; Liu and Latham 2011; Vasconcelos et al. 2016). On the other hand, RT modes performed with unstable devices (e.g., suspension devices, balance pads, Swiss balls) requires high motor control demands and production of muscle force necessary to overcome the load and also maintain stability, which can chronically contribute to the improvement of functional performance (Anderson and Behm 2005; Behm and Anderson 2006). In fact, RT performed with unstable devices seem to promote greater improvements on functional performance compared with TRT (Silva-Batista et al. 2016; Pirauá et al. 2019). Therefore, considering the principle of training specificity, whether the aim of a RT program is to improve functional performance, RT modes should attempt to simulate an unstable environment.

Suspension training (ST) is an alternative approach capable of providing less stable training conditions, which could promote greater improvements on functional performance than TRT (Angleri et al. 2020). ST is a RT mode in which specific body segments (e.g., upper or lower limbs) are attached to suspended hanging straps, creating an unstable environment, and uses the body weight and gravity to perform multi-planar and multi-joint exercises (Mok et al. 2015; Angleri et al. 2020). However, to the best of our knowledge, no study has investigated the effects of ST on functional performance in older adults. Regarding muscle mass and strength gains, although no study investigated the effects of ST in these neuromuscular adaptations in older adults, it is possible to suggest that the gains are comparable to TRT. It has been suggested that performing RT to concentric muscle failure (Jenkins et al. 2015; Schoenfeld et al. 2015) can maximize gains in muscle strength (Rooney et al. 1994; Drinkwater et al. 2005) and hypertrophy (Schott et al. 1995), due to the increase in the muscle activation, regardless of training variables manipulation or methods (Souza et al. 2014; Barcelos et al. 2018; Nobrega et al. 2018; Damas et al. 2019; Lasevicius et al. 2019). In fact, it has been recently shown that manipulation of load, time under tension and number of repetitions during RT resulted in similar muscle activation when exercises were performed to concentric muscle failure (Morton et al. 2019). Accordingly, studies comparing the effects of bench press exercise with push-ups performed with body weight, which resembles the ST scheme, showed similar increases in muscle mass and strength when both were performed to concentric muscle failure (Calatayud et al. 2015; Kikuchi and Nakazato 2017). Therefore, it is possible to suggest that if TRT and ST are performed to concentric muscle failure, muscle mass and strength gains would be similar between these RT modes. On the other hand, due to its greater instability, it is possible that ST promotes greater improvement in functional performance compared to TRT.

The aim of this study was to compare the effects of ST and TRT performed to concentric muscle failure on muscle mass, strength and functional performance in older adults. We hypothesized that ST and TRT would result in similar muscle mass and strength gains. Additionally, ST would produce greater improvements in functional performance than TRT.

Methods

Participants

Forty-two older individuals (21 men: 64 ± 3 years, height: 1.69 ± 0.07 m, body mass: 83.36 ± 15.41 kg, BMI: 28.90 ± 4.06 kg/m^2 and 21 women: 62 ± 2 years, height: 1.58 ± 0.05 m, body mass: 71.38 ± 13.54 kg, BMI: 28.63 ± 5.76 kg/m^2) volunteered to participate in this study. At first, a health assessment questionnaire was applied (Cesar et al. 2011). As inclusion criteria, participants should not have cardiac symptoms, diabetes, arrhythmias, hypertension, obesity and any musculoskeletal conditions that precluded the participation in the tests and training protocols, and not have participated in a RT program for at least 12 months before the study. Additionally, participants were advised to maintain their eating habits and to consume 40 g of isolated Whey Protein (Iso Whey–Max Titanium-Brazil®), which was provided immediately after each training session and the intake was monitored by researchers. Importantly, it has been demonstrated that aging is associated with reduction in the daily habitual protein ingestion concomitantly to the protein anabolic response, which is known to negatively affect RT adaptive responses (Kumar et al. 2009; Wall et al. 2015). As older people can ingest different daily amounts of protein, we chose to include a portion of whey protein after each RT session to maximally stimulate the rate of muscle protein synthesis and reduce the response variability between subjects. The amount of protein ingestion was based in the study of Yang et al. (2012), which demonstrated that in contrast to young adults, in whom post-exercise muscle protein synthesis are saturated with 20 g of protein, exercised muscles of older adults respond to 40 g of protein. The study was approved by the University's Ethics Committee (No. 2877542) and each participant gave informed consent prior to participation. All procedures performed herein were in accordance with the Declaration of Helsinki.

Experimental design

Initially, muscle thickness (MT) of biceps brachii (MT_{BB}) and vastus lateralis (MT_{VL}) were obtained through ultrasound. Afterwards, participants engaged into one familiarization session with training protocols and testing procedures. Then, participants underwent muscle strength tests (one repetition maximum [1RM] for biceps curl [$1RM_{BC}$] and leg extension [$1RM_{LE}$] exercises) and functional performance tests (chair stand [CS], timed up and go [TUG], maximal gait speed [MGS]). The familiarization session, 1RM and functional performance tests were performed with 72-h interval between each of them. Each participant was allocated in a randomized and balanced way, according to MT_{VL}, $1RM_{LE}$ and TUG values, to 1 of the 3 protocols: a) traditional resistance training (TRT, $n = 14$ [7 men and 7 women]); b) suspension training (ST, $n = 14$ [7 men and 7 women]) and; c) control group (CON, $n = 14$ [7 men and 7 women]). Training sessions were performed 2 days a week (Monday and Thursday or Tuesday and Friday) for 12 weeks. MT, 1RM and functional performance tests were also assessed 3 days after the last training session.

Muscle thickness (MT)

Ultrasound imaging was used to obtain measurements of MT_{BB} and MT_{VL} (Schoenfeld et al. 2018). An experienced researcher performed all assessments using a B-mode ultrasound imaging unit (Samsung, MySono U6, industry and commerce Ltda. São Paulo, Brazil). Water-soluble transmission gel was applied at each measurement site and the linear reading head transducer was positioned parallel to the muscle tissue's interface without compressing the skin. When image quality was considered satisfactory, the technician saved the image and MT dimensions were obtained by measuring the distance between the superficial and deep aponeurosis of the target muscle, as described previously (Abe et al. 2000; Schoenfeld et al. 2018). Measurements were performed in two places: (1) biceps brachii and (2) vastus lateralis. For the biceps brachii, measurements were collected at 60% distal between the lateral epicondyle of the humerus and the acromion process of the scapula. For the vastus lateralis, measurements were taken at 50% of the distance from the prominent point of the major trochanter to the lateral condyle of femur. To ensure accuracy of measurements, three images were obtained from the same spot, and then the mean was taken to obtain a final value. The coefficient of variation (CV) and typical error (TE) between two tests performed in different days, 72 h apart, of the MT_{BB} were 0.69% and 1.70 mm, respectively, and for MT_{VL} were 0.83% and 1.51 mm, respectively.

Muscle strength test

Muscle strength was assessed by 1RM test on $1RM_{BC}$ and $1RM_{LE}$ exercises, following the recommendations described by Brown and Weir (Brown and Weir 2001). To ensure that specificity of 1RM test did not affect muscle strength results (i.e., TRT would have additional benefits compared to ST), non-specific 1RM tests were performed on different apparatus than those used in training sessions (Rutherford et al. 1986; Lund et al. 2005; Mitchell et al. 2012). Thus, tests were performed on biceps curl (straight-bar) and leg extension machine for the upper and lower limbs, respectively. Initially, participants performed a general warm-up on a stationary bicycle at 20 km h^{-1} for 5 min followed by two sets of specific warm-up on the test equipment with loads subjectively determined. On the first set, participants performed eight repetitions at approximately 50% of 1RM, followed by one set of three repetitions at approximately 70% of 1RM. A 2 min rest interval was allowed between warm-up sets. After the last warm-up set, a 3 min rest was taken prior to the actual 1RM test. Participants had up to five attempts to achieve their 1RM load. A 3 min rest interval was allowed between attempts and the highest load achieved was considered as the 1RM load. The CV and TE between two tests performed in different days, 72 h apart, of the $1RM_{BC}$ were 4.54% and 1.05 kg, respectively, and for $1RM_{LE}$ were 2.22% and, 1.05 kg, respectively.

Functional performance tests

Chair stand (CS)

Participants started the test sitting on a 43-cm-height chair with their hips and back fully supported on the backrest and feet positioned on a force platform (AccuGait, AMTI, Boston, USA) (Pau et al. 2014). Participants were instructed to keep their arms crossed over their chest touching the contralateral shoulder and, as fast as possible, to completely stand up and sit down five consecutive times (McCarthy et al. 2004). The total time was obtained through the balance Clinic software (AMTI, Boston, USA) and analyzed with MATLAB 7.0 software (Math Works Inc., Natick, Massachusetts, USA) to increase timing accuracy. The CV and TE between two tests performed in different days, 72 h apart, were 8.69% and 1.06 s, respectively.

Timed up and go (TUG)

Participants started the test sitting on a chair (43-cm-height) with their arms positioned over the lateral armrests and feet over a force platform until the starting command. After the command, participants stood up using the armrests and walked as fast as possible over a distance of 3 m previously delimited, returning and sitting down with their back against the seat (Miotto et al. 1999). Time was measured and analyzed as described in the CS section. The CV and TE between two tests performed in different days, 72 h apart, were 4.06% and 0.31 s, respectively.

Maximal gait speed (MGS)

Participants were instructed to walk a distance of 15 m two consecutive times at maximal speed, timed by a photocell (Speed Test Fit, Cefise Biotecnologia Esportiva, São Paulo, Brazil). The first and last 2.5 m were discarded as it was used as acceleration and deacceleration periods, respectively. Results were composed by the fastest attempt (Steffen et al. 2002). The CV and TE between two tests performed in different days, 72 h apart, were 4.92% and 0.10 m s^{-1}, respectively.

Training protocols

Traditional resistance training (TRT)

The TRT was performed using the following exercises: smith machine-squat, prone leg curl machine, seated row machine, seated chest press machine, barbell front raise and seated EZ-bar biceps curl (Fig. 1). The same exercises' order was respected for all training sessions. The TRT consisted of 3 sets of 10–15 repetitions to concentric muscle failure with a 1-min rest interval between sets and exercises. Sets were interrupted if participants failed to maintain proper range of movement. The intensity was adjusted through sets and RT bouts to repetition range (e.g., if the individuals performed more than 15 repetitions in a set, the intensity was increased to maintain maximum repetition range in the next set and the contrary was applied when the participants were not able to complete at least 10 repetitions).

Suspension training (ST)

The ST was performed on hanging straps (Prime Sport suspension training belt, São Paulo, Brazil) with exercises corresponding to TRT as follows: squat or single leg squat, hamstring curl, low row, chest press, "Y" deltoid fly and biceps curl (Fig. 1). This exercise order was repeated for all training sessions. Regarding squat exercise, participants started the training program performing it with both legs, and when they were adapted to this condition (i.e., performing 3 sets of 15 repetitions), they changed to unilateral squat exercise. Three sets of 10–15 repetitions to concentric muscle failure were performed with 1-min rest interval between sets and exercises. The intensity adjustment was performed according to the body's segments of participants in relation to the ground (i.e., higher inclinations correspond to higher intensity and lower inclinations correspond to lower intensity). Thus, if participants completed 3 sets of 15 repetitions, the body's segments were adjusted to higher inclinations; similarly, if less than 10 repetitions were performed, inclinations were decreased.

Statistics analyses

After visual inspection, data normality was assessed using the Shapiro–Wilk test. Initially, a one-way analysis of variance (ANOVA) was performed to test differences in baseline values. Then, an independent T test was used to compare Pre–Post changes (post- minus pre-training [Δ]) (MT_{BB}, MT_{VL}, $1RM_{BC}$, $1RM_{LE}$, MGS, CS and TUG) between genders. No significant differences were found between gender analyses (all $P > 0.05$) for any of the dependent variables. Therefore, we performed the following analyses considering both genders in each group. A mixed model was applied for each dependent variable (MT_{BB}, MT_{VL}, $1RM_{BC}$, $1RM_{LE}$, MGS and TUG), having protocols (TRT, ST and CON) and time (Pre and Post) as fixed factors and participants as random factor. Only CS values were significantly different at baseline, and therefore, were considered as a covariate, and an analysis of covariance (ANCOVA) was implemented using a mixed model, having protocols and time as fixed factors, and subjects as random factor. In case of significant F value, Tukey's adjustment was used for multiple comparison purposes. Significance was established as $P \leq 0.05$ for all data analyses. Effect sizes (ES) were calculated for MT, 1RM and functional performance tests using changes from Pre to Post. ES were classified as "small" if lower than 0.2, "medium" if between 0.2 and 0.5, and "large" if higher than 0.8 (Cohen et al. 1988). Statistical analysis was carried out using SAS 9.3 software (SAS institute Inc., Cary, NC). Data are expressed as mean ± standard deviation (SD).

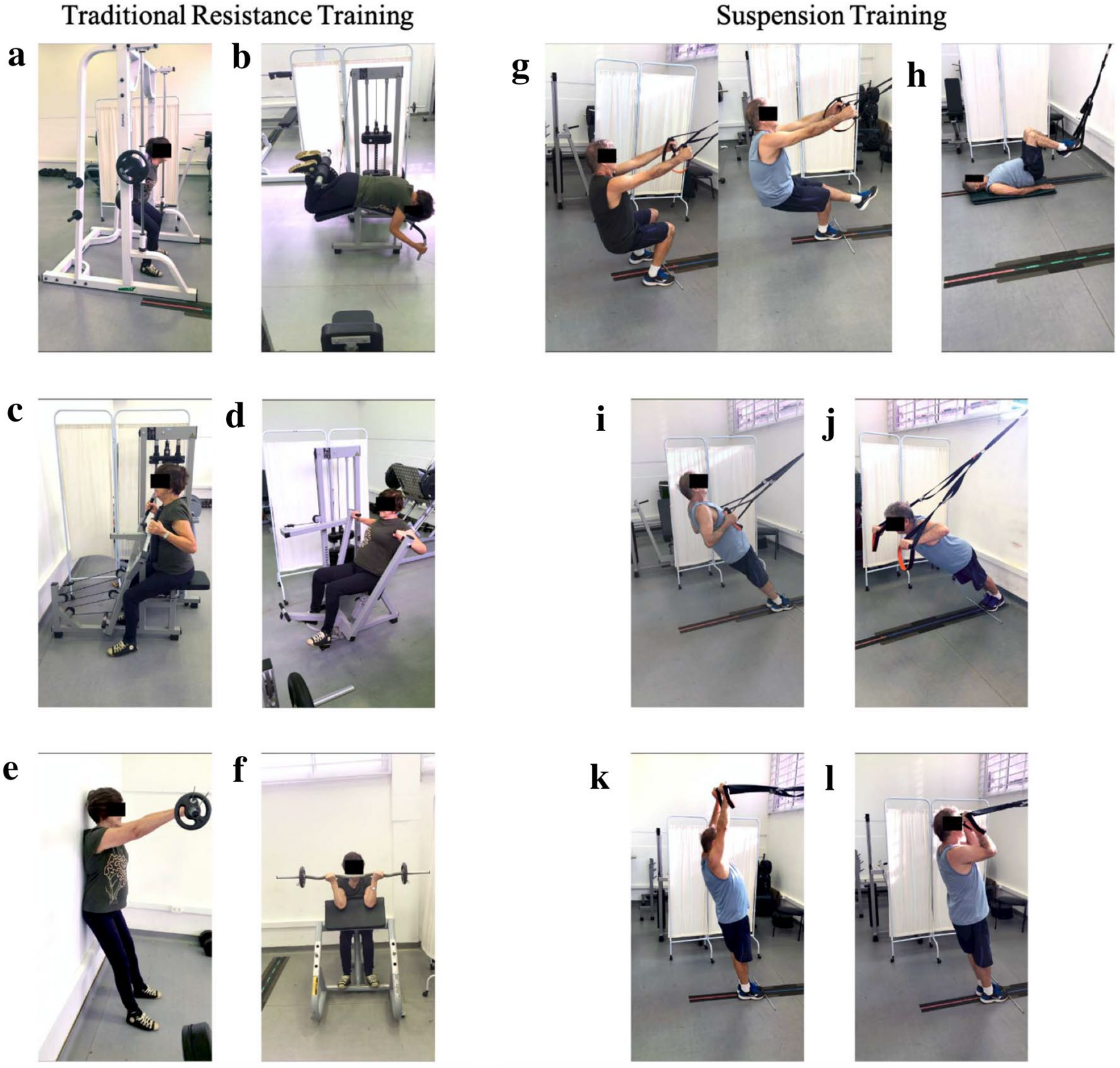

Fig. 1 Exercises in different training modes. Traditional resistance training (TRT): smith machine-squat (**a**), prone leg curl machine (**b**), seated row machine (**c**), seated chest press machine (**d**), barbell front raise (**e**), and seated EZ-bar biceps curl (**f**). Suspension training (ST): squat or a variation to single leg squat (**g**), hamstring curl (**h**), low row (**i**), chest press (**j**), “Y” deltoid fly (**k**), and bicep curl (**l**)

Results

Participants

Only participants that completed all training sessions and tests were included. Five of forty-two participants who started the study dropped out for personal reasons (three CON = non-compliance; two ST = injury unrelated to training) and were not included in the analyses. Thus, thirty-seven participants completed the study (RT = 14 [7 men, 7 women]; ST = 12 [5 men, 7 women]; CON = 11 [7 men, 4 women]). Regarding TUG test, some analyses were excluded due to data problems. Therefore, thirty-four participants were included for this analysis (RT, n = 12 [7 men, 5 women]; ST, $n = 11$ [5 men, 6 women]; CON, $n = 11$ [7 men, 4 women]).

Baseline values

One-way ANOVA revealed no significant baseline differences for MT_{BB}, MT_{VL}, $1RM_{BC}$, $1RM_{LE}$, MGS and TUG ($P > 0.05$). Only CS values were significantly lower in CON compared to TRT ($P = 0.006$).

Muscle thickness

A significant group vs. time interaction was observed for MT_{BB} ($F_{[2, 34]} = 48.62$, $P < 0.0001$) and MT_{VL} ($F_{[2, 34]} = 10.13$, $P = 0.0004$). Both training groups significantly increased MT_{BB} from Pre (TRT 27.88 ± 5.21 mm; ST 27.04 ± 3.10 mm) to Post (TRT 34.19 ± 5.90 mm, 23.35%; ST 32.79 ± 4.03 mm, 21.56%; $P < 0.0001$ for both; Fig. 2a). No significant differences were found in MT_{BB} from Pre (28.41 ± 5.83 mm) to Post in CON (28.14 ± 5.48 mm, 0.36%; $P > 0.999$; Fig. 2a). The post hoc analysis revealed no between-group differences in MT_{BB}. Importantly, TRT and ST groups demonstrated an ES of 0.91 (large) and 1.31 (large), respectively, whereas CON showed an ES of 0.00 (small). MT_{VL} values also significantly increased for all training groups from Pre (TRT 18.52 ± 3.70 mm; ST 18.72 ± 3.88 mm) to Post (RT 20.77 ± 3.63 mm, 13.03%; ST 21.02 ± 2.92 mm, 14.07%; $P = 0.0002$ and $P = 0.0004$, respectively; Fig. 2b). No significant differences were found in CON from Pre (19.92 ± 2.52 mm) to Post (19.53 ± 2.85 mm, 1.91%; $P = 0.967$; Fig. 2b). The post hoc analysis revealed no between-group differences in MT_{VL}. However, TRT and ST groups demonstrated an ES of 0.48 (medium) and 0.50 (medium), respectively, whereas CON showed an ES of 0.10 (small).

Muscle strength

There was a significant group vs. time interaction for $1RM_{BC}$ ($F_{[2,\ 34]} = 13.97$, $P < 0.0001$) and $1RM_{LE}$ ($F_{[2,\ 34]} = 10.13$, $P = 0.0005$). The training groups significantly increased $1RM_{BC}$ from Pre (TRT 23.14 ± 6.60 kg; ST 24.67 ± 5.50 kg) to Post (TRT 26.64 ± 7.26 kg, 16.06%; ST 28.00 ± 5.66 kg, 14.33%; $P < 0.0001$ for both; Fig. 2c). No significant differences were found in $1RM_{BC}$ from Pre (25.82 ± 6.90 kg) to Post in the CON (25.91 ± 6.82 kg, 0.47%; $P = 1.0000$; Fig. 2c). The post hoc analysis revealed no between-group differences in $1RM_{BC}$. Importantly, TRT and ST groups demonstrated an ES of 0.40 (medium) and 0.47 (medium), respectively, whereas CON showed an ES of 0.02 (small). $1RM_{LE}$ values also significantly increased for all training groups from Pre (TRT: 46.29 ± 14.44 kg; ST: 50.42 ± 17.31 kg) to Post (TRT: 52.21 ± 15.81 kg, 14.89%; ST: 58.42 ± 17.05 kg, 18.06%; $P < 0.0001$ for both; Fig. 2d). No significant differences were found in CON from Pre (51.55 ± 17.31 kg) to Post (52.91 ± 14.85 kg, 3.43%; $P = 0.819$; Fig. 2d). The post hoc analysis revealed no between-group differences in MT_{VL}. However, TRT and ST groups demonstrated an ES of 0.31 (medium) and 0.36 (medium), respectively, whereas CON showed an ES of 0.07 (small).

Maximal gait speed (MGS)

Only a main time effect was observed for MGS ($F_{[1,\ 34]} = 16.92$; $P = 0.0002$). The post hoc test revealed significant increases from pre (TRT 1.93 ± 0.16 m/s; ST 2.06 ± 0.26 m/s; CON 1.97 ± 0.26 m/s) to Post (RT 2.04 ± 0.16 m/s, 6.26%; ST 2.17 ± 0.24 m/s, 5.99%; CON 2.02 ± 0.25 m/s, 2.87%; $P = 0.0002$; Fig. 3a) experimental period. Importantly, only CON showed increases lower

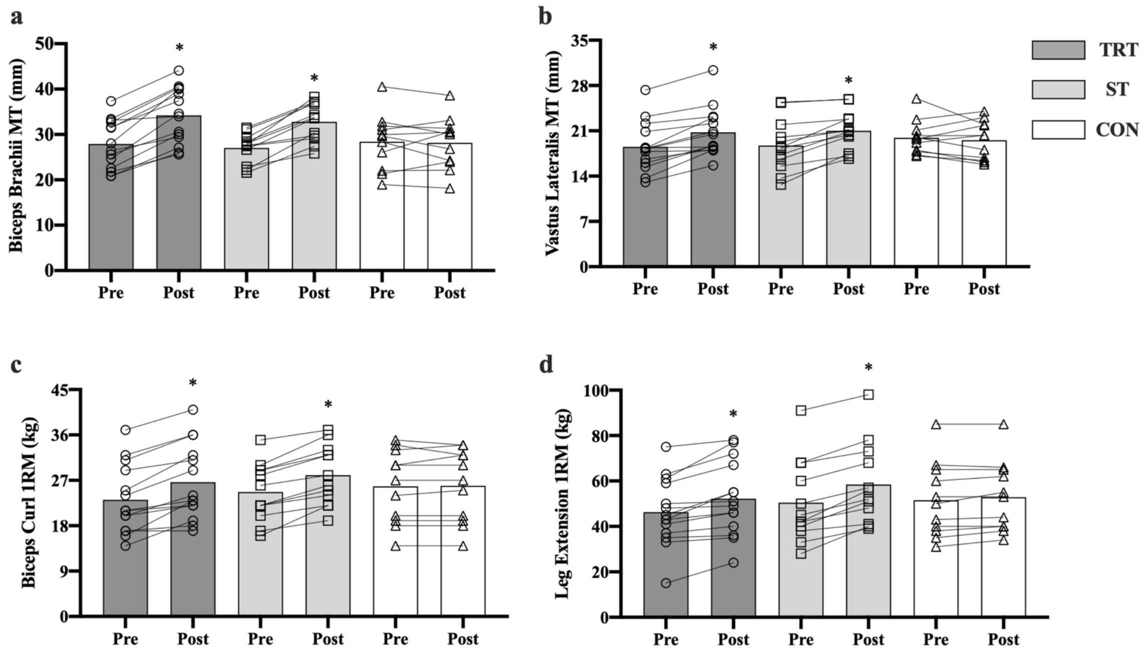

Fig. 2 Muscle thickness of Biceps brachii (**a**), vastus lateralis (**b**), muscle strength (1RM) of biceps curl (**c**), leg extension (**d**) at baseline (Pre) and after 12 weeks (Post) for the resistance training (TRT), suspension training (ST) and control (CON) groups. *Significantly different from Pre (group vs. time interaction; $P < 0.0001$). Values presented as mean ± SD

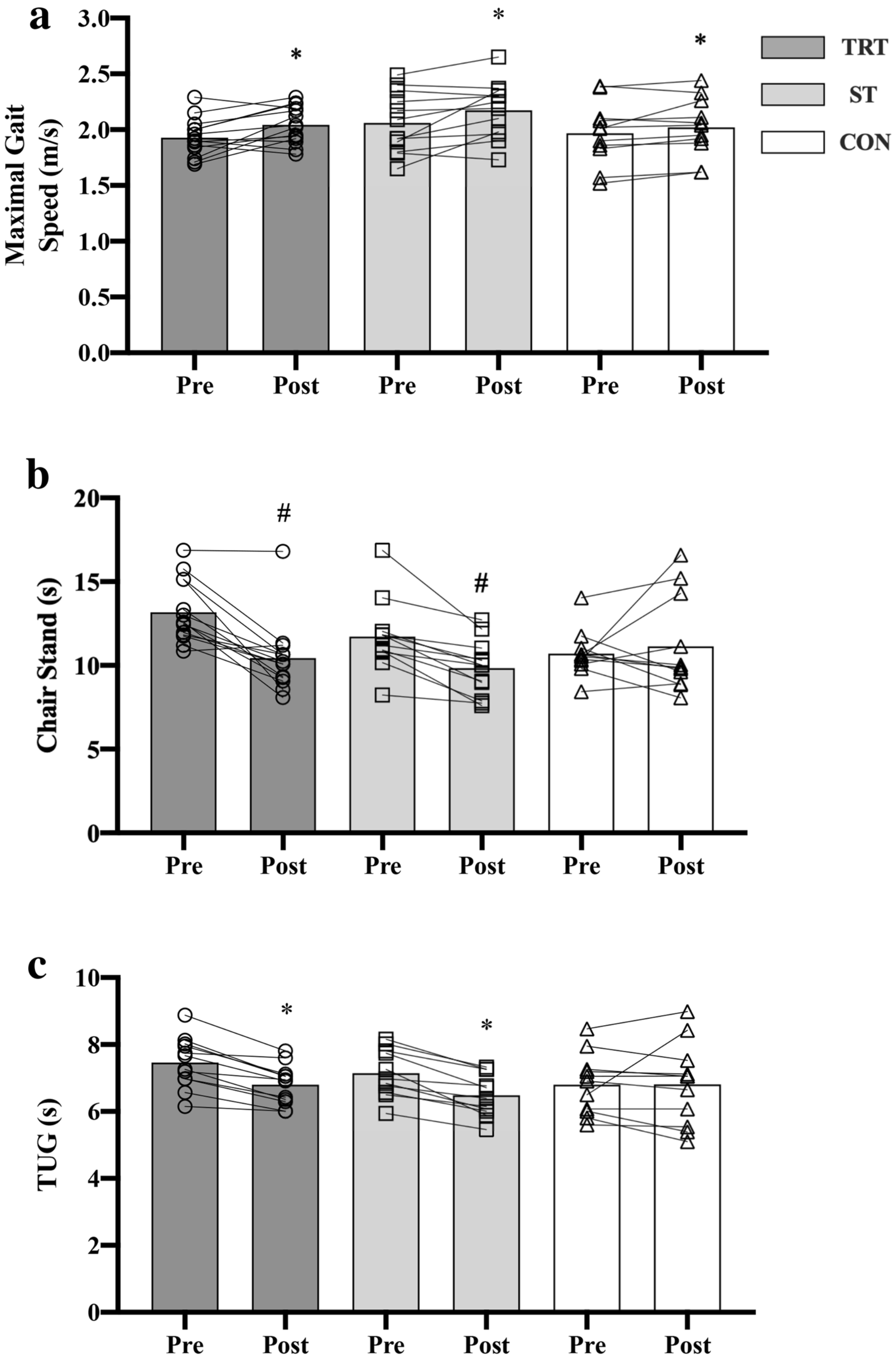

Fig. 3 Maximal gait speed (MGS) (**a**), chair stand (CS) (**b**), timed up and go (TUG) (**c**) values at baseline (Pre) and after 12 weeks (Post) for resistance training (TRT), suspension training (ST) and control (CON) groups. *Significantly different from Pre (group vs. time interaction; $P < 0.0001$). $^{\#}$Significantly different from CON at the respective timepoint (main group effect; $P \leq 0.05$). Values presented as mean ± SD

than the coefficient of variation of the measure. Finally, TRT and ST groups demonstrated an ES of 0.56 (large) and 0.35 (medium), respectively, whereas CON showed an ES of 0.14 (small).

Chair stand (CS)

There were significant differences in CS values at baseline ($P > 0.05$). When baseline differences in CS values were taken into account (repeated measures ANCOVA), a significant group effect was found ($P = 0.0305$; Fig. 3b), with significantly lower CS values for TRT and ST compared to CON ($P = 0.04$ and $P = 0.05$, respectively).

Timed up and go (TUG)

There was a significant group vs. time interaction for TUG ($F_{[2, 31]} = 6.52$, $P = 0.0043$). The training groups significantly decreased TUG from Pre (TRT 7.46 ± 0.72 s; ST 7.14 ± 0.68 s) to Post (TRT 6.80 ± 0.56 s, − 8.66%; ST 6.48 ± 0.60 s, −9.16%; $P = 0.0011$ and $P = 0.0018$, respectively; Fig. 3c). No significant differences were found in CON from Pre (6.80 ± 0.86 s) to Post (6.81 ± 1.18 s, − 0.05%; $P = 0.722$; Fig. 3c). The post hoc analysis revealed no between-group differences in TUG. Importantly, the TRT and ST groups demonstrated an ES of 0.77 (large) and 0.79 (large), respectively, whereas CON showed an ES of 0.03 (small).

Discussion

To the authors' knowledge, this is the first study comparing the effects of suspension training (ST) with traditional resistance training (TRT) on muscle mass, strength and functional performance in older adults. Our main findings suggest that ST improves muscle mass, strength and functional performance similarly to TRT.

Regarding muscle mass and strength, similar increases were found between TRT and ST performed to concentric muscle failure, confirming our initial hypothesis. Consistent with these results, we (Angleri et al. 2017; Nobrega et al. 2018; Damas et al. 2019) and others (Mitchell et al. 2012; Morton et al. 2016; Schoenfeld et al. 2017) have demonstrated similar muscle hypertrophy and strength gains between protocols performed to concentric muscle failure even when manipulating RT variables (e.g., load, volume, type of contraction or frequency) (Damas et al. 2019), training schemes (e.g., periodized vs. non-periodized) (Pelzer et al. 2017) and RT systems (e.g., TRT, drop-set or crescent pyramid) (Angleri et al. 2017). However, for muscle strength, similar gains are not universal. Even if the exercise is performed to concentric muscle failure, muscle strength gains are more specific to the movement performed in training than to the RT modulation (e.g., high- vs. low-load) (Mitchell et al. 2012). As noted by Buckner et al. (2017), 1RM test may be influenced by protocol specificity, with better outcomes for training protocols that most closely resemble the test. Therefore, in the present study all 1RM tests were performed on different apparatus (i.e., straight-bar and leg extension) from those used during the RT program (i.e., TRT: seated EZ-bar biceps curl and smith-machine squat; ST: squat and biceps curl on straps). Thus, we expand the previous results, demonstrating that an alternative RT mode capable of decreasing training stability, such as ST, also promotes muscle hypertrophy and strength gains comparable to TRT, at least when performed to concentric muscle failure.

Our initial hypothesis suggests that ST would be able to improve functional performance higher than TRT. Surprisingly, contrary to our hypothesis, improvements on MGS, CS and TUG were similar between groups. In relation to MGS, improvements were also observed in the CON group (2.87%) after 12 weeks. However, these gains are within the measurement error (CV 4.92%) and, therefore, caution should be taken when interpreting these results. It has been suggested that ST promotes greater functional performance improvements than TRT due to a more unstable state (Aguilera-Castells et al. 2018; Angleri et al. 2020). However, it is possible that individuals allocated to the instability condition (i.e., ST) quickly adapt to the new task even in the initial stages of training due to the high levels of neural adaptation in these stages (Del Vecchio et al. 2019; Lahouti et al. 2019). In fact, if new instability accessories (i.e., increases in instability) are not added throughout the training program performed with instability, it is possible that differences between ST and TRT on functional performance could not be detectable. In this sense, Silva-Batista et al. (2016) compared TRT to a RT protocol performed with instability (which resembles the ST scheme) on functional performance. Contrary to our study, results demonstrated greater improvements on functional performance for the RT performed with instability. However, in the study of Silva-Batista et al. (2016), the degree of instability for the exercises was progressively increased throughout the training sessions for the RT protocol performed in unstable environment, which may have produced a more challenging unstable environment for this protocol throughout the entire training period. On the other hand, in our study, the training progression was carried out through an increase in intensity (i.e., positioning of the participants' body segments in relation to the ground) instead of an increase in instability, as commonly applied in ST (Gaedtke and Morat 2015). It is worth mentioning that Silva-Batista et al. (2016) study's was conducted with Parkinson's disease patients. Therefore, care must be taken when interpreting the results. Future studies are necessary to investigate the progression of instability accessories in the ST.

Our study provides some practical insights that should be considered. ST is a RT mode with a simple configuration, takes up little space, is possibly easier and more economical to implement at public hospitals, rehabilitation centers or at the practitioner's own residence. Furthermore, ST can be adjusted according to the practitioners' requirements, allowing the accomplishment of a great variety of exercises and training regime without detracting from potential results. However, it is noteworthy that although training strategies in unstable environments are usable in several populations, the present study was carried out with healthy older adults with an average age of 64 years. Due to the lack of studies investigating the risks and limitations of ST, care must be taken when prescribing this RT mode for other populations, such as frail elderly. Future studies should investigate if ST could be safely prescribed to other populations.

Conclusions

In conclusion, ST promotes similar muscle mass, strength and functional performance improvements compared to TRT in older adults.

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Author contributions Conceptualization: SDS, VA and CAL. Data curation: SDS, DGS, JGAB, VA, RAMJ, NFD and CAL. Formal analysis: SDS, DGS, JGAB, VA and CAL. Investigation: SDS, DGS, JGAB, VA, RAMJ, NFD, MCC and CAL. Methodology: SDS, DGS, JGAB, VA, RAMJ, NFD, MCC and CAL. Project administration: SDS and CAL. Supervision: SDS and CAL. Writing, review and editing: SDS, DGS, JGAB, VA, SRN, MCC and CAL.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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