Resistance Training with Instability Does Not Hamper Total Training Volume and Muscle Strength Gains in Older Adults: a Secondary Analysis from REI Study

Yslaíny Araújo Silva, MSc, PT[1], Bruno Remígio Cavalcante, PhD[2], Letícia Bojikian Calixtre, PhD, PT[1], Milena Lucilla Lacio Tomaz, MSc[2], Mariana Ferreira de Souza, PhD[2], Ana Carolina Rodarti Pitangui, PhD, PT[1], Rodrigo Cappato de Araújo, PhD, PT[1]

[1]Graduate Program in Rehabilitation and Functional Performance (PPGRDF), Physical Therapy Department, Universidade de Pernambuco, Petrolina, Pernambuco, Brazil; [2]Graduate Program in Physical Education (PPGEF), Physical Education Department (CEFIS), Universidade Federal do Vale do São Francisco, Petrolina, Pernambuco, Brazil

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ABSTRACT

Background

Resistance training with instability (REI) emerged as a promising training modality for older adults aiming to counteract age-related changes.

Objectives

We compared the effects of 12 weeks of REI and traditional resistance exercise (RE) on muscle strength in older adults with cognitive impairment. We further explored if total training volume (TTV) significantly differs among training groups.

Methods

This is a secondary analysis of the REI study. Participants were randomly assigned to REI (n=22) or RE (n=23). RE protocol involved moderate-intensity, free-weight, and machines-based resistance exercises (3 sets, 10–15 repetitions). REI received a similar training protocol, in which exercises were simultaneously performed with instability/unstable devices (e.g., squat exercise under a foam pad or Bosu® ball). Maximal isometric strength and isokinetic parameters were assessed at baseline and after completion of a 12-week intervention through a hydraulic handgrip and isokinetic dynamometer, respectively. TTV (sets × repetitions × load) was computed based on external training load over the 12 weeks.

Results

No differences were observed between groups (p=.35) after the intervention. Over 12 weeks, REI and RE improved isometric handgrip strength (p<.001) and isokinetic performance (p=.04). We also did not find differences in the TTV between training groups (p=.28).

Conclusion

We demonstrated that both REI and RE training induced similar gains in muscle strength. Combining unstable surfaces/instability devices did not hamper TTV, which may have clinical applications in the context of exercise for older adults.

Key words: aging, muscle strength, resistance training, instability

INTRODUCTION

Resistance exercise with instability (REI), also known as "instability resistance training" or "metastable resistance training", involves performing resistance exercises (free-weight, machine-based, or weight bearing) within metastable states of equilibrium including irregular terrain and equipment such as proprioceptive discs, and Swiss and BOSU® balls. Using instability within a training regime generates variations in the levels of stability by promoting an increase in postural sway and displacement of the center of mass beyond the support base. Previous studies highlighted the role of REI protocols in the context of sports training and rehabilitation of athletes after musculoskeletal injuries.[1,2] One of the main assumptions for its use in these settings is that generally, individual and team-based sports expose the practitioner to technical/tactical situations that involve different degrees of instability, including quick responses and complex motor strategies (e.g., maintenance of balance on top a surfboard, cutting in beach volleyball).

Over the past 20 years, several studies have examined the role of REI in the context of healthy aging.[3–8] A meta-analysis led by Behm *et al*.[3] suggested that this modality was able to promote muscle strength, power, and balance in older people.[3] It is worth mentioning that in this review, only three studies[9–11] with this population were included, which only looked at the effects of REI on dynamic muscle strength. Although moderate-to-high effect sizes were observed, it is essential to highlight that indirect assessments of muscle strength were performed, such as sit-to-stand, arm curl,[11] and muscle strength of trunk.[10] No specific tests were used to assess the peak of torque through isokinetic muscle strength assessment. Additionally, studies only included healthy participants without considering the presence of cognitive impairment, which may have important implications in terms of exercise effectiveness.

Since Behm and colleagues' publication,[3] several experimental studies have amplified the focus of REI research by examining its role on other health outcomes including cognitive[5] and physical function,[12] as well as neuromuscular measures (e.g., isometric handgrip strength).[6] Despite the fact that most studies indicate positive effects of REI on such outcomes, further research is needed to foster precise recommendations for older adults.

A critical concept of resistance exercise (RE) programs is that the magnitude of muscle strength and hypertrophy may be related to the total training volume (TTV)—a variable that can be computed by multiplying the number of sets × repetitions × load used in a specific exercise or muscle group—where higher TTVs are related with better adaptations.[13–15] Given that REI prescription typically involves the use of light-to-moderate loads, higher motor task complexity, and neuromuscular activation of stabilizer muscles, these programs are sometimes questioned regarding their ability to increase TTV and, as a consequence, they will not be able to induce significant neuromuscular adaptations compared to traditional exercise models (moderate-to-high intensity protocols). One study led by Silva-Batista *et al*.[16] compared the effects of 12 weeks of REI vs. RE training on the TTV in older adults with moderate-to-severe Parkinson's disease. The results showed the TTV was significantly lower during REI intervention compared to RE protocol.[16] However, despite these differences, both interventions significantly improved 1RM of leg press. Whether these findings would be replicated in older adults with probable mild cognitive impairment needs to be confirmed.

Therefore, we compared the effects of 12 weeks of REI and traditional resistance exercise (RE) on muscle strength in older adults with cognitive impairment. We further explored if total training volume (TTV) significantly differs among training groups. Our hypothesis was that both interventions would promote similar muscle strength and TTV.

METHODS

Participants

Sixty-seven older adults with probable mild cognitive impairment (78% women, age: 71±5 years, BMI: 28.1±5 kg/m^2, 45% < 12 years of education, Montreal Cognitive Assessment [MoCA]: 19.2±4.5 points) were included in this analysis. Detailed eligibility criteria were described previously.[5] The study was approved by the Ethics and Research Committee of the University of Pernambuco (protocol no. 2.576.313) and registered in the Brazilian Registry of Clinical Trials (#RBR-4kqs22). All volunteers signed the consent form. The project was carried out in Petrolina (Brazil) from August to November 2018.

Study Design

This study is a secondary analysis of the REI study—a randomized trial that primarily looked at the effects of 12 weeks of REI on cognitive outcomes in older adults with probable mild cognitive impairment.[5] To address the purpose of this study, we included participants originally allocated to the training groups. We did not include participants from the health education control group due to the unfeasibility of assessing the load progression as well as computing TTV. Before and 12 weeks after intervention (72 to 96 apart), we assessed the maximal voluntary isometric contraction (MVIC) and isokinetic muscle strength variables using a hydraulic handgrip and an isokinetic dynamometer, respectively. The external training load (of all exercises) was also monitored throughout each training week to determine changes in muscle strength and TTV. The assessments of MIVC and isokinetic variables were performed on non-consecutive days, with an interval of at least 24 hours between them. A total of 45 participants were randomized into intervention groups: Resistance Exercise with Instability (REI group) (n=22) or Traditional Resistance Exercise (RE) (n=23). Randomization procedures were performed at the end of baseline assessments using a randomized sequence stratified by sex and age. A researcher not involved in the recruitment, evaluation, or intervention was responsible for generating the sequence of randomization and allocation of participants using free and open-source software (WINPEPI; http://www.brixtonhealth.com/pepi4windows.html).

Exercise sessions were performed three times a week for 12 weeks in both groups.

Outcomes

To describe the participants, we gathered information on age (in years), % of women, level of education (% of participants with <12 years of study), and the presence of comorbidities using a standardized questionnaire. The body mass index was calculated using the quotient of body mass (in kg) by height (in meters) squared. Global cognitive status was assessed using a validated and translated version of MoCA.[17]

Maximum Voluntary Isometric Contraction (MVIC)

A hydraulic handgrip dynamometer (Model SH-500, SAEHAN, Republic of Korea) was used to measure MVIC, according to the American Society of Hand Therapists'[13] recommendations. The MVIC was obtained from both hands in three attempts separated by a 1-minute interval. In each trial, the subjects were instructed to apply maximum isometric force to the equipment for 5 seconds. During the execution of the test, it was recommended that the participant's arm remain static, and a single evaluator performed standardized verbal stimuli. The MVIC was determined for each hand as the highest value obtained in the three trials.

Isokinetic Variables

Isokinetic muscle strength was assessed using an isokinetic dynamometer (Kin-Com 125E model, version 3.2; Chattanooga Group, Chattanooga, TN). The torque produced by the quadriceps and hamstring muscles was evaluated using a protocol with an angular velocity of 60°/s during concentric knee extension and flexion actions.

Participants performed three sets of five repetitions for each limb, with 2- to 5-minute intervals between trials and 5 to 10 minutes between limbs. Before the described evaluation procedures, the participants performed a specific warm-up on the equipment by performing 10 submaximal repetitions. To avoid compensatory movements, belts were attached to the seat and positioned around the trunk and pelvis, as recommended by the manufacturer. For the present analysis, peak torque (Nm/Kg) and total work (J) on dominant (DL) and non-dominant (NDL) limbs were measured as indicators of isokinetic muscle function. Dominance was established based on the leg used to kick a ball. Bilateral asymmetry of the knee muscles was defined as a 10% contralateral (DL/NDL) strength imbalance.[18] In addition, the hamstrings to quadriceps strength ratio (H/Q ratio) was evaluated, and we consider 0.60 as the normative value.[19]

Calculation of the Total Training Volume (TTV)

The external training load (in kg) used in each exercise was evaluated throughout the intervention. The progression of the load was carried out considering the individual capacity and type of exercise. The exercises were organized in two groups according to the part of the body they were focused on: 1) trunk and upper limbs, including horizontal bench press and pulley row; and 2) lower limbs, including pelvic lift, leg press, and squat. Then, TTV was computed by multiplying the number of sets × repetitions × load for the exercises that composed each group.

A blinded researcher assessed handgrip strength and isokinetic variables. However, the researchers responsible for supervising the intervention monitored the number of series, repetitions, and training load for later calculation of TVV. Therefore, it was not possible to perform a blind analysis of the TTV.

Interventions

The intervention protocols were described in detail previously.[5] In summary, the REI and RE groups underwent 12 weeks of resistance training, three times per week in non-consecutive days. The exercises involved squat exercises, dumbbell horizontal bench presses, leg presses, pulley rows, pelvic raises, calf raises, and abdominal exercises. Each exercise was performed in three series with repetition zones varying from 10 to 15 maximal repetitions (RM). Isometric abdominal exercises were sustained for 10 to 30 seconds. The rest interval between sets ranged from 60 to 90 seconds, and between exercises from 2 to 3 minutes. After the 4th week of training, the RE group received a protocol similar to RE, with the addition of unstable surfaces and equipment such as BOSU®, proprioception disc, and Swiss balls (Figure 1).

Trained therapists supervised all sessions to ensure adherence to the training protocol and safety. The load progression was performed according to the ACSM recommendations,[20] so when the upper limits of the target zone were reached in three consecutive training sessions, the load of the next session was increased by 2–5% for the upper limb exercises, and 5–10% for the lower limb exercises. The progression of instability on the REI protocol was individualized and subjectively established when the individual achieved balance (e.g., ease execution of movements on unstable bases and change in external load), particularly between weeks 4 and 8 (level 1) and 9 to 12 (level 2). Finally, participants were instructed to maintain a standard movement speed and attention while performing all the exercises.

Statistical Analysis

All analyses considered a significance level of $p < .05$ and were performed in the open-access software Jamovi (version 2.3.21; https://www.jamovi.org/). Descriptive statistics were performed for continuous variables with mean and standard deviations, absolute values, and percentages for

FIGURE 1. Squat exercise with the addition of instability

categorical variables to summarize data obtained at baseline and follow-up.

The effects of the training protocols on muscle strength variables were determined by a Generalized Mixed Models analysis using Gamma distribution and Log function link. In this model, random intercepts and slopes and fixed effects of time (baseline and follow-up) and groups (REI and RE) were included, as well as the interaction between group and time. Effect sizes were calculated for comparisons that showed significant differences (p<.05) and were interpreted as < .20 trivial, .20–.50 small, .50–.80 moderate, and >.8 large.

The weekly TTV inclination lines for the trunk/upper limbs and lower limbs exercises were compared between REI and RE. For this analysis, the TTV values of the last week of training (12^{th} week) were removed to minimize issues with missing data.

RESULTS

The flow diagram of participants analyzed in this secondary analysis of the REI Study is shown in Figure 2. The study was conducted in Petrolina, Brazil, between August 27th and November 23rd, 2018. Forty-five participants were assessed at baseline and were randomly allocated to one of two intervention groups (REI = 22 and RE = 23). During the intervention period, eight participants withdrew (three in the RE group and five in the REI group), and the data were imputed to perform the intention-to-treat analysis.

The groups were similar in sociodemographic, clinical characteristics, and comorbidities. More detailed information is presented in Table 1.

Table 2 presents the results of the interventions´ effects on muscle strength indicators, in which there is no time × group interaction and no group effect. Significant time effects were observed on the MVIC, indicating that both groups showed increased handgrip isometric strength during the training protocol. Both groups presented an increase in isokinetic variables (PT and TW) of extensor ($p \leq$.005) and flexor muscles ($p \leq$.04). The gain in handgrip strength showed a large effect size (1.13). Changes in extensor and flexor peak torque and total work had a small effect size (<.50).

No differences were found in bilateral asymmetry and hamstring quadriceps ratio.

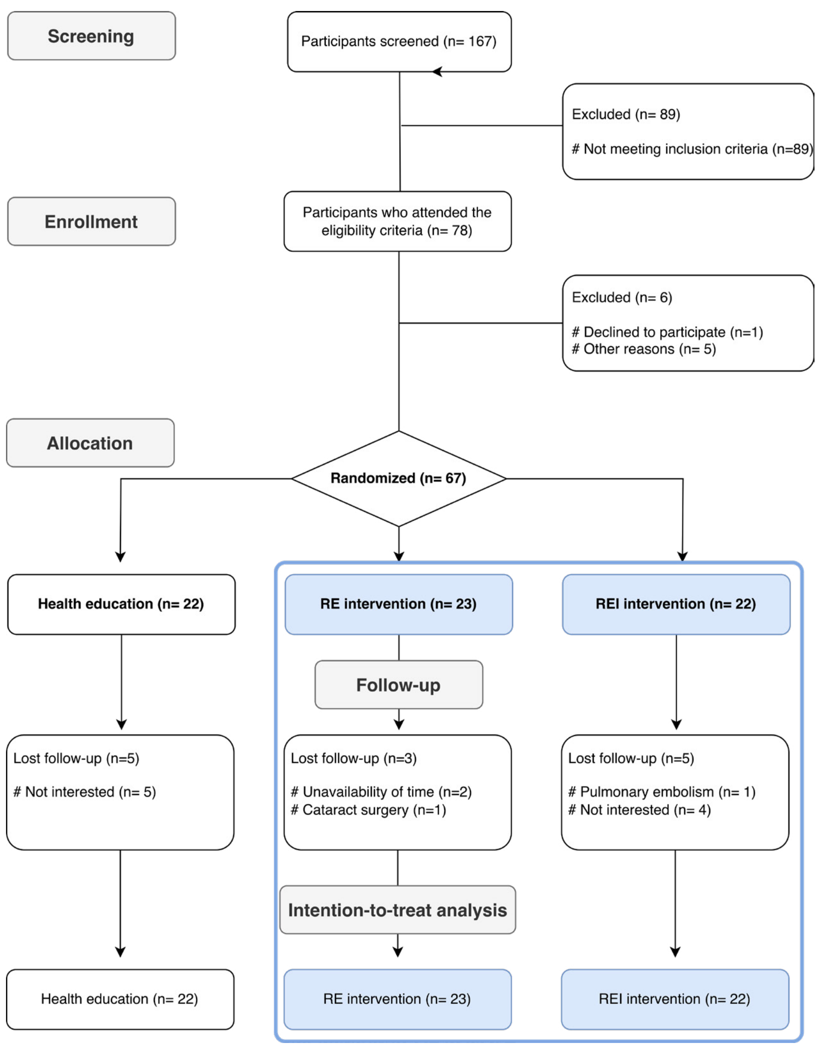

FIGURE 2. The flow diagram of secondary analysis of the REI Study

Figure 3 summarizes the TTV behavior for the trunk and upper limbs (panel A) and lower limbs (panel B) exercises in the REI and RE groups throughout the intervention period.

TABLE 1.
Baseline participant characteristics[a]

Descriptive variables	*REI*	*RE*
Age (years)	71 ± 6	71 ± 6
Women (%)	77	78
Low education level (%)[b]	45	43
BMI (kg*m^{-2})	27.1 ± 5.4	28.4 ± 3.9
MoCA (score)	18.9 ± 4.4	20.0 ± 4.4
Falls in the last year (%)	7	8
Hypertension (%)	54	78
Diabetes (%)	14	17
Osteoporosis (%)	18	22
Rheumatological disease (%)	36	43
Depression (%)	18	30

[a]Values expressed as mean ± standard deviation or %.
[b] Less than 12 years of study.
REI = resistance training with instability; RE = resistance exercise training; BMI = Body Mass Index; MoCA = Montreal Cognitive Assessment.

No significant differences were found between the slopes of the regression line that represents the behavior of the TTV in the exercises for the trunk and upper limbs (p=.977) and the exercises for the lower limbs (p=.281), indicating that the behavior of the TTV was similar between the REI and RE groups over the 12 weeks of training.

DISCUSSION

The key findings of our study were that 1) both interventions significantly improved muscle strength, and 2) combining instability with resistance exercise training did not hamper weekly TTV in community-dwelling older adults with probable mild cognitive impairment.

It is well-established that traditional resistance training is effective in promoting neuromuscular adaptations in older adults. Little is known regarding the effects of combining instability with RE in these outcomes.[3,6,7,16,21,22] A previous study that looked at the effects of REI observed significant improvements in isometric MVIC.[6] The magnitude of muscle gain was similar across the groups with an average of 1.6 and 1.9 kg after 12 and 24 weeks, respectively. Using data from 58 healthy older women, Pirauá *et al*.[7] also observed that both REI and RE were able to promote an average gain ranging from 1.8 to 2.7 kg in handgrip strength. Our results corroborate with these studies,[6,7] reinforcing that resistance

TABLE 2.
Results of the 12-week intervention on muscle function variables according to allocation groups[a,b]

Outcomes	*RE Group (n = 23)*		*REI Group (n = 22)*		*Fixed Effects*			*Effect Size*[b]
	Pre	*Post*	*Pre*	*Post*	*G*	*T*	*G×T*	*T factor*
Handgrip MVIC (Kgf)	20.28 (1.38)	23.45 (1.67)	21.60 (1.50)	24.18 (1.68)	0.68	<0.001	0.10	1.13
Isokinetic Variables (Non-Dominant Limb)								
PT on extension (Nm/kg)	42.63 (2.78)	45.01 (2.94)	40.77 (2.72)	43.63 (2.91)	0.68	<0.001	0.71	0.38
PT on flexion (Nm/kg)	29.74 (2.46)	33.75 (2.80)	28.52 (2.42)	31.15 (2.64)	0.60	<0.001	0.48	0.47
TW on extension (J)	386.44 (27.4)	397.27 (28.2)	359.97 (26.1)	393.24 (28.5)	0.68	0.005	0.14	0.26
TW on flexion (J)	193.06 (16.6)	206.35 (17.7)	194.38 (17.0)	205.98 (18.1)	0.97	0.04	0.94	0.22
H/Q ratio	69.94 (4.49)	75.28 (4.84)	70.12 (4.61)	71.58 (4.70)	0.78	0.14	0.41	-
Isokinetic Variables (Dominant Limb)								
PT on extension (Nm/kg)	42.29 (2.86)	45.16 (3.05)	41.40 (2.86)	44.30 (3.06)	0.83	<0.001	0.95	0.47
PT on flexion (Nm/kg)	31.35 (2.62)	33.04 (2.93)	29.57 (2.53)	32.08 (2.78)	0.58	<0.001	0.74	0.46
TW on extension (J)	403.87(30.6)	455.56 (34.5)	361.76 (28.0)	416.36 (32.2)	0.35	<0.001	0.61	0.48
TW on flexion (J)	189.29 (16.4)	203.59 (17.6)	177.18 (15.7)	186.99 (16.5)	0.53	0.04	0.76	0.22
H/Q ratio	74.22 (5.73)	77.65 (6.00)	71.02 (5.61)	73.10 (5.77)	0.63	0.12	0.73	-
Asymmetry								
BilAsymm – Extension	10.28 (1.72)	10.58 (1.74)	10.14 (1.72)	10.12 (1.84)	0.88	0.93	0.91	-
BilAsymm – Flexion	18.29 (3.14)	18.94 (3.22)	17.31 (3.01)	17.37 (3.08)	0.75	0.86	0.88	-

[a]Values expressed as mean (SD).
[b]Effect sizes were calculated only for variables where significant differences were observed (p < .05).
G = group; T = time; G β T – group × time interaction; MVIC = maximum voluntary isometric contraction; PT = peak torque; TW = total work;
H/Q ratio = ratio between concentric peak torque of hamstrings and quadriceps; BilAsymm = strength differences between non-dominant and dominant limbs.

training protocols, independently of instability, are able to produce similar gains in MVIC measured by a handgrip.

A systematic review of Labott *et al*.[23] showed that exercise training induces significant within-group changes in handgrip strength, while between-group comparisons revealed small effect size and considerable heterogeneity. The authors suggest that small transfer effects might be explained due to the lack of task-specific exercises. In addition, Bohannon[24] argued that changes above 2.2 kg for the dominant limb can be interpreted as a real change.[24] Thus, the average gain of ~2.6 kg observed in the present study indicates that both protocols could provide meaningful increases in muscle strength.

Over a 12-week intervention, our training protocol promoted significant within-group changes (despite small effect sizes) in the strength of the quadriceps and hamstring muscular groups. However, we did not find between-group differences at the completion of the intervention. The increase in muscle strength in the RE group was expected, and corroborates the evidence in the literature confirming that resistance training benefits physical function in older adults.[25,26] Few studies have explored the role of REI on isokinetic outcomes,[16,22] and most of them included a sample of Parkinson's disease patients. In those studies, authors have found that over 12 weeks the REI and RE equally improved the peak of torque in the quadriceps and triceps surae.[16,22]

We have some hypotheses that might help to explain differences in the magnitude of within-group changes between the current and past studies, which include exercise prescription features and training specificity. Firstly, our prescription includes repetitions ranging from 10 to 15 compared with previous studies wherein participants started from 10 to 12 repetitions in the first month to 6 to 8 repetitions maximum in the last month (favoring muscle strength adaptations). Secondly, our prescription did not include knee extension and flexion exercises using an open kinetic chain. Considering that exercise-induced adaptations are associated with the adequate use of the training principles,[20] the lack of specificity in our training protocol may have contributed to the current results.

Our results showed no significant changes in the H/Q ratio. Research suggests that H/Q ratio values lower than 60–70% are associated with a higher risk of knee injuries,[27] gait asymmetry and variability, and impact on functional tasks.[28,29] We observed that our participants presented adequate results, with values between 70–75%. Another important aspect that increases the risk of knee injuries involves the presence of bilateral asymmetry greater than 10% in muscle strength.[18] In the current study, our participants showed mean values of 10% and between 17–19% of asymmetry for quadriceps and hamstrings, respectively. The tested protocols could not modify the asymmetry rates, especially concerning the hamstring muscles, which indicate a possible limitation of the training programs. Studies have shown that asymmetry or decreased strength of the hamstrings is associated with more significant body sway[18] and may be related to a higher incidence of falls since fallers have greater asymmetry than non-fallers.[30] Our protocols focused on multijoint exercises that activate several muscle groups and increase the co-contraction. However, the leg press and squat exercises did not generate sufficient stimuli to rebalance the knee flexor muscles, requiring greater attention to this muscle group with the prescription of specific exercises.

Previous research has highlighted the importance of TTV as a determinant of training progression, as well as exercise-induced adaptations (e.g., higher TTV seems to be related with muscle strength and mass gains) in young and older individuals. In this study, we also showed that the TTV was similar between REI and RE during intervention, reinforcing that combining traditional RE with instability devices or unstable surfaces did not hamper training progression. Collectively, these results support the notion of REI as an alternative intervention to promote neuromuscular adaptations in older adults.

This study has limitations that deserve to be mentioned. First, it is a secondary analysis of a clinical trial which

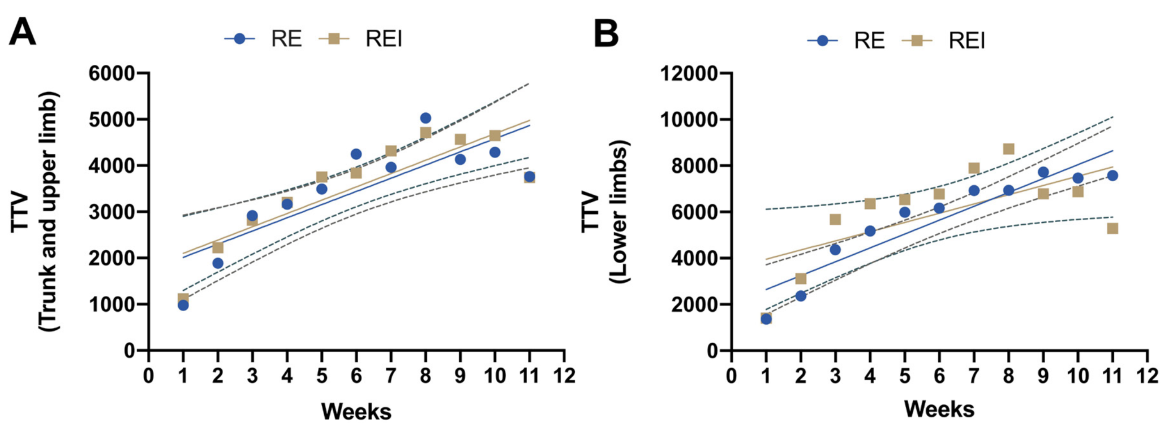

FIGURE 3. Regression line indicating the TTV slope (sets × repetitions × load) between the training groups in the trunk and upper limbs exercises (panel A) and lower limbs (panel B) over the 12 weeks of training
Blue and yellow dots represent RE and REI groups, respectively.
Dashed lines show 95% confidence intervals (95%CI).
TTV is expressed in arbitrary units.

primarily analyzed the effects of REI on cognitive outcomes. Second, due to the feature of exercise interventions, the blinding of therapists was not feasible. Third, our trial included older adults with probable mild cognitive impairment; therefore, the results cannot be generalized for populations with different characteristics.

CONCLUSION

In summary, 12-week REI and RE protocols promoted similar improvements in handgrip strength and of isokinetic dynamometer indicators among older people with probable mild cognitive impairment. In addition, our results demonstrated that including REI did not hamper the TTV compared to the traditional RE protocol, suggesting that REI might be an alternative strategy for the maintenance of exercise-induced neuromuscular adaptations during aging.

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CONFLICT OF INTEREST DISCLOSURES

We have read and understood the *Canadian Geriatrics Journal*'s policy on conflicts of interest disclosure and declare that we have none.

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Correspondence to: Cappato de Araújo, PhD, PT, Universidade de Pernambuco—UPE (Campus Petrolina), Department of Physical Therapy, Laboratório de Pesquisa em Saúde e Desempenho Funcional, Cidade Universitária, Vila Eduardo, Petrolina-PE, Brazil 56328-903
E-mail: rodrigo.cappato@upe.br