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Are resistance and aerobic exercise training equally effective at improving knee muscle strength and balance in older women?

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Abstract

This study aimed to compare the magnitude of knee muscle strength and static and dynamic balance change in response to 8 months of progressive RE and AE training in healthy community-dwelling older women. A secondary aim was to assess the relationship between muscle strength and balance changes (up and go test (UGT), one-leg stance test, and center of pressure measures). This study was a secondary analysis of longitudinal data from a randomized controlled trial, a three-arm intervention study in older women (n = 71, mean age 69.0 y). The results suggest that both interventions elicited *likely* to *almost certain* improvements (using magnitude-based inference) in balance performance. Leg strength was improved after RE whereas it was *unclear* following AE. Improvements in strength were *almost certainly moderate* after RE and *possibly trivial* after AE, with *very likely* greater improvements following RE compared to AE. A large and significant negative correlation (r = −0.5; CI 90%: −0.7 to −0.2) was found between ΔUGT and change in both knee extension and knee flexion strength after 8-month RE. In conclusion, our results showed that both types of training improve balance, but RE was also effective at improving leg strength. In addition, improvements in both knee extension and flexion strength after RE appear to make an important contribution to meaningful improvements in static and dynamic balance.

Keywords

Muscle strength; Isokinetics; Postural control; Endurance training; Aging

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Conflicts of interest statement

None.

1. Introduction

Increase or at least maintenance of capacity above the threshold risk for falls is central to prevent serious fall injuries such as hip fractures that often result in long-term functional impairment, nursing home admission and increased mortality (Marks, Allegrante, Ronald MacKenzie, & Lane,2003). Extensive literature has suggested that lower extremity weakness and balance impairment are associated with an increased risk of falls (Moreland, Richardson, Goldsmith, & Clase, 2004), mobility limitations (Donoghue, Savva, Cronin, Kenny, & Horgan, 2014; Visser et al., 2005), and hospitalizations (Cawthon et al., 2009). Thus, researchers and clinicians are interested in identifying the best exercise programme that is effective in decreasing fall risk. Epidemiological studies have provided the hypotheses for subsequent interventional studies that have documented the efficacy of exercise interventions to prevent falls (Gillespie et al., 2012) and improve balance (Howe, Rochester, Neil, Skelton, & Ballinger, 2011). Among the general population of community-dwelling older adults, aerobic exercise (AE) training and resistance exercise (RE) training are commonly prescribed and widely accepted, based on the variety of favourable adaptations that AE and RE as single interventions can elicit in older adults (Chodzko-Zajko et al., 2009). Although balance improvements may occur after long-term exercise interventions, the physiological mechanisms associated with balance improvement may vary between different types of exercise, such as AE and RE. Epidemiological studies have shown that low muscle strength or age-related sarcopenia are associated with impaired balance control in older adults (Bijlsma et al., 2013; Orr, 2010). Thus, exercise training without a specific balance component may be effective in improving balance control due to a direct influence on muscle mass and strength. Considering the obvious specificity of RE to activate muscle skeletal contraction and hypertrophy compared with AE, it is reasonable to expect a different influence of muscle strength change in balance improvements after RE and AE interventions. On the other hand, the benefits of strength may not transfer effectively to concomitant improvements in functional outcomes such as balance, functional tasks, or activities of daily living (Granacher, Gollhofer, Hortobagyi, Kressig, & Muehlbauer, 2013). The contradictory evidence may be due to differences in training intensity, frequency, type of resistance training, equipment (such as free weights, resistance machines, or elastic bands), and types of measurements Recently we investigated the effects of RE and AE on strength and balance in older women (Marques et al., 2011), but consistent with other studies (Alfieri et al., 2012; Orr et al., 2006) the relationship between change in strength and the change in balance was not investigated. Moreover, recent reports have emphasized the importance of using alternative statistical measures for data interpretation, instead of focusing on the P value (Halsey, Curran-Everett, Vowler, & Drummond, 2015). Specifically, when interpreting intervention-balance studies an approach for determining meaningful changes such as effect size estimates and their precision (confidence intervals) should be considered (Halsey et al., 2015; Hopkins, Marshall, Batterham, & Hanin, 2009). Thus, the aims of this study were to describe the magnitude of balance and strength changes after RE and AE interventions, and to examine the relation between muscle strength and balance changes after 8 months of training.

2. Methods

2.1. Data source

We used data from an 8-month randomized controlled trial examining the effects of RE and AE on physical function, bone mineral density, osteoprotegerin (OPG) and receptor activator of NF-κB ligand (RANKL). On completion of initial screening 71 sedentary older women aged 61 to 83 years were randomly assigned to one of three study arms: RE (n = 23), AE (n = 24), and wait-list control group (CON, n = 24). The study design, protocol, inclusion and exclusion criteria, the contents of RE and AE interventions, baseline characteristics of the subjects, and the primary outcomes were described in detail elsewhere (Marques et al., 2011). Briefly, exercise sessions were performed on nonconsecutive days, 3 days per week, and each session lasted approximately 60 min (including a dynamic warm-up (~10 min) specific (resistance or aerobic) training period (~40 min), and cool-down (~5 min) over a period of 32 weeks. The RE protocol aimed to develop muscle mass and strength in the following muscle groups: quadriceps, hamstrings, gluteal, trunk and arms, and abdominal muscles using variable resistance machines (Nautilus Sports/Medical Industries, Independence, VA). The intensity of the training stimulus was initially set at 50% to 60% of one-repetition maximum (1RM), and then progressed to 80% of 1RM. The other exercise group participated in a training programme design to improve aerobic capacity. The exercise intensity was initially set at 50% to 60% of the subject's heart rate reserve for the first two months, and after increased to 85%. All participants provided informed consent, and the study was carried out in full compliance with the Helsinki Declaration. All methods and procedures were approved by the institutional review board.

2.2. Measurements

Participants completed a self-report questionnaire and buccal swabs (to obtain DNA for genotyping of the C/T – 13910 mutation) (only at baseline) and several procedures and measures including blood draw (to obtain serum for RANKL and OPG assay), anthropometry, body composition, measures of different domains of physical function (muscle strength, static and dynamic balance), accelerometer-measured physical activity, and current diet were assessed at baseline and at the end of the intervention (week 32). A more thorough description of the methodology and primary results has previously been published (Marques et al., 2011). A description of the measures relevant to this manuscript, collected at both occasions, is provided here.

2.2.1. Strength measures—The baseline to 8-month changes in two strength measures were examined as predictors of balance performance improvement: peak torque knee extensor (KE) strength and peak torque knee flexor (KF) strength. Isokinetic knee extensor and flexor strength of the left leg at 60°/s (1.05 rad/s) was measured on an isokinetic dynamometer (Biodex System 4 Pro; Biodex, Shirley, NY) in accordance with the manufacturer's instructions. Each participant, after familiarisation with the equipment, performed three maximal efforts with two minutes of rest between tests.

2.2.2. Outcome measures—Balance was assessed by the same rater, blinded to group assignment, in the same laboratory environment. Dynamic balance was assessed using the up and go test (UGT) and static balance was measured using the one-leg stance test (OLST). Before starting the tests, participants remained seated and rested for five minutes. In the UGT, the score corresponded to the shortest time to rise from a seated position, walk 2.44 m (8 feet), turn, and return to the seated position, measured to the nearest 1/10th s. For the OLST participants stood upright as still as possible in an unassisted unipedal stance (on the nondominant leg) on a 40–60 cm force platform (Force Plate AM 4060-15; Bertec, Columbus, OH) with eyes open, looking straight ahead, and arms by the side of the trunk. Data from horizontal forces (Fy and Fx) and COP time-series were low-pass filtered with a zero-lag, fourth-order Butterworth filter with a cut-off frequency of 10 Hz. The outcome variables were anterior-posterior (AP) and medial-lateral (ML) mean velocity (cm/s) of the COP; the elliptical area (EA) was calculated using the equation: $\sqrt{2}\sigma y \times \sqrt{2}\sigma x$. Mean velocity was determined by dividing the total distance along the signal trajectory by the total recording time. The EA/time ratio was also included in the analysis.

2.2.3. Adjustment variables—Baseline adjustment variables considered for inclusion in our models were age, body mass index (BMI), total lean mass, total percentage body fat mass, and daily physical activity. Height and body mass were taken using standardized procedures and BMI was computed as the ratio mass/height^2 (kg/m^2). Whole-body DXA (Hologic QDR 4500, software, APEX v3.0 software; Bedford, MA) was used to assess total lean mass and total fat mass as described previously (Marques et al., 2011). A uniaxial accelerometer (ActiGraph GT1 M; ActiGraph, Pensacola, FL), secured with an adjustable belt on the hip was used to measure physical activity time during waking hours for 7 consecutive days as previously described (Marques et al., 2011). The average daily moderate to vigorous physical activity (MVPA) of at least 5 days of valid wear was included as covariates in this study.

2.3. Statistical analysis

All data were initially inspected using descriptive statistics and by visually reviewing a graphic display. Descriptive information was reported as means ± standard deviations unless otherwise stated. The absolute change (Δ) was calculated between week 32 and baseline values of all strength-related variables and the outcomes. The results were analysed on an intention-to-treat basis, and missing data due to lack of follow-up (the method assumed data were missing at random) were replaced using the process of multiple imputation in accordance with previous publication (Marques et al., 2011).

Magnitude-based inference statistics was selected as traditional statistical approaches generally fail to indicate the magnitude of an effect, which is more relevant to physical performance (Hopkins, 2010), and to provide more clinically meaningful results (Hopkins et al., 2009). The precision of the magnitude inference was set at 90% confidence interval (CI). Standardized thresholds derived from between-subject standard deviations of the baseline value were used to assess the magnitude of effects (ES). The following threshold values for ES were employed: <0.2 as trivial, >0.2 as small, >0.6 as moderate, >1.2 as large, >2.0 as very large, and >4.0 as extremely large (Hopkins et al., 2009). Additionally, we calculated the probabilities of whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile change or difference. The smallest worthwhile change/

difference for all variables was calculated from the two evaluations from the CON group expressed as the coefficient of variation (CV) (Chandler, Duncan, Kochersberger, & Studenski, 1998). The qualitative chances of either higher or lower difference were evaluated as follows: 1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; >99%, almost certain. If the chances of a substantially higher or lower difference were both >5%, the true difference was assessed as 'unclear' (Hopkins et al., 2009).

To address the second aim of the present study we first examined the association between each predictor (change in knee strength variables) with each balance outcome in a separate linear regression model without any covariates. Because our results showed an *unclear* change (with *trivial* magnitude) in knee strength after AE, these associations were tested only in the RE group. Recognizing our limited sample size, we tested the association between each potential covariate with the outcomes of interest, and they were included in multivariate models if they achieved statistical significance. The following criteria were adopted to interpret the magnitude of the correlation (r) between these measures: <0.1 as trivial; 0.1–0.3 as small; >0.3–0.5 as moderate; >0.5–0.7 as large; >0.7–0.9 as very large; and >0.9–1.0 as almost perfect (Hopkins et al., 2009). Data analysis was performed with IBM SPSS Statistics 22. Final results were considered statistically significant if they achieved a significance level of P less than 0.05.

3. Results

3.1. Participant characteristics

Details of the participant flow of recruitment and screening have been published before (Marques et al., 2011). In total, 71 women aged 69.0 ± 5.3 (range 61–83) fulfilled the inclusion criteria and were willing to participate (79% participation rate). Seventeen participants withdrew during the intervention. No differences (p = 0.315) in dropout rates were observed between groups. Mean age of the participants at baseline was 69 ± 6 years, and 73% were overweight (BMI ≥ 25.0 kg/m^2), and these distributions were not significantly different among the study groups. There were also no significant group differences in any of the other baseline characteristics (Table 1).

3.2. Primary outcomes

The natural variation of the CON group expressed as the CV (90% CI) was 31.9% (25.0; 44.8) for the EA, 39.7% (30.9; 56.3) for OLST, 31.8% (24.9; 44.6) for EA/time, and 6.3% (5.0; 8.5) for UGT, 19.6% (15.5; 27.0) for AP COP velocity, 32.8% (25.7; 46.1) for ML COP velocity,11.3% (9.0; 15.4) for KF strength, and 11.1% (8.9; 15.1) for KE strength.

The EA, OLST, EA/time, ML COP velocity, and KE and KF strength presented unclear differences between groups at baseline. AP COP velocity presented unclear differences between groups, except when comparing AE with the CON group where differences were possible small. UGT presented likely and very likely moderate differences between RE and the AE and CON groups, respectively.

The within-group changes of 32 weeks in all balance outcomes and KF and KE strength are presented in Table 2. The CON group presented a possible trivial to small increase in EA and ML COP velocity, and increase in AP COP velocity, while a likely trivial to moderate increase was observed for EA/time, UGT, and decrease in OLST, KE strength, and KF strength. The RE group presented Likely to Almost Certain improvements with small to large magnitude in all parameters. Similar changes occurred in the AE group, except for KF and KE strength that were unclear.

The between-group changes of 32 weeks in all balance outcomes, and KF and KE strength are presented in Table 3. After training the EA, OLST, EA/time, UGT, AP COP velocity, and ML COP velocity improved with a small to large magnitude and with a likely to almost certain probability compared with the CON group force parameters, KE and KF, improved almost certainly with a moderate magnitude in the RE group compared with the CON group, while possibly changes were observed in the AE group compared with the CON group. Differences were unclear between the two intervention groups and any benefit or harm was of trivial to small magnitude, except the KE and KF strength that had a very likely improvement comparing the RE group with the AE group with a moderate effect.

3.3. Predicting improvements in balance with training-induced changes in knee strength

Changes in KE and KF strength were largely associated with the change in UGT ($r \sim -0.50$; 90% CI −0.73 to −0.19 and −0.74 to −0.22, respectively) after RE. In addition, only the change in KE strength was significantly correlated to improvements in the static balance (OLST) performance ($r = 0.58$, large, 90% CI 0.28–0.77). We note that the variance in balance change explained by strength predictors was approximately 30% (Table 4).

Changes in all force-plate-related measurements were not significantly associated with change in strength. In addition, all potential covariates were not significantly associated with any of the balance outcomes, and thus no adjusted model was created (only crude regression models were performed). We performed a sensitivity analysis by adjusting the regression models by age. The results remained virtually unchanged compared with those in the main analysis (data not shown).

4. Discussion

In this study, our aim was firstly to quantify the magnitude of the exercise effect in muscle strength and balance in older women after two different training modes (RE vs. AE). In this regard, findings showed that 32 weeks of either aerobic or resistance training elicited *likely* to *almost certain* (*small* to *large*) improvements in dynamic/agility performance (UGT), static balance (OLST), and COP parameters. AE training *very likely* lowered (with *moderate* effect) the AP COP velocity while RE training was shown to be *likely* effective (*small* decrease). Strength measurements were improved after RE whereas it was unclear following AE. Both exercise interventions *likely* to *almost certain* improved balance outcomes compared to control group, however the difference between AE and RE was deemed unclear. Improvements in knee strength were *almost certainly moderate* after RE and *possibly trivial* after AE, with *very likely* greater improvements following RE compared to AE.

Our second aim was to examine the relationship between the observed changes in knee muscle strength after 8 months of RE and improvements in balance. In the current study, a large negative correlation was observed between the ΔUGT and change in both KE and KF strength after 8-month RE. The change in static balance performance was largely associated with KE strength only after RE training. Associations were s*mall/trivial* between change in strength and COP parameters ($p > 0.05$).

In older adults, decrements in balance, including the performance in UGT and OLST, have been consistently associated with an increased risk of falls (Brill, Probst, Greenhouse, Schell, & Macera, 1998). To mitigate age-related declines in balance performance and prevent falls in old age, the effect of exercise interventions has been tested (Howe et al., 2011). In general, evidence supporting the effectiveness of AE (such as walking) is insufficient to draw any conclusions while strength exercise is considered moderately efficient based on weak evidence (Howe et al., 2011). In line with findings from a previous study in older adults with knee osteoarthritis (Messier et al., 2000), our results showed that both interventions were *likely* to *almost certain* beneficial for improving the ability to maintain standing balance and COP movement during standing balance, as well as dynamic balance/mobility in untrained healthy older women. A systematic review published in 2008 concluded that progressive RE training alone is not uniformly effective in improving balance, as only approximately half of the included studies (14/29 RCT) showed positive results. Our data, together with other recent studies (Gonzalez et al., 2014; Joshua et al., 2014; Lustosa et al., 2011) are adding new evidence supporting the effectiveness of RE for improving balance in older people. To the best of our knowledge, only one study have addressed the effect of RE training on static balance using magnitude-based inference approach to quantifying and interpreting effects (Gonzalez et al., 2014), reporting *likely beneficial* effects of 12 training sessions on single leg standing performance. The effect of exercise training on COP measurements is not well-documented and results have been discordant (Orr, Raymond, & Fiatarone Singh, 2008). In the present study both interventions were *likely* to *almost certain* (*small* to *large*) effective for improving postural parameters derived from force plate data. In addition, the change in AP COP velocity was *very likely* higher in the AE in comparison with the RE ($ES = -0.7$). The reason for this apparent superiority is unclear as our AE protocol was based on regular locomotive (e.g., walking), and some rhythmic (e.g., dancing) exercises without volitional or reactive steps in response to an environmental challenge. However, some adaptations specific to AE such as the kinesthetic, visual, motor control and cognitive inputs associated with walking-based activities could explain the efficacy of AE on all postural stability outcomes. The ability to walk depends on being able to control dynamic balance, thus requiring the control of the trajectory of the COP (Shkuratova, Morris, & Huxham, 2004). Importantly, the magnitude of improvement after both exercise interventions, with the exception of the *large* effect on UGT performance after RE training, ranged from *small* to *moderate*. Improvements in balance after RE have been attributed mostly by enhanced muscle strength, neural function and force control, as muscle torque is required to maintain balance (Orr et al., 2006). Nevertheless, both interventions involved single component exercise, thus specific balance exercises were not performed. Considering the specificity principle of training, improvements in balance would be amplified by adding balance training in both static and dynamic conditions.

In accordance with our expectations, the RE was *very likely* and *almost certainly* effective in improving KE and KF strength, respectively, and was *very likely* more effective for developing strength than AE. Evidence has consistently demonstrated on the basis of substantial data that older adults can substantially increase their strength after RE (Chodzko-Zajko et al., 2009), thus supporting our finding. Factors primarily responsible for increases in muscle strength after RE have been extensively determined, which include both morphological (increase in muscle cross-sectional area – hypertrophy, and other possible adaptations including hyperplasia, changes in fiber type, muscle architecture, myofilament density and the structure of connective tissue and tendons) and neurological adaptations (Folland & Williams, 2007). Although there is a growing body of evidence that AE training can induce skeletal muscle hypertrophy in sedentary individuals, including at old age (Konopka & Harber, 2014), our results showed an *unclear* change in knee strength after AE. Possibly a higher training frequency (>3 days per week) may be required to achieve a large number of muscle contractions that places a high-volume, low-load on skeletal muscle compared to RE training (Harber et al., 2009; Konopka et al., 2010). However, others have found that AE significantly increased muscle strength outcomes with a training frequency similar to ours (3 times a week) (Lovell, Cuneo, & Gass, 2010; Misic, Valentine, Rosengren, Woods, & Evans, 2009). Our findings may be related to some distinct mechanisms involved in aerobic activities performed overground, treadmill or cycle ergometers (Prosser, Stanley, Norman, Park, & Damiano, 2011). Also, in our overground protocol increasing intensity was based in rising movement velocity and not external load/resistance. Yet, the implications of these different exercising conditions on muscle strength gains remains unresolved and warrants further discussion and research. Aerobic-based exercise interventions need to be better defined according to, protocol duration, training frequency, target intensity, type of movement (only waking, cycling, or combination with ball games, relay races, dance movements, or obstacle courses) use of cardiovascular equipment (such as treadmills, stationary cycles, elliptical machines, and stair stepping machines) vs. overground walking. If the exercise intervention being tested is too divergent, conclusions cannot be drawn. Therefore, more studies are needed to support the present findings. Further, our results showed that AE training, although less effective then RE to improve muscle strength, elicited changes in knee strength that were *very likely* greater compared to CON group. Therefore, AE training should be perceived as a valid strategy to counteract the muscle loss associated with normal aging, as displayed by our CON group.

In this study we also tested the assumption that increase in muscle strength is an underlying mechanism for the improvement in balance control with exercise, which is currently under debate due to limited sound evidence (Orr, 2010). Only few studies explored the relationship between increased muscle strength and improved balance, and the majority of trials found null results (Bean et al., 2010; Chandler et al., 1998; Misic et al., 2009; Orr et al., 2006; Suri, Kiely, Leveille, Frontera, & Bean, 2011). Indeed, significant correlations between strength measures and balance performance are mostly provided by cross-sectional or observational studies, thus precluding the estimation of unambiguous causal effects (Orr, 2010). We observed that improvements in knee strength were *largely* associated with improvements in both dynamic and static balance in the RE group. Interestingly, the improvements in muscle strength explained 26–35% of total variance of balance change with exercise, which is somewhat higher than the cross-sectional associations between KE strength and balance reported by others (Carter et al., 2002). In line with a previous cross-sectional study (Bijlsma et al., 2013), we found *trivial* to *small* associations between strength change and change in COP movements parameters. Together, these data highlights a possible transfer of training-related gains from one component to other.

The primary strength of this study is the inclusion of quantitative postural control measures from COP parameters with a force platform, and both static a dynamic balance tests. In addition, we evaluated data from a RCT examining the effects of two long-duration training interventions (8 months), which have been understudied.

There are, however, a number of limitations to be considered when interpreting the results. A major limitation of this study is the lack of concurrent measures of other muscle groups such as ankle dorsiflexors and plantarflexors, hip abductor and adductors, and trunk muscle, which are suggested to be associated with variables of static/dynamic balance. However, the kinetics and kinematics of leg joints change with aging, consisting of increasing the work load of the proximal extensor muscles and reducing ankle efforts (Monaco, Rinaldi, Macri, & Micera, 2009). Muscle power was not considered in this study, although additional data suggest that muscle power rather than strength is a stronger determinant of physical performance and mobility skills in older adults (Bean et al., 2010). In addition, KE and KF are not the only factors contributing to balance improvements with exercise, especially in older adults. Indeed, changes in the various systems contributing to reduced balance control occur with aging and some (e.g. vestibular, proprioceptive and reaction time) may be also amenable to improvement with exercise interventions. The combination of strength and endurance training (i.e., concurrent training) was not investigated in the present study, although this training prescription appears to be an effective strategy in elderly populations (Cadore & Izquierdo, 2013). Finally, because we intentionally selected a healthy community-dwelling older women for this study, generalizability of these results in frail and/or institutionalized elderly persons, recurrent fallers, or persons with severe mobility limitations or chronic diseases is yet to be determined.

The findings of this study support adopting both RE or AE training to improve balance in community-dwelling older women, however, RE training showed superior benefits on muscle strength. Also, it was found that changes in leg strength were significantly associated with static and dynamic balance after RE training. Additional studies are needed to clarify the relationship of strength improvement and balance change, since our results demonstrated only associations with time-based balance tests but not with changes in COP movement during standing balance.

The present study brings relevant data to a broad audience in the geriatrics and gerontology field interested in the diagnosis, prevention, treatment and management of sarcopenia and balance problems. Data regarding these associations after exercise training have special interest in professional practice, as muscle weakness is a common target in exercise interventions.

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Table 1

Descriptive characteristics of study participants at baseline. Data are presented as mean ± standard deviation.

Characteristic	CON group (n = 24)	RE group (n = 23)	AE group (n = 24)
Age (years)	68 ± 6	67 ± 5	70± 5
Height (m)	1.55 ± 0.05	1.56 ± 0.10	1.52 ± 0.07
Weight (kg)	67.2 ± 10.7	69.5 ± 11.2	63.7 ± 9.6
BMI (kg/m^2)	28.1 ± 3.5	28.8± 4.6	27.5 ± 3.8
Total fat mass (%)	38.4 ± 4.6	38.8 ± 4.4	39.2 ± 4.5
Total lean mass (kg)	39.4 ± 5.0	41.8 ± 8.6	37.3 ± 5.2
Time spent in MVPA (min/day)	78.8 ± 40.5	93.2 ± 26.3	86.2 ± 32.1

BMI, body mass index; MVPA, moderate to vigorous physical activity.

Table 2

Knee Strength variables and outcome measures at baseline and statistics for effects and inferences in the 32 weeks (% change) for within-groups comparisons.

Variables	CON group (n = 24)				RE group (n = 23)				AE group (n = 24)			
	Baseline (mean ±SD)	% Change (mean; 90% CI)	ES; 90% CI	QI	Baseline (mean±SD)	% Change (mean; 90% CI)	ES; 90% CI	QI	Baseline (mean±SD)	% Change (mean; 90% CI)	ES; 90% CI	QI
UGT, s	6.05 ± 0.80	4.0; 0.9 to 7.3	0.3; 0.1 to 0.5	Likely	5.47 ±0.53	−12.0; −15.8 to −8.0	−1.3; −1.7 to −0.8	Almost certain	5.90 ± 0.94	−12.7; −16.1 to −9.2	−0.9; −1.2 to −0.6	Almost certain
OLST, s	26.89 ± 16.17	−14.9; −28.1 to 0.8	−0.2; −0.5to 0.01	Likely	26.29 ± 13.22	25.0; 3.1 to51.5	0.4; 0.01 to0.7	Likely	28.80 ± 14.88	31.2; 1.0 to 34.7	0.4; 0.02 to 0.8	Likely
EA, cm^2	7.25 ± 4.37	6.4; −7.5 to 22.5	0.1; −0.1 to 0.3	Possibly	7.37 ± 4.84	−46.0; −59.2 to −28.5	−0.9; −1.3 to −0.5	Almost certain	7.24 ± 4.30	−49.1; −60.5 to −34.4	−1.1; −1.5 to −0.7	Almost certain
EA/time	0.40 ± 0.34	25.1; 8.7 to 43.9	0.2; 0.1 to 0.4	Likely	0.42 ± 0.47	−56.8; −69.7 to −38.5	−0.8; −1.2 to −0.5	Almost certain	0.49 ± 0.67	−61.2; −74.4 to −41.2	−0.9; −1.3 to −0.5	Almost certain
AP COP velocity,cm/s	4.02 ± 1.12	6.4; −2.8 to 16.5	0.2; −0.1 to 0.5	Possibly	4.01 ± 1.06	−11.6; −20.8 to −1.3	−0.4; −0.8 to −0.04	Likely	3.73 ± 1.15	−19.1; −29.5 to −7.3	−0.6; −1.1 to −0.2	Very Likely
ML COP velocity, cm/s	4.80 ± 2.13	−5.6; −18.3 to 8.9	−0.1; −0.4 to 0.2	Possibly	4.71 ± 2.07	−25.1; −35.7 to −12.7	−0.7; −1.1 to −0.3	Very Likely	4.34 ± 1.85	−27.8; −39.9 to −13.4	−0.7; −1.1 to −0.3	Very Likely
KE strength, Nm	80.97± 15.51	−7.8; −12.6 to −2.7	−0.3; −0.5 to −0.1	Likely	88.98 ± 29.17	10.7; 5.6 to 16.1	0.3; −0.2 to 0.4	Very Likely	84.26 ± 17.29	−1.8; −6.4 to 3.1	−0.01; −0.2 to 0.2	Unclear
KF strength, Nm	42.99 ± 10.78	−5.3; −10.3 to 0.0	0.2; −0.3 to 0.0	Possibly	51.94 ± 19.02	24.3; 15.4 to 33.8	0.6; 0.4 to 0.8	Almost certain	46.38 ± 12.72	2.1; −5.2 to 10.0	0.1; −0.2 to 0.3	Unclear

AP, anterior-posterior; COP, center of pressure; EA, elliptical area; ES, Effect Size; KE, knee extensor; KF, knee flexor; ML, medial-lateral; OLST, one-leg stance test; QI, qualitative inference; UGT, up and go test.

Table 3

Difference between groups and statistics for effects and inferences in the 32 weeks.

	Group Comparison (RE-CON)			Group Comparison (AE-CON)			Group Comparison (AE-RE)		
Variables	**Difference between groups (% mean; 90% CI)**	**ES; 90% CI**	**QI**	**Difference between groups (% mean; 90% CI)**	**ES; 90%CI**	**QI**	**Difference between groups (% mean; 90% CI)**	**ES; 90%CI**	**QI**
UGT, s	−14.7; −19.1 to −10.0	−1.2; −1.6 to −0.8	Almost certain	−16.1; −20.2 to −11.9	−1.2; −1.6 to 0.9	Almost certain	−0.8; −6.4 to 5.1	−0.1; −0.5 to 0.4	Unclear
OLST, s	46.9; 14.4−88.5	0.6; 0.2−0.9	Very Likely	54.2; 13.5−109.3	0.6; 0.2−1.0	Very Likely	5.0; −23.5 to 44.1	0.1; −0.4 to 0.5	Unclear
EA, cm^2	−49.3; −62.8 to −30.9	−1.0; −1.4 to −0.5	Almost certain	−52.2; −64.0 to −36.4	−1.1; −1.5 to −0.7	Almost certain	−5.7; −34.7 to 36.3	−0.1; −0.6 to 0.4	Unclear
EA/time	−65.5; −76.3 to −49.7	−1.1; −1.5 to −0.7	Almost certain	−69.0; −79.9 to −52.1	−1.1; −1.5 to −0.7	Almost certain	−10.2; −47.2 to 52.7	−0.1; −0.6 to 0.4	Unclear
AP COP velocity, cm/s	−13.7; −24.7 to −1.0	−0.5; −1.0 to −0.04	Likely	−21.0; −32.6 to −7.5	−0.7; −1.2 to −0.2	Very Likely	−8.5; −22.9 to 8.5	−0.3; −0.8 to 0.3	Unclear
ML COP velocity, cm/s	−19.0; −34.4 to 0.0	−0.5; −0.9 to 0.0	Likely	−22.0; −38.2 to −1.5	−0.5; −1.0 to −0.03	Likely	−3.5; −23.6 to 21.4	−0.1; −0.5 to 0.4	Unclear
KE strength, Nm	19.9; 11.4−29.1	0.7; 0.4− 1.0	Almost certain	6.4; −1.3 to 14.6	0.3; −0.06 to 0.7	Possibly	−11.3; −16.9 to −5.3	−0.5; −0.7 to −0.2	Very Likely
KF strength, Nm	29.5; 18.2−41.8	0.8; 0.5−1.1	Almost certain	6.4; −2.9 to 16.6	0.2; −0.1 to 0.6	Possibly	−17.8; −25.8 to −9.0	−0.6; −0.9 to −0.3	Very Likely

AP, anterior-posterior; COP, center of pressure; EA, elliptical area; ES, Effect Size; KE, Knee extension; KF, Knee flexion; ML, medial-lateral; OLST, one-leg stance test; QI, qualitative inference; UGT, up and go test.

Table 4

Correlation (r, 90% CI), R^2, and least-squares regression slope (*B*) for the relationship between change in isokinetic strength and change in balance variables after 32 weeks of RE training.

Balance outcome (s)	Predictor (Nm)	r (90% CI)	R^2	Magnitude	*B*	*P*
Δ UGT	Δ Knee extension PT	−0.509 (−0.73 to −0.191)	0.26	Large	−0.035	0.013
	Δ Knee flexion PT	−0.528 (−0.742 to −0.215)	0.28	Large	−0.033	0.009
Δ OLST	Δ Knee extension PT	0.579 (0.284–0.773)	0.35	Large	0.808	0.004

Δ, change; CI, confidence interval; OLST, one-leg stance test; PT, Peak torque; UGT, up and go test.