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Original Study

Effects of Resistance Training on Functional Strength and Muscle Mass in 70-Year-Old Individuals With Pre-sarcopenia: A Randomized Controlled Trial

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A B S T R A C T

Objective: Sarcopenia has been defined as age-related loss of muscle mass and function. The aim of this randomized controlled trial was to examine the effects of a 10-week instructor-led resistance training program on functional strength and body composition in men and women aged 70 years with pre-sarcopenia.

Design, Setting, and Participants: Participants were randomized to either 10 weeks of a physical training regimen including optional nutritional supplementation (n = 36) or to a control group (n = 34) (ClinicalTrials.gov, no. NCT03297632). The main outcome was changes in the Short Physical Performance Battery (SPPB) score. Secondary outcomes included the Timed Up and Go test, chair sit-stand time, lean body mass, and fat mass.

Results: The intervention had no significant effect on SPPB in the total cohort ($P = .18$), when comparing changes in the intervention group with the control group. However, those given the intervention in the male subcohort increased 0.5 ± 0.4 (mean ± standard error for the difference) points in SPPB during follow-up ($P = .02$) compared to male controls. With respect to secondary outcomes, the intervention group decreased 0.9 ± 0.6 seconds in chair sit-stand time compared to controls ($P = .01$). Furthermore, the intervention resulted in significantly greater improvements for the training group than control group in all measures of body composition ($P \leq .01$ for all). For example, lean body mass increased by a mean of 1147 ± 282 g ($P < .001$), and total fat mass decreased by a mean of 553 ± 225 g ($P = .003$), favoring the intervention group.

Conclusion/Implications: The main finding of this intervention study is that an easy-to-use, functional resistance training program was effective in maintaining functional strength and increasing muscle mass in older adults with pre-sarcopenia.

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The term "sarcopenia" is often used to describe muscle atrophy, and currently sarcopenia affects up to 50% of individuals aged ≥80 years.[1] The European Working Group on Sarcopenia in Older People (EWGSOP) has proposed the staging of sarcopenia as "pre-sarcopenia," defined as low muscle mass, and "sarcopenia," defined as low muscle mass and strength or poor physical performance.[2] Low muscle mass and sarcopenia have been shown to independently predict falls, fractures, mortality, and overall poor health,[3,4] which often influence quality of life in older people. Given the consequences of sarcopenia associated with aging,[5,6] preventive measures with focus on older people would be of importance. Because physical inactivity predisposes for muscle wasting and loss of function, one important strategy to prevent sarcopenia could include increased physical activity.

Resistance training (RT) programs have been demonstrated to increase muscle function and muscle mass to some degree in the general older individual.[7,8] Less is known about the effects of RT programs in older individuals with sarcopenia or pre-sarcopenia, which is of interest given the consequences outlined above. Furthermore, additional knowledge is also needed considering feasibility, sustainability,

AH and PN contributed equally to the present paper.
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and safety of RT in individuals with sarcopenia or pre-sarcopenia.[9] As older individuals seem to prefer easy, accessible training regimens that are easy to perform in any setting, body weight–based exercise programs may be preferable to programs involving gym equipment.[10] The purpose of this study was to examine the effects of a 10-week instructor-led body weight–based resistance exercise program in men and women aged 70 years with pre-sarcopenia. The primary objective was to investigate whether the program improved functional strength. A secondary objective was to examine whether the training improved body composition including muscle mass.

Methods

Study Design

The present investigation is a randomized, controlled, parallel-group, 2-arm trial with 1:1 allocation ratio (ClinicalTrials.gov, no. NCT03297632). This study was approved by the regional research ethical review board of Umeå (Dnr 2017-132-31M), with extension and reported according to the CONSORT guidelines.[11]

Participants

The participants included in the present study were selected from an ongoing, population-based, primary prevention study: the Healthy Ageing Initiative (HAI). In short, all 70-year-old individuals living in Umeå municipality, northern Sweden, were invited to complete a health survey with the aim of reducing the future risk of non-communicable disease. The HAI study has no exclusion criteria and an attendance rate of 68% of the eligible population. The research protocol has been described in detail elsewhere.[12] The eligibility criteria for the present study were based on the normative values of the first diagnosis criterion for pre-sarcopenia and sarcopenia laid out by the EWGSOP, which in this population translated to appendicular lean mass index (defined as arm lean mass + leg lean mass divided by height squared) $\leq$ 7.29 (range, 5.69-7.29) among men, and $\leq$5.93 (range, 4.50-5.93) among women.[2]

Intervention

All participants were assessed at baseline, then randomized to a control or intervention group using a total of 72 opaque sealed envelopes containing notes with “Training” or “Control” written on them (36 of each). Envelopes were prepared and controlled by A.H. and N.S. prior to randomization. The envelopes were then scrambled before each participant was allowed to draw an envelope and thus find out which group they were allocated to under the supervision of S.V. and L.B. Participants in the control group were asked to go about their normal lives and were scheduled for a second assessment 10 weeks later. Persons in the intervention group were assigned to participate in a 10-week instructor-led progressive RT program consisting of 3 sessions ($\sim$45 minutes each) per week with groups of $\leq$12 participants. All participants were assessed at the end of the intervention. The investigator performing the assessments at baseline and follow-up was blinded to group allocation.

The RT intervention was designed to increase participants' functional strength and muscle mass. Moderate to high RT intensity was applied using the Borg CR-10 scale,[13,14] with participants' perceived exertion scoring 6 to 7 of a maximum of 10. During the sessions, 8 exercises were performed with the aim of engaging muscle groups in the whole body, with a focus on strengthening of the lower-extremity muscles using functional exercises that are relevant for activities of daily living.[14] Also, suspension bands were used as support for a majority of the exercises. Please see Supplementary Figure 1 for pictures and supplementary video for a short film describing the exercises performed in the RT intervention.

All training sessions started with 5 to 10 minutes of whole-body warm-up exercises. During the first week of training, no weight was used; the focus was on learning the exercises in a safe way using only participants' body weight and suspension bands. In the first week, exercises were performed in 2 sets of 12 repetitions each, followed by 3 sets of 10 repetitions each in weeks 2 to 4. The intensity of the program increased in terms of sets and resistance, with maintenance of CR-10 scores of 6 to 7. In weeks 5 to 7, participants performed 4 sets of 10 repetitions each. Up until this point, participants had been instructed that concentric and eccentric muscle contractions should last for approximately 2 seconds each. In weeks 8 to 10, the focus was on muscle power training using the same exercises, although participants were instructed to perform these exercises with considerably faster muscle contractions. During the training sessions, 2 instructors were present and supervised the training. The instructors' role was both to make sure the exercises were performed correctly, in a safe way, and also to monitor the maintenance of intensity. Once a week, the instructors noted the weight each participant used in every exercise by using a luggage scale. During the training sessions, instructors asked the participants what they scored on CR-10 scale; if they scored less than 6, more weight was added progressively. By using a protocol where the weight each participant used every week was noted, participants knew where to start the next week. For the exercises without weights, such as resistance band exercises, markers on the floor were used to easily know where to start and how to increase resistance. Resistance bands and weight vests, weight belts, and backpacks filled with weights or water bottles were offered. A nutritional supplement (taken once a day for 10 weeks) was also offered to participants in the intervention group, but it was not a mandatory component of the program. The 250-mL liquid supplement was milk based with added milk protein, supplying 175 kcal in the form of 19 g carbohydrates, 21 g protein, and 1.5 g fat (week 1-7 of the intervention) or 10 g carbohydrates, 30 g protein, and 1.5 g fat (week 8-10 of the intervention) (Gainomax Protein Drink, Norrmejerier, Umeå, Sweden).

Assessment

Primary outcome

Functional strength and physical function in the lower extremities were assessed using the Short Physical Performance Battery (SPPB).[15] The SPPB includes assessment of a standing balance test, a walk test, and a chair sit-stand test. For the balance test, participants were asked to stand in a side-by-side position, a semitandem position, and a full-tandem position. To receive 1 point and advance to the semitandem stance, participants had to be able to hold the side-by-side position for at least 10 seconds. The same procedure was used for the tandem positions. The walk test included a 4-m walk from standing position in preferred gait speed (the fastest time of 2 trials was used). For the chair sit-stand test, participants were asked to complete 5 chair sit-stand cycles as rapidly as possible with the arms folded across the chest.

Total SPPB scores (range, 0-12) were calculated by summing up the 3 individual scores [each ranging from 0 (unable to complete test) to 4]. Cut points for individual test scores of 1 to 4 were based on previously established quartiles of timed performance (for the gait speed and chair sit-stand tests) or criteria (for the balance test), according to the methods developed by Guralnik et al.[15] Higher total scores indicated greater lower-extremity functional strength.

Secondary outcomes

The separate tests included in the SPPB were used as separate outcomes. Participants performed the Timed Up and Go (TUG) test,

which quantifies functional mobility, lower-leg muscle strength, and gait performance.[13] Participants started in a seated position on a chair with armrests, then stood and walked 3 m at normal gait speed, turned 180°, walked back to the chair, and sat down. The test was performed once and timed.

Using a hydraulic hand dynamometer (Jamar; Patterson Medical, Warrenville, IL), isometric muscle strength was tested as a marker of general body strength. Participants were instructed to stand while maintaining the nondominant arm at 90° with the elbow close to the waist, and the maximum grip strength (in kilograms) was measured. The maximum value obtained in 2 consecutive attempts was recorded. Participants' height while barefoot (in meters) was determined using a stadiometer (Holtain Limited; Crymych, Dyfed, United Kingdom) and their body weight (in kilograms) was measured using a clinical scale (HL 120; Avery Berkel, Fairmont, MN). Body mass index was calculated by dividing the body weight with height squared.

Lean body mass (LBM) was analyzed using a Lunar iDXA device (GE Healthcare Lunar, Madison, WI).[14] The appendicular lean mass index was calculated by dividing the total muscle mass in the arms and legs by height squared, according to the EWGSOP standard. Also total fat mass (FM) was derived from the iDXA scan.[15]

Statistical Analysis

Descriptive statistics were calculated, and values are presented as means and standard deviations. The paired-samples *t*-test was used to assess changes within groups in functional strength and body composition over time (baseline to post-intervention). Between-group comparison of outcome measures was conducted using analysis of covariance, where the value for the outcome at the 10th week of follow-up was used as independent variable with adjustment for baseline values for the outcome.[16] Statistical interaction for the outcomes of interest was tested by creating product interaction terms for sex and intervention (both 0 or 1), which were added to the other independent variables (sex, intervention, and baseline value for the outcome variable tested) in the statistical models. For these analyses, P values < 0.1 were considered to be significant. For all other analyses, P values $< .05$ were considered to be significant. All statistical tests were performed using SPSS software (version 24 for Macintosh; IBM

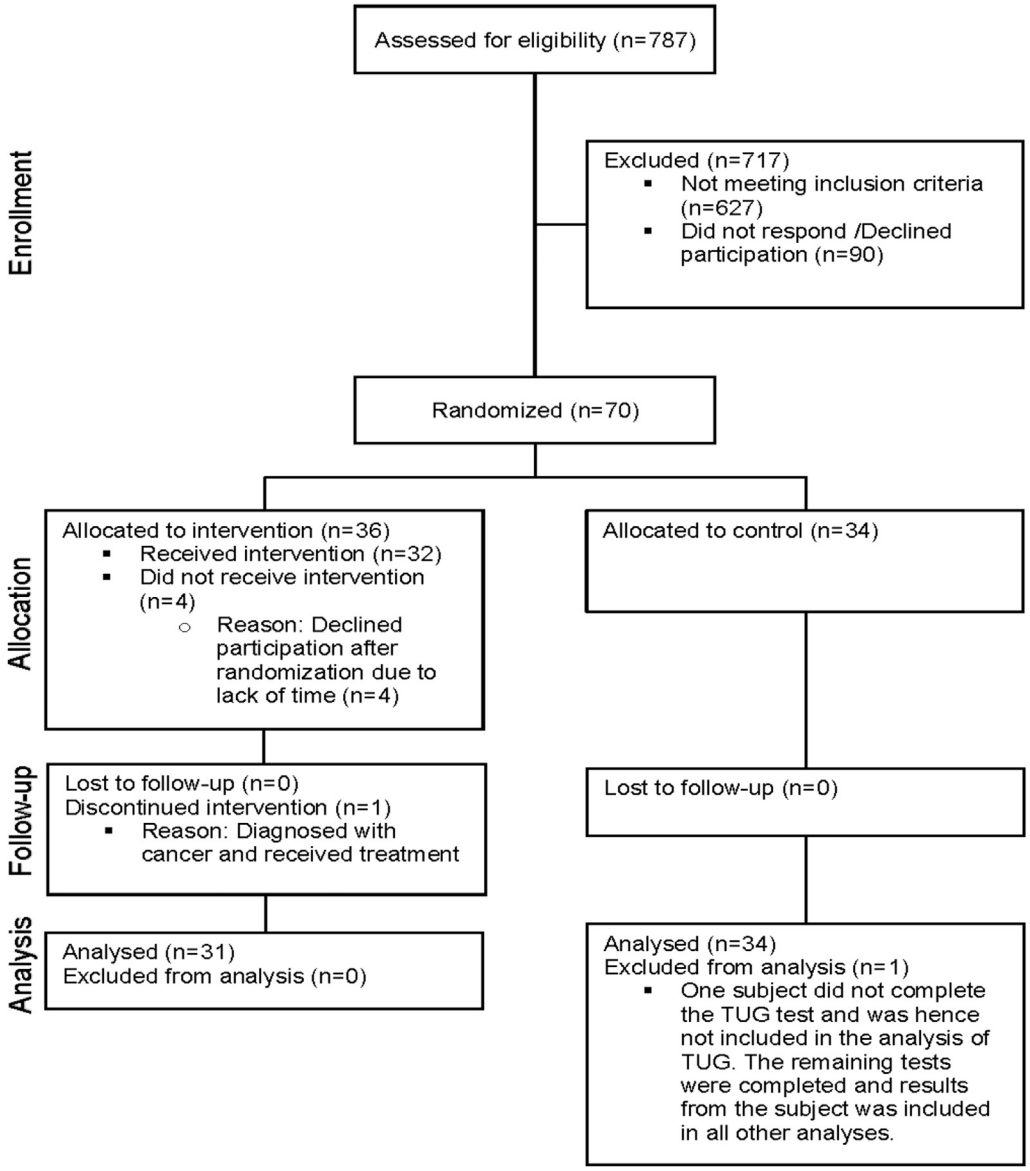

Fig. 1. Flow chart of study participants and allocation.

Corporation, Armonk, NY) by researchers blinded to participant allocation.

Results

Participant Recruitment, Allocation, and Adherence to Intervention

Of the 787 individuals who had been participating in the HAI study during the past year (August 2016 to July 2017), a total of 161 persons (76 men and 85 women) met the inclusion criterion based on a low muscle mass, as defined in the Methods section. Recruitment ceased when the predetermined sample size of 72 subjects (34 men and 38 women) was met. The main reason for declining participation was due to not having the time to participate. Of the 72 persons included, 2 persons failed to attend baseline testing, week 1 August 2017, resulting in a total study sample of 70 persons prior to randomization (Figure 1). After baseline testing, 36 persons were randomized to the intervention group and 34 persons to the control group. Four of the 36 participants randomized to the intervention group dropped out before the intervention started because of lack of time, and one person dropped out after 8 weeks of the intervention because of severe disease; thus, 31 participants in the intervention group finished the assessment conducted after 10 weeks. The mean intervention attendance rate to the training sessions was 91% (range, 63%-100%) and 26 of 31 (84%) participants in the intervention group chose to take the nutritional supplement. All participants assigned to the control group finished the second assessment.

Participant Characteristics

The characteristics of the sample, including baseline data, are shown in Table 1. The mean age of the participants was 70.9 ± 0.03 years, with equal representation of men and women (54% women). Body mass indices ranged from 16.4 to 32.4 (mean, 23.3). The groups had similar characteristics at baseline, although the intervention group performed slightly better at tests on physical function, for example, walking speed and sit-to-stand time. The LBM measurements for the 2 groups were similar. Four subjects in each group reported a previous fracture.

Table 1
Participant Characteristics at Baseline

Variables	Control (n = 34)	Intervention (n = 36)	Total (N = 70)
Age, y	70.0 ± 0.29	70.9 ± 0.28	70.9 ± 0.03
Female, n (%)	18 (53)	20 (56)	38 (54)
Height, m	1.69 ± 0.11	1.68 ± 0.09	1.69 ± 9.63
Weight, kg	67.4 ± 14.0	64.8 ± 11.5	66.1 ± 12.7
BMI	23.33 ± 3.01	22.72 ± 2.35	23.01 ± 2.69
SPPB			
Walk, s	3.8 ± 0.98	3.3 ± 0.69	3.5 ± 0.87
Sit to stand, s	10.6 ± 4.08	9.5 ± 2.73	10.1 ± 3.46
Balance, 0-4	3.7 ± 0.7	3.8 ± 0.5	3.8 ± 0.6
Total score	11.0 ± 1.71	11.4 ± 1.38	11.2 ± 1.55
TUG, s	9.9 ± 2.34	9.0 ± 1.83	9.4 ± 2.13
Hand grip, kg	29.9 ± 11.1	32.0 ± 10.0	31.0 ± 10.5
DXA measurements			
Total fat mass	23.06 ± 8.07	20.53 ± 4.98	21.82 ± 6.72
Total lean mass	41.84 ± 8.60	41.66 ± 7.70	41.74 ± 8.10
Arm lean mass	4.55 ± 1.44	4.46 ± 1.30	4.50 ± 1.36
Leg lean mass	13.63 ± 3.10	13.46 ± 2.80	13.54 ± 2.91
ALMI	6.24 ± 0.85	6.25 ± 0.86	6.24 ± 0.85

ALMI, appendicular lean mass index; BMI, body mass index; DXA, dual-energy x-ray absorptiometry.
Values are presented as means ± standard deviations, except where otherwise indicated.

Effects of the Intervention on Estimates of Functional Strength

When comparing the intervention group and control group, the change in the SPPB total during follow-up was not significant ($P = .18$), although the sit-to-stand test was significantly improved by 0.9 ± 0.6 (mean ± standard error for the difference) seconds in the intervention group compared with the control group ($P = .01$; Table 2). Moreover, there was a significant interaction for sex with respect to the effects of the intervention during follow-up for several outcomes ($P < .10$). In men (Figure 2), the intervention group increased 0.5 ± 0.4 points during follow-up in the SPPB total score ($P = .02$) and decreased 1.2 ± 0.6 seconds in TUG ($P = .04$) compared to that in male controls. During follow-up, the intervention group showed improvement in all functional outcomes, including the total SPPB score (all $P < .05$), TUG time ($P < .001$), and handgrip strength ($P = .007$). In contrast, the control group showed no improvement in functional outcomes, except for TUG time ($P = .02$).

Effects of the Intervention on Body Composition

The intervention group showed significant improvement in LBM and FM compared with the control group ($P < .01$ for both; Table 2) during follow-up. Thus, LBM increased by 1147 ± 282 g ($P < .001$) and total FM decreased by a mean of 553 ± 225 g ($P = .003$), compared with the control group. In addition, lean arm mass, lean leg mass, and the appendicular lean mass index improved in the intervention group compared to the control group ($P < .001$ for all). LBM increased 2.8% in the intervention group whereas FM decreased 2.4%, with no apparent sex difference in intervention effect (Figure 3). In the control group, no significant change in any body composition parameter was observed during the intervention period.

Effects of the Intervention on Perceived Health and Side Effects

During the course of the training intervention, several aspects of perceived health and possible side effects were documented from the intervention group. A participant who previously had undergone shoulder surgery experienced shoulder pain, particularly during push-ups, with pain sensations also between training sessions. Another participant experienced vertigo on a few occasions during training sessions. A third participant experienced knee pain that endured for about 1 week. Most of the participants in the training group reported delayed-onset muscle soreness, mainly located to hamstrings and quadriceps femoris. Furthermore, 2 participants reported cessation of back pain, a condition they had well before the start of the study. Additionally, another participant reported less headache and total relief of neck pain as compared to before the start of the intervention.

Discussion

In the present randomized study, a 10-week body weight–based RT program resulted in significant effects on the primary outcome of the SPPB test, but only in the male subgroup. With respect to the other functional outcomes, there was a significant effect of the intervention on the sit-to-stand test in the total cohort of men and women. Overall, all outcomes improved significantly in the intervention group, whereas all results but the TUG time remained stable in the control group. With respect to body composition, the intervention group improved in all measures of body composition, including high gains in LBM, compared with the control group. Importantly, all exercises were designed so that they would be easy to perform in participants' homes, in contrast to programs involving the use of weight machines.[10]

Low muscle mass is known to independently predict falls,[17] fractures, and overall poor health, including death.[4] The development of a

Table 2
Changes in the Outcomes During the 10-Week Intervention Period

	Within-Group Differences						Between-Group Differences		
	Control (n = 34)			Intervention (n = 31)			Control (n = 34)	Intervention (n = 31)	
	Baseline	10 wk	*P*	Baseline	10 wk	*P*	Difference	Difference	*P*
SPPB									
Walk, s	3.81 ± 0.98	3.85 ± 1.64	.83	3.29 ± 0.72	3.09 ± 0.67	.007	0.05 ± 1.27	−0.20 ± 0.39	.24
Sit to stand, s	10.6 ± 4.08	10.5 ± 4.00	.46	9.43 ± 2.81	8.25 ± 2.12	.005	−0.30 ± 2.24	−1.18 ± 2.19	.01
Balance, 0-4	3.7 ± 0.7	3.8 ± 0.5	.37	3.8 ± 0.5	3.8 ± 0.5	>.999	0.1 ± 0.5	0.0 ± 0.5	.54
Total score, 0-12	11.0 ± 1.71	11.1 ± 1.94	.82	11.4 ± 1.45	11.7 ± 0.97	.048	0.06 ± 1.51	0.32 ± 0.87	.18
TUG, s	9.89 ± 2.34	9.10 ± 3.14	.02	8.90 ± 1.94	7.57 ± 1.53	<.001	−0.78 ± 1.87	−1.33 ± 1.44	.12
Handgrip, kg	30.0 ± 11.1	30.5 ± 10.6	.41	30.7 ± 9.55	32.0 ± 10.7	.007	0.56 ± 3.90	1.30 ± 2.50	.36
DXA measurement									
Total fat mass, kg	23.1 ± 8.07	23.1 ± 7.91	.89	20.5 ± 4.99	20.0 ± 4.64	.002	0.022 ± 0.90	−0.56 ± 0.90	.003
Total lean mass, kg	41.8 ± 8.64	41.9 ± 8.63	.69	40.8 ± 7.60	41.9 ± 7.94	<.001	0.007 ± 1.35	1.17 ± 0.80	<.001
Arm lean mass, kg	4.56 ± 1.44	4.57 ± 1.46	.71	4.30 ± 1.22	4.53 ± 1.31	<.001	0.015 ± 0.22	0.23 ± 0.28	<.001
Leg lean mass, kg	13.6 ± 3.07	13.6 ± 3.02	.66	13.2 ± 2.81	13.6 ± 2.82	<.001	−0.044 ± 0.65	0.44 ± 0.37	<.001
ALMI	6.24 ± 0.85	6.23 ± 0.86	.58	6.17 ± 0.87	6.40 ± 0.89	<.001	−0.005 ± 0.25	0.24 ± 0.17	<.001

ALMI, appendicular lean mass index.
Values are presented as means ± SDs.

customized physical training program that could improve muscle strength and mass in frail older individuals is thus of interest. Weight training is known to predominantly increase muscle strength initially by neuromuscular adaptation, in younger and older individuals.[18] The observed increase in muscle mass during a training period of only 10 weeks was thus an unexpected, though encouraging finding of this study. Thus, RT programs most often have limited effects on muscle hypertrophy in older adults,[18] and the effects seem to be influenced by aging. In a meta-analysis including a total of 1328 individuals with a mean age of 65 years, the effects of RT on lean body were rather similar to that in our study, albeit during 20 weeks of training.[19] In addition, the effects were lower in subjects with a higher age. The effects of training in our study are especially encouraging because we only included individuals with low muscle mass, which may be regarded as irreversible in older people. The increases in muscle mass could have been influenced both by the nutritional supplement offered to individuals in the intervention group and the specific RT program used. Several previous studies have identified protein intake as a key factor for sarcopenia prevention in older people,[20–22] especially during RT in adults.[23] This was the reason for offering the supplement, and the effects seen on muscle mass was likely influenced by this component. In addition, the type and high intensity of training most likely influenced the gains seen. The participants were highly motivated and trained at high intensity 3 times a week, with a participation rate of 91%. Previously, high-intensity RT programs, rather than training at low intensity, has been shown to result in high increases in muscle strength in untrained older individuals.[24,25]

Given the high effects of the RT program on muscle mass, similar improvements would be expected on the functional measures. However, the improvements were smaller and reached significance predominantly in the male subcohort. These gender-specific effects may be attributable to external factors, such as motivation and competition, which were observed during training and could have influenced the results. In support of this hypothesis, the effects of the intervention on LBM were similar in men and women. The relatively low effects on the main outcome of SPPB also can be explained likely by a ceiling effect. Thus, the mean baseline score was 11.2 of a maximum of 12, with no room for improvement for many participants. This ceiling effect was obvious for the standing balance test, whereas the intervention had significant effect on the sit-to-stand test that also is part of the SPPB. As an increase in lean arm mass was observed in the intervention group, the assessment of upper body strength in addition to lower extremity strength, for example, the Continuous Scale–Physical Functional Performance,[26] might therefore have been of interest to test in addition to hand grip strength.

A potential limitation of the present study is the sample size. A larger sample would have increased the statistical power of the analysis, which might have influenced the results, especially in the

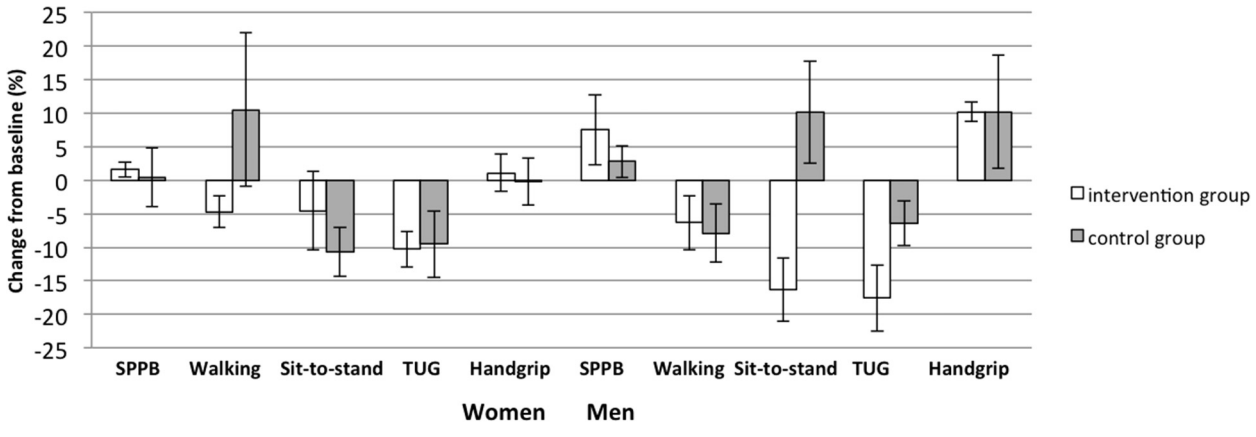

Fig. 2. Changes from baseline in functional strength in the intervention group and control group for men and women separately. Means and standard error of the mean are presented.

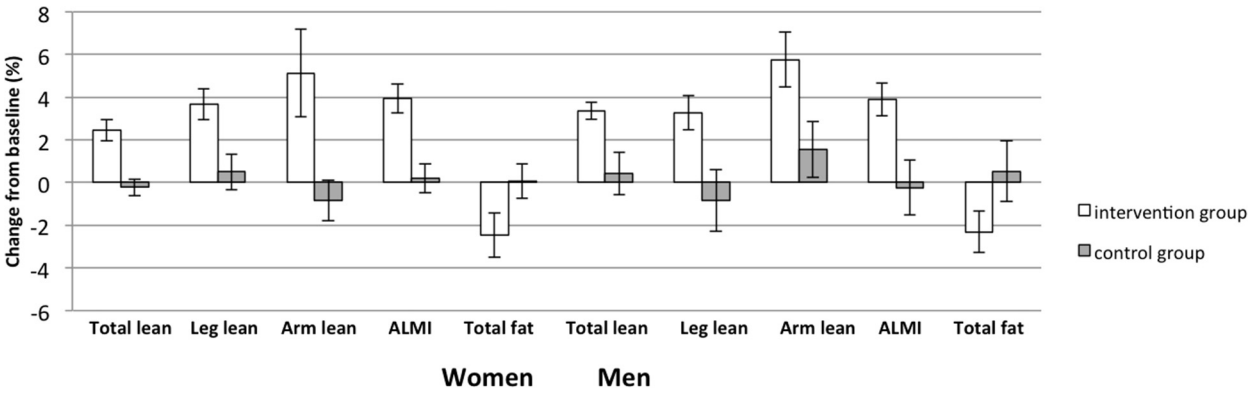

Fig. 3. Changes from baseline in body composition in the intervention group and control group for men and women separately. Means and standard error of the mean are presented. (ALMI, appendicular lean mass index.)

sex-stratified analysis. Yet, the effect of the intervention on body composition was significant, and the lack of effect on SPPB scores in the total cohort was likely also influenced by a ceiling effect. In addition, we could not determine whether the observed effects of the intervention were due to the training program and/or the recovery drink. Thus, the inclusion of an additional training group that did not receive the recovery drink would have been of value. Given the effects especially on muscle mass in the intervention group, the possibility of a measurement error must be considered. However, the changes seen in fat mass and LBM were in accordance with the changes seen in total body weight, measured by a digital scale. In addition, any measurement error would influence the intervention and control groups similarly. Finally, dual-energy x-ray absorptiometry has been demonstrated to be very accurate in determining LBM and changes in LBM.[15,27] The major strength of the present study was the randomized design with assessors blinded to the intervention, decreasing the risk of bias and confounding. Another strength is the design of the training program, which does not require gym equipment and focuses on functional exercises that are easy to perform in any setting.

Conclusions/Relevance

The key finding of this study is that an easy-to-use strength training program with a focus on body weight–based exercises was effective in preventing loss in functional strength and increasing muscle mass and in older adults with pre-sarcopenia. Based on our experience with the intervention program, we suggest that it is important to progressively increase training load and to motivate participants to train at a high intensity. These improvements may influence future falls, fractures, and overall poor health. Finally, the effects with respect to muscle mass should be examined further in additional studies to determine whether they were caused jointly by nutritional supplementation and training. The sample for the present study was population based, with no exclusion criteria applied to men and women with pre-sarcopenia. We thus believe that the results can be generalized to older individuals with low muscle mass.

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Supplementary Data

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.jamda.2018.09.011.

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