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Resistance Exercise for the Aging Adult: Clinical Implications and Prescription Guidelines

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ABSTRACT

Sarcopenia and weakness are known to precipitate risk for disability, comorbidity, and diminished independence among aging adults. Resistance exercise has been proposed as a viable intervention to elicit muscular adaptation and improve function. However, the reported prevalence of resistance exercise participation among US adults aged >50 years is very low. This may be largely attributable to inconsistency in study results that fail to fully inform the clinical and public health community of its overall value. Therefore, the purpose of this commentary review is to report the findings of recently published meta-analyses that systematically examined the overall value of resistance exercise among healthy aging adults for strength and lean body mass outcomes. Evidence reveals that not only is resistance exercise very effective for eliciting strength gain and increases in lean body mass, but that there is a dose-response relationship such that volume and intensity are strongly associated with adaptations. These findings reflect and support the viability of progression in resistance exercise dosage to accommodate optimal muscular adaptive response. Progressive resistance exercise should thus be encouraged among healthy adults to minimize degenerative muscular function associated with aging.
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KEYWORDS: Aging; Meta-analysis; Muscular strength; Older adult; Resistance exercise; Sarcopenia

The term sarcopenia has emerged as an equivocal designation of vulnerability to weakness, disability, disease comorbidity, and diminished independence among aging adults. Decreases in muscle tissue quantity and quality may begin to occur before the fourth decade[1] and gradually worsen through the later stages of adulthood. Moreover, these age-related declines often coincide with subclinical chronic inflammation and oxidative stress,[2] insulin resistance,[3] myosteatosis (ie, intra- and intermuscular adipose tissue infiltration), and increased overall fat mass (ie, "sarcopenic obesity").[4,5] Sarcopenia represents a complex phenotype of numerous interrelated pathologies, exposures, and behavioral characteristics, and thus, failure to prevent its progression may significantly exaggerate risk of frailty and mobility disability[6,7] and impede optimal quality of life.[8]

Although a robust association exists between chronological age and virtually every symptom, aging per se is a crude proxy for establishing emergent risk. Because sarcopenia is *not* considered to be a "disease," but rather a collection of conditions that translate to gradual functional deficit and comorbidity, it is rarely detected at a premorbid stage and often causes significant latent consequences and residual dysfunction. Specific age-related declines in muscle mass and force production capacity reflect underlying perturbations in the metabolic, hormonal, and neurological physiology. Although somewhat distinct, these changes characterize the collective sequelae of the aging progression, which is to a large extent, known to manifest without clinical presentation. From a morphological context, muscle cross-sectional area[9] and single-fiber atrophy accounts for some of the variability in strength loss among elderly persons, and this atrophy appears to be exaggerated in Type II fiber. Moreover, in conjunction with chronic inflammation and oxidative stress, age-related apoptotic motor neuron loss is

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proposed to directly attenuate strength, rate of force development, and muscular power,[10] and eventually lead to declines in muscle fiber number and physiological cross-sectional area.

Notwithstanding the original intent of "sarcopenia" as a designation for muscle atrophy, this term also is loosely applied to indicate attenuation in strength capacity and muscle quality (ie, strength per unit of muscle mass).[11] Empirical evidence has established sarcopenia and generalized weakness as robust independent predictors of functional decline.[12] However, these factors also may contribute to consequent physical *inactivity* among aging adults. Thus, it is seemingly logical to presume that sarcopenia precedes functional deficit and disability, but it also is likely that disuse itself may lead to exaggerated weakness and thus sarcopenia. This circular cause and consequence of events has made the operationalization, detection, and treatment of this phenotype an exceedingly complex clinical issue to disentangle. Indeed, given the increasing prevalence of sarcopenia[13] and related functional deficit and disability among aging men and women, the escalating health care burden of this condition is presumably extensive.[14]

CLINICAL SIGNIFICANCE

- Aging is associated with increased risk for weakness, disability, and diminished independence.
- Meta-analytic evidence now supports the effectiveness of progressive resistance exercise for strength and lean body mass among aging adults.
- Muscular adaptation to resistance exercise is independently associated with volume and intensity in a dose-response manner.
- Efforts to facilitate participation in progressive resistance exercise would serve as a viable preventive strategy for the older adult population.

RESISTANCE EXERCISE AND AGING

There is considerable variation in muscular atrophy and weakness among aging adults, which is suggested to be somewhat attributable to the peak in mass and strength attained earlier in life.[15] Therefore, even though significant adaptation are possible in the "oldest old,"[16] it may be expected that the benefits of early intervention will translate to preservation of long-term health and independence. Research has identified a disproportionate decline of strength and muscle mass, indicating that these age-related debilities are somewhat independent.[17,18] Resistance exercise is generally recommended as the preferred approach to elicit improvements in muscular hypertrophy and strength adaptations.[19] Following even short-term resistance exercise interventions, aging adults may expect improvements in protein synthesis similar to younger cohorts despite lower pre-exercise capacities.[20] However, at present, only 27% of the US population is estimated to participate in leisure-time resistance exercise, and these rates are substantially less for individuals over the age of 50 years.[21]

Although the effectiveness of resistance exercise for older adults has recently been deemed to be supported by the highest category of evidence (ie, "Evidence Category A"),[22] the overall value of resistance exercise for strength and muscle mass among aging persons has been inconsistent across investigations. Specifically, there have been no published accounts that examine the benefit of resistance exercise in aging persons while considering potential moderating variables such as dosage, treatment durations, and age ranges on longitudinal adaptation. To that end, we recently published the first comprehensive meta-analyses to assess treatment effects for multiple strength measures and lean body mass, as well as the potential moderating variables germane to resistance exercise prescription.[23,24]

WHOLE BODY MUSCULAR STRENGTH

Previous meta-analyses to examine the effects of resistance exercise for strength have restricted the primary outcome to a single strength measure (ie, knee extensors).[25,26] Considering the disproportionately greater loss of lower-body strength and muscle mass that occurs during aging, as well as the relevance of lower-limb strength to locomotion, instrumental activities of daily living, and risk of slip-and-fall accidents,[27] these analyses are quite salient. However, in order to improve clinical generalizability associated with prescription of resistance exercise in older adults, our research has expanded upon previous studies to examine multiple strength outcomes, representative of "whole-body" function (ie, leg press, knee extension, chest press, and lat pull). The main findings of this investigation indicated a robust association between resistance exercise and lower- and upper-body strength outcomes among adults >50 years ($n = 1079$).[23] Specifically, for the lower body, we observed a main effect equal to approximately 30% strength gain for both leg press and knee extension following 18 weeks of training. Similarly, increases of nearly 25% were identified for both upper-body exercises. These findings bear clinical significance considering the association between weakness and movement impairment,[28,29] as well as the reliance on whole-body strength capacity to fulfill many activities of daily life.

LEAN BODY MASS

Lean body mass is regarded as a convenient parameter related to pathology, as well as a viable surrogate indicator of skeletal muscle tissue. However, as has been the case

Training Dosage	Weeks 1-8				Weeks 9-16				Weeks 17-24			
	Weeks 1-2	Weeks 3-4	Weeks 5-6	Weeks 7-8	Weeks 9-10	Weeks 11-12	Weeks 13-14	Weeks 15-16	Weeks 17-18	Weeks 19-20	Weeks 21-22	Weeks 23-24
Volume (# Sets/muscle group)	1	1	1-2	1-2	2	2	2	2-3	2-3	2-3	2-3	2-3
Intensity (Training Load)	15-20 RM	15-20 RM	15 RM	15 RM	12 RM	12 RM	10 RM	10 RM	8-10 RM	8-10 RM	6-8 RM	6-8 RM
Frequency/Split	1-2/Full Body	1-2/Full Body	2/Full Body	2-3/Full Body	2-3/Full Body	2-3/Full Body	3/Full Body	3/Full Body	3/Full Body	3/Full Body -or- Split: 2 Upper/2 Lower	Split: 2 Upper/2 Lower	Split: 2 Upper/2 Lower
Training Agenda	Familiarization	Familiarization	Familiarization	Muscular Endurance	Muscular Endurance & Hypertrophy	Muscular Endurance & Hypertrophy	Muscuolar Hypertrophy & Strength	Muscuolar Hypertrophy & Strength	Muscuolar Hypertrophy & Strength	Muscular Strength	Muscular Strength	Muscular Strength
Rest Period Between Sets (sec)	n/a	n/a	60-90 sec	60-90 sec	90 sec	90 sec	90 sec	90-120 sec	90-120 sec	120 sec	120-180 sec	120-180 sec
Mode (Exercise choices)	Body Weight; Postural / Stabilization; Selectorized Machines	Body Weight; Postural / Stabilization; Selectorized Machines	Body Weight; Postural / Stabilization; Selectorized Machines	Body Weight; Postural / Stabilization; Selectorized Machines	Postural / Stabilization; Selectorized Machines	Postural / Stabilization; Selectorized Machines; Free Weights	Postural / Stabilization; Selectorized Machines; Free Weights	Postural / Stabilization; Selectorized Machines; Free Weights	Selectorized Machines; Free Weights	Selectorized Machines; Free Weights	Selectorized Machines; Free Weights	Selectorized Machines; Free Weights

Volume: The number of RE sets for a given muscle group, per training session. **Intensity**: Resistance load that corresponds with a maximal number of repetitions (RM) (eg, 10RM: load that corresponds with approximately 10 allowable repetitions). **Frequency**: The number of times per week each muscle group should be trained. **Split**: The general partitioning of RE for specific body parts (eg, Full Body: resistance exercises are performed for all major muscle groups in a given session). **Training Agenda**: The respective purpose (or goal) for a given period of RE (ie, Familiarization: A period of time devoted to gaining familiarity with the resistance exercises, as well as general physiological adaptation). **Rest Period between Sets**: The minimum amount of time devoted to rest/recovery between successive sets of RE for a given muscle group. **Mode**: The type of RE movements and loading parameters. *Body weight* RE comprises movements in which the patient's body mass is used as resistance (eg, calisthenics including body weight chair stand, squat, lunge, supine hip extension raises, etc.). *Postural/Stabilization* exercises are specific isometric postural and dynamic exercises (eg, forward and lateral planks, trunk curl-ups, supine straight-leg hip flexion, etc.) intended to improve low back health, posture, and joint stabilization. *Selectorized machines* represent standard resistance exercise machines (eg, Cybex, Nautilus, FreeMotion, etc.). *Free weight* exercises take place through the use of free-moving implements (eg, barbell chest press, dumbbell biceps curl, etc.).

Figure Sample 6-month progressive resistance exercise model for healthy, older adults (adapted and modified with permission from Peterson[36]).

with strength outcomes, there is a great deal of inconsistency reported in the literature pertaining to the dose-response relationship of resistance exercise for muscular adaptation. Previous meta-analyses have restricted the evaluation of lean body mass as a secondary outcome or have synthesized data from across combined cohorts of middle-aged and older adults, and have generally yielded conflicting results.[30,31] Our data were derived from 81 cohorts and confirmed a strong association between resistance exercise and increases in lean body mass among adults >50 years of age (n = 1328).[24] Specifically, the analysis revealed that following 20 weeks of resistance exercise, both men and women experienced an approximate 1-kg increase in lean body mass. Although a modest effect when compared with the potential adaptive response of young adults, this finding is in contrast to the nearly 0.2-kg annual decline that may occur[32] through sedentary lifestyles beyond 50 years of age. Further, this study identified a negative association between age and lean body mass, and thus it may be expected that early resistance exercise participation will yield greater increases in lean mass and translate to preservation of muscle function and independence.

RESISTANCE EXERCISE PRESCRIPTION RECOMMENDATIONS

Current guidelines for physical activity in older adults have been developed by the American College of Sports Medicine and American Heart Association.[33] These "minimum" recommendations call for "muscle-strengthening activity" to be performed 2 or more nonconsecutive days per week, using a single set of 8-10 resistance exercises for the whole body, and at a moderate to high level of effort that allows 10-15 repetitions.[33] Although the established guidelines provide a basis for maintaining muscular fitness, there is now ample evidence to confirm the viability of *progressive* resistance exercise for improving strength and muscle mass among healthy aging adults. As the number of people aged 65 years or older continues to increase,[34] it is conceivable that efforts to facilitate the provision of this exercise modality would have tremendous consequences for improved public health in the aging population.

With regard to prescription of resistance exercise, evidence from our recent investigations also has identified a robust, independent association between "dosage" and adaptive responses. Specifically, for full-body strength capacity, training intensity (ie, as denoted by percentage of 1-repetition maximum) was determined to be a significant predictor such that higher intensities were reflective of greater absolute and relative improvements.[23] For the purposes of the analysis, we categorized resistance exercise training into low (<60% 1-repetition maximum), low/moderate (60%-69% 1-repetition maximum), moderate/high (70%-79% 1-repetition maximum), and high (≥80% 1-repetition maximum) intensity. Accordingly, each incremental increase in intensity category was reflective of an approximate 5.5% increase in respective strength outcome.[23]

Moreover, training volume (ie, as denoted by the total number of performed sets of resistance exercise) was identified as a robust predictor of increased lean body mass. Although the majority of included studies were relatively homogenous, there was enough variability to detect a significant association in the main effect, such that performing more sets of resistance exercise was indicative of greater increases in lean body mass. Training volume was operationalized per session; however, unpublished data from this analysis revealed that volume per week was also a significant predictor of lean body mass increase. Based on these collective findings, it is possible to manipulate respective dosage by altering the total number of exercises, the number of sets performed per exercise, and the number of training sessions per week, making this a simplistic and adaptable designation of total training volume.

Among aged individuals with existing morbidities, careful risk stratification is necessary to ensure safety during resistance exercise participation. Doing so allows higher-risk patient populations to follow guidelines established by the American College of Sports Medicine.[35] Otherwise, *healthy* aging adults should be entirely capable of safe participation in progressive resistance exercise protocols. As is generally accepted for novice trainees of any age, prescription of resistance exercise should include a "familiarization" period, in which very low dosage training (ie, low volume and intensity) takes place 1-2 times per week (Figure). Following the familiarization to resistance exercise, it may be expected that older adults can benefit from gradual increases in training volumes and intensities to accommodate improvements in strength and muscle hypertrophy. Moreover, it is likely that progression in dosage would be best tolerated across more frequent training (ie, 3-4 days per week), allowing for lower volumes per session, and subsequent gradual progression of intensity over time.[36]

With careful planning, the application of progressive resistance exercise among otherwise healthy older adults is not only safe and feasible, but also provides an effective means of eliciting optimal adaptation in both force production capacity and muscular hypertrophy. Considering the strong influence of age-related atrophy and muscular weakness on subsequent functional deficit and comorbidity, it is conceivable that targeting these parameters through progressive resistance exercise would help to maintain independence, health, and overall quality of life. Accordingly, increased public health and clinical efforts to encourage the provision of this health behavior are indeed warranted.

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