REVIEW ARTICLE

The Intensity and Effects of Strength Training in the Elderly

Frank Mayer, Friederike Scharhag-Rosenberger, Anja Carlsohn, Michael Cassel, Steffen Müller, Jürgen Scharhag

SUMMARY

Background: The elderly need strength training more and more as they grow older to stay mobile for their everyday activities. The goal of training is to reduce the loss of muscle mass and the resulting loss of motor function. The dose-response relationship of training intensity to training effect has not yet been fully elucidated.

Methods: PubMed was selectively searched for articles that appeared in the past 5 years about the effects and dose-response relationship of strength training in the elderly.

Results: Strength training in the elderly (>60 years) increases muscle strength by increasing muscle mass, and by improving the recruitment of motor units, and increasing their firing rate. Muscle mass can be increased through training at an intensity corresponding to 60% to 85% of the individual maximum voluntary strength. Improving the rate of force development requires training at a higher intensity (above 85%), in the elderly just as in younger persons. It is now recommended that healthy old people should train 3 or 4 times weekly for the best results; persons with poor performance at the outset can achieve improvement even with less frequent training. Side effects are rare.

Conclusion: Progressive strength training in the elderly is efficient, even with higher intensities, to reduce sarcopenia, and to retain motor function.

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Hochschulambulanz der Universität Potsdam, Zentrum für Freizeit-, Gesundheits- und Leistungssport:
Prof. Dr. med. Mayer, Dr. phil. Scharhag-Rosenberger, Dr. rer. nat. Carlsohn, Dr. med. Cassel, Dr. phil. Müller, PD Dr. med. Scharhag

By 2050, the proportion of people older than 60 in Germany will rise to some 40% and the proportion of those older than 80 to 10% to 15%. Furthermore, the official retirement age will rise to 67 years from 2012. This means that from today's perspective, one in three working adults will be older than 50. Maintaining the ability to work and earn a living, independence, and self sufficiency in daily life and leisure time will therefore become increasingly important over the coming decades. A crucial factor in this is sustaining a high individual strength capacity. The challenges facing elderly people (>60 years) do not differ from those facing younger people; in individual cases, age dependent, structural and functional adaptations and a decreasing physiological resilience will have to be considered (1).

The less active a person's lifestyle, the earlier age-related changes will manifest (2). A reduction in motor capacity and visual and vestibular skills are foremost among these changes. In addition to a reduction in muscle fibers (type 1 and especially type 2 fibers, especially in the lower extremity), the responsibility for this lies with neuronal factors (a reduction in spinal motoneurons or spinal inhibitions) and impairments to mechanical muscle function (such as for example reduced maximum frequency or reduced elasticity) (3).

Muscle strength gradually decreases from the 30th year until about the 50th year of life. In the 6th decade of life, an accelerated, non-linear decrease by 15% has been observed, and by the 8th decade, this may be up to 30%. This additionally results in a substantial impairment in the sensorimotor information exchange, with a reduction in the quality of intermuscular and intramuscular coordination. Functional losses in strength and balance capacity, and increasing gait uncertainties are the result. The risk of acute problems owing to falls and injuries and chronic recurrent and degenerative illnesses rises (4).

Several studies have shown that strength (resistance) training can counteract age related impairments (3, 5, e1). The crucial factor in maintaining strength capacity is an increase in muscle mass. Additionally, an increase in muscle activity and frequency during isometric and dynamic muscle work have been observed. The extent of adaptation in elderly people is comparable to that in younger people. Sarcopenic muscle fibers thus do not per se have reduced mechanical muscle function but have a confirmed potential for adapting to strength (resistance) training. However, the validity of this observation is limited by the fact that the proportion of elderly people who do strength (resistance) training is currently low (about 10% to 15%).

The extent to which effects can be achieved when the physiological ageing process is considered has not been conclusively resolved. Furthermore, it needs to be clarified which intensities of training are advisable and possible in elderly people.

Method

The current review article is based on a selective literature search in PubMed for publications of the five years from 2005 to 2010. The aim was to collect current data on the effects and recommendations for the amount of exercise that should be taken by elderly patients. We used the following search terms:

- "strength training AND elderly" and "resistance training AND elderly"
- "training AND elderly"
- "sarcopenia"
- "muscle force AND elderly"
- "fall prevention AND elderly"
- "Strength training AND prevention".

From the search results, the authors identified relevant articles in which the effectiveness of strength (resistance) training had been studied. We focused especially on the aspect of up-to-date-ness and gave preference to more recent articles. Additionally we included in our evaluation publications that studied the dosage of strength (resistance) training in elderly people.

Results

The literature search yielded per search strategy more than 1500 published articles from the past 5 years. We screened the titles and abstracts for information on the effects and the dose-response relation of strength (resistance) training in elderly people and identified a total of 33 recent articles as the basis for our literature review.

Effects of strength (resistance) training in elderly people

Clinical as well as epidemiological studies showed the effect of athletic activity on morbidity and mortality indicators in elderly people. Laboratory-based studies showed that 20 to 30 minutes of strength (resistance) training, 2 to 3 times per week, has positive effects on risk factors for cardiovascular disorders, cancer, diabetes, and osteoporosis (6–9, e2). Furthermore, progressive strength (resistance) training is accepted in treating sarcopenia and to improve postural control (10).

The results of a recent Cochrane review including 121 randomized controlled trials (with some 6700 participants) showed that in most studies, strength (resistance) training is done 2 to 3 times per week. As a rule, this results in a notable increase in muscle strength, a moderate increase in the distance covered walking, a better performance for rising from a sitting position, and a subjectively higher mobility. Furthermore, increased stamina, an increased mitochondrial capacity, and a drop in the resting heart rate have been shown (6).

The measure for structural adaptation in elderly persons is the same as in young people: increases in both protein synthesis and contractile elements (5). Hypertrophy specific training for several weeks to months has been found beneficial in this setting (e3). By measuring the cross section of the muscle—for example, by computed tomography scanning—an increase in muscle volume has been shown in elderly men and women after a training period of 6 to 9 weeks. An increase in the cross sectional diameter of the muscle of some 10% has been confirmed; this was true for both type 1 fibers and type 2 fibers. Compared with the baseline level, this effect even seems more pronounced in elderly people than in younger ones (3, 5). A rapid increase in strength has been observed especially during the first few weeks—depending on the baseline level. This is due to neural adaptation mechanisms in the sense of improved acquisition and frequency of motor skills (3). In addition, an increased efficiency of the motor units resulted in elderly people tolerating submaximal loads for a longer duration—for example, during hypertrophy specific training.

In spite of losing its elasticity, aging muscle tissue is able to resist mechanical stretching of the muscle, especially in eccentric exercise (3). With this in mind, targeted, negative-dynamic training (such as brake load, weight transfer) is considered as very important. Especially intramuscular and intermuscular coordinating skills can be trained in this manner. Furthermore, the cardiocirculatory and metabolic strain is lower than for concentric and isometric exercise.

Only few randomized controlled studies currently exist of the adaptability of tendon tissue with increasing age. In addition to decreasing elasticity of the tendons, increased deposits of metabolic end products in the tendons have been documented (5). Furthermore it is known that placing physical load on tendon structures will raise oxygen intake, blood flow, and the net rate of collagen synthesis, resulting in an increase in the tendon's diameter. These adaptations have, however, not yet been experimentally verified in randomized controlled studies.

Physical activity can lead to an increase in, or reduction in the loss of, bone density, particularly in elderly postmenopausal women (7, e4). In low bone density, such effects on the spine as well as the hips have been shown (7). Adequate stimulation of osteogenesis and an increase in bone density can be achieved especially by means of very intense loading. However, results differ with regard to efficient dosage of training. Bemben et al. studied the effects of 8 months of maximum strength (resistance) training (3 times/week) and strength (resistance) training with additional whole-body vibration training on bone metabolism (among others, on alkaline phosphatase), bone density (DXA), and muscle force in postmenopausal women (11). They found

TABLE

Effects and examples of recommended training dosages and possible organizational approaches to different forms of strength training for elderly people

Objectives	Possible effects of training	Dosage	Possible organizational approaches
Increase in muscle strength	Increase in muscle mass	8–12 repetitions per muscle group in 70–85 % of the one-repetition-maximum, 3 sets; 2–3 training units per week; at least 8-12 weeks	Fitness studio; gymnasium, home program, initially under instruction, later independently
	Training of intramuscular coordination	Up to 8 repetitions per muscle group with intensities of more than 80% of the one-repetition-maximum; 3–5 sets; 3 training units per week; several weeks	Fitness studio; gymnasium, home program, under instruction
	Training of intermuscular coordination	Several repetitions; up to daily training units; high speed of movement, among others	Training on uneven surfaces with or without additional weights; under instruction, later independently
Reduction of sarcopenia	Increase in muscle mass	8–12 repetitions per muscle group in 60–80% of the one-repetition-maximum; 3 sets, 3 training units per week, at least 8–12 weeks	Fitness studio; gymnasium, home program, initially under instruction, later independently
Adaptation of tendons and bones	Increase in net synthesis of collagen; reduction in bone density loss	Medium to high intensities (>60–80% of the one-repetition-maximum, >body weight); several training units per week; weeks to months	Fitness studio; gymnasium, under instruction
Prevention of falls and injuries	Optimizing postural control; training of intermuscular coordination	Several repetitions; up to daily training units; high speed of movement	Training on uneven surfaces with or without additional weights; under instruction, later independently
	Training of intramuscular coordination	Up to 8 repetitions per muscle group in intensities of more than 80% of the one-repetition-maximum; 3–5 sets; 3 training units per week; several weeks	Fitness studio; gymnasium, home program, under instruction

greater muscle force in both intervention groups, but no differences regarding bone metabolism and bone density. Burke et al. found after a multimodal 8-week exercise program (balancing exercises and strength [resistance] training in postmenopausal women with confirmed osteoporosis) with high compliance rates an improvement of isometric muscle force in the ankle joint and knee joint muscles as well as balancing skills (12).

A current topic of discussion is whether or not the effects of strength (resistance) training also translate for elderly patients in different clinical groups (e5). Kingsley et al. observed after 12 weeks of strength (resistance) training in female patients with fibromyalgia an increase in strength and a reduction in symptoms (13). Mangione et al. studied the effect of 10 weeks of twice weekly, high-intensity, outpatient strength (resistance) training after a neck of femur fracture (14). One year after the fracture, the strength performance capacity, walking speed, the distance covered in 6 minutes' walking, and the functional and medical results were statistically significantly better than in the control group. Similar results have been observed for patients with arthritis of the large joints of the leg (15, 16, e6). High-intensity strength (resistance) training seems therefore also useful and efficient in the treatment and after-treatment of selected symptoms in elderly patients.

The frequency of falls and injuries rises from the 5th decade of life. After the age of 65 years, 30% of people fall at least once a year (10). Orr postulates in the results of a systematic literature review a negative effect of insufficiency of muscle on postural control in elderly people, but causality should not be assumed as a given (10, e7). Daniels showed in this context that isolated strength (resistance) training is less effective for postural control than multimodal programs that include different components, such as balance, strength, flexibility, and stamina with mostly higher intensities. More recent studies have investigated whether sensorimotor training may be beneficial in addition to mere strength (resistance) training (17–19). Alfieri et al. conducted multisensory training in persons of about 70 years of age for 12 weeks, which included optimizing the stability of posture, strength (resistance) training, sensorimotor training on uneven surfaces, and coordinating tasks (17). The results showed that multisensory training is superior to mere strength (resistance) training with regard to the variable of postural control. Extending strength (resistance) training by sensorimotor training, or adding this component, is therefore beneficial in elderly people.

The discussion about using strength (resistance) training in a beneficial manner is often linked with the debate of possible negative side effects and contraindications, especially when elderly patients are concerned. Diverse studies that we have already cited have shown, however, that the rate of side effects is very low if the dose is adapted to the patient. Liu and Latham have conducted a systematic literature search of the adverse effects of strength (resistance) training (20). Only 25% of included studies reported adverse effects. The most common ones were musculoskeletal problems after training. In some studies, such adverse effects resulted in the subject being excluded from the study, but no precise exclusion rates can be verified.

Forms and dosage of strength (resistance) training in elderly people

In spite of the widespread acceptance among experts that strength (resistance) training is necessary, even at an older age, numerous aspects of the dose-response relation have not been explained conclusively (3, 5, e8–e10). Activities of daily life, which in elderly people are usually accompanied by increasing physical inactivity and insufficient weight bearing exercise, are not sufficient as a training stimulus for the muscles. Elderly men and women who do not undergo additional training will lose body strength and the strength of the arms to a disproportionate extent.

Available training programs usually vary in terms of their intensity, the number of repetitions and sets of weights as well as the duration and frequency of the training units *(Table)*. Progressive muscle training requires precise instructions about the external load and is mainly directed according to intensity. The external load is defined by traditional training equipment (sequence training equipment), free weights, resistance bands or cuffs, participants' own body weight or computer guided equipment—for example, isokinetic training equipment. Depending on the intensity, physiological adaptation processes are being initiated—for example, an increase in the cross-sectional muscle diameter or a higher acquisition of motor units. The way in which the exercises are performed contributes to transferring muscle force to activities of everyday life—for example, getting up from a sitting position, holding one's posture, or carrying the shopping.

The view that at an advanced age, load bearing intensity should be reduced in order to avoid injuries and chronic overuse is widespread. However, this effect is not supported by current evidence, and several working groups have pointed out the need for higher intensities for elderly as well as young people. In a meta-analysis of 29 randomized controlled studies including a total of 1313 subjects older than 65 years, Steib et al. showed a notable dependence of the improved strength capacity on the intensity of the weight training (21). High-intensity strength (resistance) training (>75% of the maximal strength capacity) thus triggers higher increases in strength than training of medium or low intensity. More differentiated recommendations regarding the duration and frequency of individual training units can, however, not be deduced.

Ciolac et al. conducted combined, 13 week, high-intensity training in two groups (women aged around 29 and 65). They recorded an increase in strength in both groups, without any differences between groups. No adverse effects occurred (22). In a follow-up study, men (aged around 25, 65, and 72) also underwent 13 weeks of strength (resistance) training. They were also found to have relevant increases in strength as an adaptation to the training with heavy weights (23). In elderly people, high-intensity progressive strength (resistance) training is therefore effective, and substantial adverse effects are not to be expected.

Typically, strength (resistance) training aiming for hypertrophy is done at least 3 times a week for 8 to 12 weeks; a longer training period increases a more sustained effect (5). A classic training program consists of 3 to 4 sets with about 10 repetitions per muscle group, at an intensity of about 80% of the one-repetition-maximum. This recommendation does not differ from that for young people, but a lower one-repetition-maximum can be assumed.

For muscle strength to increase progressively, the intensity of the exercise will have to be adapted to the improved muscle force after some 6 to 8 weeks, in order to maintain an adequate training stimulus. In addition to the objective of muscular hypertrophy, strength (resistance) training aims to increase muscle force by improving the acquisition, frequency, and synchronization of motor units (3). Such training of intramuscular coordination should be done in elderly people with higher (to maximum) weights with fewer repetitions per set, as a rule of thumb.

Current data have shown that training with fast movement speeds while bearing weights are effective and useful for everyday exercise (21). Depending on the exercise task, strength can be assumed to develop according to the task specific and situation specific contribution of the different muscle groups.

Conflict of interest statement
The authors declare that no conflict of interest exists.

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KEY MESSAGES

- Strength (resistance) training if effective in elderly persons and can be undertaken without notable adverse effects.
- Strength (resistance) training is subject to a dose-response relation. Higher intensities yield greater effects than low or medium intensities.
- Strength (resistance) training in elderly persons aims to increase muscle mass (hypertrophy) on the one hand, and on the other hand, promote neuronal adaptation (intermuscular and intramuscular coordination).
- Adding sensorimotor components to strength (resistance) training—to improve postural control—make sense in elderly persons in the sense of a multimodal training program.
- Using strength (resistance) training has been used in the prevention and rehabilitation of different symptoms—for example, in osteoporosis and degenerative joint disorders.

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Corresponding author
Prof. Dr. med. Frank Mayer
Hochschulambulanz der Universität Potsdam
Am Neuen Palais 10, Haus 12
14469 Potsdam, Germany
fmayer@uni-potsdam.de

For eReferences please refer to:
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