Progression Models in Resistance Training for Healthy Adults

POSITION STAND

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SUMMARY

American College of Sports Medicine Position Stand on Progression Models in Resistance Training for Healthy Adults. *Med. Sci. Sports Exerc.* Vol. 34, No. 2, 2002, pp. 364–380. In order to stimulate further adaptation toward a specific training goal(s), progression in the type of resistance training protocol used is necessary. The optimal characteristics of strength-specific programs include the use of both concentric and eccentric muscle actions and the performance of both single- and multiple-joint exercises. It is also recommended that the strength program sequence exercises to optimize the quality of the exercise intensity (large before small muscle group exercises, multiple-joint exercises before single-joint exercises, and higher intensity before lower intensity exercises). For initial resistances, it is recommended that loads corresponding to 8–12 repetition maximum (RM) be used in novice training. For intermediate to advanced training, it is recommended that individuals use a wider loading range, from 1–12 RM in a periodized fashion, with eventual emphasis on heavy loading (1–6 RM) using at least 3-min rest periods between sets performed at a moderate contraction velocity (1–2 s concentric, 1–2 s eccentric). When training at a specific RM load, it is recommended that 2–10% increase in load be applied when the individual can perform the current workload for one to two repetitions over the desired number. The recommendation for training frequency is 2–3 d·wk^{-1} for novice and intermediate training and 4–5 d·wk^{-1} for advanced training. Similar program designs are recommended for hypertrophy training with respect to exercise selection and frequency. For loading, it is recommended that loads corresponding to 1–12 RM be used in periodized fashion, with emphasis on the 6–12 RM zone using 1- to 2-min rest periods between sets at a moderate velocity. Higher volume, multiple-set programs are recommended for maximizing hypertrophy. Progression in power training entails two general loading strategies: 1) strength training, and 2) use of light loads (30–60% of 1 RM) performed at a fast contraction velocity with 2–3 min of rest between sets for multiple sets per exercise. It is also recommended that emphasis be placed on multiple-joint exercises, especially those involving the total body. For local muscular endurance training, it is recommended that light to moderate loads (40–60% of 1 RM) be performed for high repetitions (> 15) using short rest periods (< 90 s). In the interpretation of this position stand, as with prior ones, the recommendations should be viewed in context of the individual's target goals, physical capacity, and training status.

INTRODUCTION

The ability to generate force has fascinated humankind throughout most of recorded history. Not only have great feats of strength intrigued people's imagination, but a suf-

ficient level of muscular strength was important for survival. Although modern technology has reduced the need for high levels of force production during activities of everyday living, it has been recognized in both the scientific and medical communities that muscular strength is a fundamental physical trait necessary for health, functional ability, and an enhanced quality of life. Resistance exercise using an array of different modalities has become popular over the past 70 years. Although organized lifting events and sports have been in existence since the mid to late 1800s, the scientific investigation of resistance training did not dramatically evolve until the work of DeLorme and Watkins (46). Following World War II, DeLorme and Watkins demonstrated the importance of "progressive resistance exercise" in increasing muscular strength and hypertrophy for the rehabilitation of military personnel. Since the early 1950s and 1960s, resistance training has been a topic of interest in the scientific, medical, and athletic communities (19–21,31,32). The common theme of most resistance training studies is that the training program must be "progressive" in order to produce substantial and continued increases in muscle strength and size.

Progression is defined as "the act of moving forward or advancing toward a specific goal." In resistance training, progression entails the continued improvement in a desired variable over time until the target goal has been achieved. Although it is impossible to continually improve at the same rate with long-term training, the proper manipulation of program variables (choice of resistance, exercise selection and order, number of sets and repetitions, rest period length) can limit natural training plateaus (that point in time where no further improvements takes place) and consequently enable achievement of higher levels of muscular fitness (236). Trainable fitness characteristics include muscular strength, power, hypertrophy, and local muscular endurance. Other variables such as speed, balance, coordination, jumping ability, flexibility, and other measures of motor performance have also been positively enhanced by resistance training (3,45,216,238,249).

Increased physical activity and participation in a comprehensive exercise program incorporating aerobic endurance

activities, resistance training, and flexibility exercises has been shown to reduce the risk of several chronic diseases (e.g., coronary heart disease, obesity, diabetes, osteoporosis, low back pain). Resistance training has been shown to be the most effective method for developing musculoskeletal strength, and it is currently prescribed by many major health organizations for improving health and fitness (7–9,71,206,208). Resistance training, particularly when incorporated into a comprehensive fitness program, reduces the risk factors associated with coronary heart disease (84,86,126,127), non–insulin-dependent diabetes (72,180), and colon cancer (141); prevents osteoporosis (91,158); promotes weight loss and maintenance (56,135,251,259); improves dynamic stability and preserves functional capacity (56,79,138,235); and fosters psychological well-being (59,235). These benefits can be safely obtained when an individualized program is prescribed (172).

In the American College of Sports Medicine's position stand, "The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults," the initial standard was set for a resistance training program with the performance of one set of 8–12 repetitions for 8–10 exercises, including one exercise for all major muscle groups; and 10–15 repetitions for older and more frail persons (8). This initial starting program has been shown to be effective in previously untrained individuals for improving muscular fitness during the first 3–4 months of training (33,38,63,165,178). However, it is important to understand that this recommendation did not include resistance training exercise prescription guidelines for those healthy adults who wish to progress further in various trainable characteristics of muscular fitness. The purpose of this position stand is to extend the initial guidelines established by the American College of Sports Medicine (ACSM) for beginning resistance training programs and provide guidelines for progression models that can be applied to novice, intermediate, and advanced training.

FUNDAMENTAL CONCEPTS OF PROGRESSION

Progressive overload. Progressive overload is the gradual increase of stress placed upon the body during exercise training. Tolerance of increased stress-related overload is a vital concern for the practitioner and clinician monitoring program progression. In reality, the adaptive processes of the human body will only respond if continually called upon to exert a greater magnitude of force to meet higher physiological demands. Considering that physiological adaptations to a standard, nonvaried resistance training program may occur in a relatively short period of time, systematically increasing the demands placed upon the body is necessary for further improvement. There are several ways in which overload may be introduced during resistance training. For strength, hypertrophy, local muscular endurance, and power improvements, either 1) load (resistance) may be increased, 2) repetitions may be added to the current load, 3) repetition speed with submaximal loads may be altered according to goals, 4) rest periods may be shortened for endurance improvements or lengthened for strength and power training, 5) volume (i.e., overall total work represented as the product of the total number of repetitions performed and the resistance) may be increased within reasonable limits, or 6) any combination of the above. It has been recommended that only small increases in training volume (2.5–5%) be prescribed so as to avoid overtraining (69).

Specificity. There is a relatively high degree of task specificity involved in human movement and adaptation (217) that encompasses both movement patterns and force-velocity characteristics (95,113,261). All training adaptations are specific to the stimulus applied. The physiological adaptations to training are specific to the 1) muscle actions involved (50,51,115), 2) speed of movement (51), 3) range of motion (15,144), 4) muscle groups trained (69), 5) energy systems involved (153,213,248), and 6) intensity and volume of training (21,109,194,222). Although there is some carryover of training effects, the most effective resistance training programs are those that are designed to target specific training goals.

Variation. Variation in training is a fundamental principle that supports the need for alterations in one or more program variables over time to allow for the training stimulus to remain optimal. It has been shown that systematically varying volume and intensity is most effective for long-term progression (241). The concept of variation has been rooted in program design universally for many years. The most commonly examined resistance training theory including planned variation is periodization.

Periodization. Periodization utilizes variation in resistance training program design. This training theory was developed on the basis of the biological studies of general adaptation syndrome by Hans Selye (224). Systematic variation has been used as a means of altering training intensity and volume to optimize both performance and recovery (110,166,209). However, the use of periodization concepts is not limited to elite athletes or advanced training, but has been used successfully as the basis of training for individuals with diverse backgrounds and fitness levels. In addition to sport-specific training (112,140,147,154), periodized resistance training has been shown to be effective for recreational (47,118,238) and rehabilitative (62) training goals.

Classic (linear) model of periodization. This model is characterized by high initial training volume and low intensity (239). As training progresses, volume decreases and intensity increases in order to maximize strength, power, or both (68). Typically, each training phase is designed to emphasize a particular physiological adaptation. For example, hypertrophy is stimulated during the initial high-volume phase, whereas strength is maximally developed during the later high-intensity phase. Comparisons of classic strength/power periodized models to nonperiodized models have been previously reviewed (68). These studies have shown classic strength/power periodized training superior for increasing maximal strength (e.g., 1 repetition maximum (1 RM) squat), cycling power, motor performance, and jumping ability (192,238,241,256,257). However, a short-term study has shown similar performance improvements between periodized and multiple-set nonperiodized models

(13). It has been shown that longer training periods (more than 4 wk) are necessary to underscore the benefits of periodized training compared with nonperiodized training (257). The results of these studies demonstrate that both periodized and nonperiodized training are effective during short-term training, whereas variation is necessary for long-term resistance training.

Undulating (nonlinear) periodization. The nonlinear program enables variation in intensity and volume within each 7- to 10-day cycle by rotating different protocols over the course of the training program. Nonlinear methods attempt to train the various components of the neuromuscular system within the same 7- to 10-day cycle. During a single workout, only one characteristic is trained in a given day (e.g., strength, power, local muscular endurance). For example, in loading schemes for the core exercises in the workout, the use of heavy, moderate, and lighter resistances may be randomly rotated over a training sequence (Monday, Wednesday, Friday) (e.g., 3–5 RM loads, 8–10 RM loads, and 12–15 RM loads may used in the rotation). This model has compared favorably with the classical periodized and nonperiodized multiple-set models (13). This model has also been shown to have distinct advantages in comparison with nonperiodized, low-volume training in women (154,165).

IMPACT OF INITIAL TRAINING STATUS

Initial training status plays an important role in the rate of progression during resistance training. Training status reflects a continuum of adaptations to resistance training such that level of fitness, training experience, and genetic endowment contribute categorically. Untrained individuals (those with no resistance training experience or who have not trained for several years) respond favorably to most protocols, thus making it difficult to evaluate the effects of different training programs (68,92). The rate of strength increase differs considerably between untrained and trained individuals (148), as trained individuals have shown much slower rates of improvement (83,107,111,221). A review of the literature reveals that muscular strength increases approximately 40% in "untrained," 20% in "moderately trained," 16% in "trained," 10% in "advanced," and 2% in "elite" over periods ranging from 4 wk to 2 yr. Individuals who are "trained" or "intermediate" typically have approximately 6 months of consistent resistance training experience. "Advanced" training referred to those individuals with years of resistance training experience who also attained significant improvements in muscular fitness. "Elite" individuals are those athletes who are highly trained and achieved a high level of competition. Although the training programs, durations, and testing procedures of these studies differed, these data clearly show a specific trend toward slower rates of progression of a trainable characteristic with training experience.

The difficulty in continuing gains in strength appears to occur even after several months of training. It is well documented that changes in muscular strength are most prevalent early in training (92,185). Investigations that have examined the time course of strength gains to various training protocols support this concept. Short-term studies (11–16 weeks) have shown that the majority of strength increases take place within the first 4–8 wk (119,192). Similar results have been observed during 1 yr of training (185). These data demonstrate the rapidity of initial strength gains in untrained individuals, but also show slower gains with further training.

TRAINABLE CHARACTERISTICS

MUSCULAR STRENGTH

The ability of the neuromuscular system to generate force is necessary for all types of movement. Muscle fibers, classified according to their contractile and metabolic characteristics, show a linear relationship between their cross-sectional area (CSA) and the maximal amount of force they can generate (66). In whole muscle, the arrangement of individual fibers according to their angle of pull (pennation), as well as other factors, such as muscle length, joint angle, and contraction velocity, can alter the expression of muscular strength (90,144). Force generation is dependent on motor unit activation (217). Motor units are recruited according to their size (from small to large, i.e., size principle) (117). Adaptations with resistance training enable greater force generation. These adaptations include enhanced neural function (e.g., greater recruitment, rate of discharge (159,181,217)), increased muscle CSA (6,170,232), changes in muscle architecture (136), and possibly a role of metabolites (215,226,230) for increased strength. The magnitude of strength enhancement is dependent on the muscle actions used, intensity, volume, exercise selection and order, rest periods between sets, and frequency (245).

Muscle action. Most resistance training programs include primarily dynamic repetitions with both concentric (muscle shortening) and eccentric (muscle lengthening) muscle actions, whereas isometric muscle actions play a secondary role. Greater force per unit of muscle size is produced during eccentric actions (142). Eccentric actions are also more neuromuscularly efficient (55,142), less metabolically demanding (58), and more conducive to hypertrophy (115), yet result in more delayed onset muscle soreness (52) as compared with concentric actions. Dynamic muscular strength improvements are greatest when eccentric actions are included in the repetition movement (50). The role of muscle action manipulation during resistance training is minimal with respect to progression. Considering that most programs include concentric and eccentric muscle actions in a given repetition, there is not much potential for variation in this variable. However, some advanced programs use different forms of isometric training (e.g., functional isometrics (128)), in addition to use of supramaximal eccentric muscle actions in order to maximize gains in strength and hypertrophy (139). These techniques have not been extensively investigated but appear to provide a novel stimulus conducive to increasing muscular strength. *For progression during strength training for novice, intermediate, and advanced individuals, it is recommended that both concentric and eccentric muscle actions be included.*

Loading. Altering the training load affects the acute metabolic (40), hormonal (42,146,150,152,171,211), neural (96,102,104,143,217), and cardiovascular (67,242) responses to resistance exercise. Proper loading during strength training encompasses either 1) increasing load on the basis of a load-repetition continuum (e.g., performing eight repetitions with a heavier load as opposed to 12 repetitions with a lighter load), or 2) increasing loading within a prescribed zone (e.g., 8–12 RM). The load required to increase maximal strength in untrained individuals is fairly low. Loads of 45–50% of 1 RM (and less) have been shown to increase dynamic muscular strength in previously untrained individuals (11,78,218,243, 253). It appears greater loading is needed with progression. At least 80% of 1 RM is needed to produce any further neural adaptations and strength during resistance training in experienced lifters (96). Several pioneering studies indicated that training with loads corresponding to 1–6 RM (mostly 5–6 RM) was most conducive to increasing maximal dynamic strength (19,194,253). Although significant strength increases have been reported using loads corresponding to 8–12 RM (46,147,163,232), this loading range may not be as effective as heavy loads for maximizing strength in advanced lifters. Research examining periodized resistance training has demonstrated that load prescription is not as simple as originally suggested (68). Contrary to early short-term resistance training studies from the 1960s, where a 6 RM load was indicated, it now appears that using a variety of training loads is most conducive to maximizing muscular strength (68,147,238) as opposed to performing all exercises with the same load. This is especially true for long-term training. For novice individuals, it has been recommended that moderate loading (60% of 1 RM) be used initially, as learning proper form and technique is paramount (63). However, a variety of loads appears to be most effective for long-term improvements in muscular strength as one progresses over time (68,241). *It is recommended that novice to intermediate lifters train with loads corresponding to 60–70% of 1 RM for 8–12 repetitions and advanced individuals use loading ranges of 80–100% of 1 RM in a periodized fashion to maximize muscular strength. For progression in those individuals training at a specific RM load (e.g., 8–12 repetitions), it is recommended that a 2–10% increase be applied on the basis of muscle group size and involvement (i.e., greater load increases may be used for large muscle group, multiple-joint exercises than small muscle group exercises) when the individual can perform the current intensity for one to two repetitions over the desired number on two consecutive training sessions.*

Training volume. Training volume is a summation of the total number of repetitions performed during a training session multiplied by the resistance used. Training volume has been shown to affect neural (107,112), hypertrophic (48,247), metabolic (40,258), and hormonal (87,145,149,150,152,190, 209,252) responses and subsequent adaptations to resistance training. Altering training volume can be accomplished by changing the number of exercises performed per session, the number of repetitions performed per set, or the number of sets per exercise. Low-volume (e.g., high load, low repetitions, moderate to high number of sets) programs have been

characteristic of strength training (96). Studies using two (49,167), three (19,20,147,232,234), four to five (50,122, 131,177), and six or more (123,218) sets per exercise have all produced significant increases in muscular strength in both trained and untrained individuals. In direct comparison, studies have reported similar strength increases in novice individuals who trained using two and three sets (32), and two and four sets (195), whereas three sets have been reported as superior to one and two (20).

Another aspect of training volume that has received considerable attention is the comparison of single- and multiple-set resistance training programs. In most of these studies to date, one set per exercise performed for 8–12 repetitions at an intentionally slow velocity has been compared with both periodized and nonperiodized multiple-set programs. A common criticism of these investigations is that the number of sets per exercise was not controlled for other variables such as intensity, frequency, and repetition velocity. This concern notwithstanding, comparisons have mostly been between one popular single-set training program relative to multiple-set programs of various intensity, and they have yielded conflicting results. Several studies have reported similar strength increases between single- and multiple-set programs (38,130,178,212,227,231), whereas others reported multiple-set programs superior (20,24,219,237,244) in previously untrained individuals. These data have prompted the notion that untrained individuals respond favorably to both single- and multiple-set programs and formed the basis for the popularity of single-set training among general fitness enthusiasts (63). In resistance-trained individuals, though, multiple-set programs have been shown to be superior for strength enhancement (147,154,155,222) in all but one study (114). No study has shown single-set training to be superior to multiple-set training in either trained or untrained individuals. It appears that both programs are effective for increasing strength in untrained individuals during short-term training (e.g., 3 months). Long-term progression-oriented studies support the contention that higher training volume is needed for further improvement (24,165). *It is recommended that a general resistance training program (consisting of either single or multiple sets) should be used by novice individuals initially. For continued progression in intermediate to advanced individuals, data from longer term studies indicate that multiple-set programs should be used with a systematic variation of training volume and intensity (periodized training) over time, as this has been shown to be the most effective for strength improvement. In order to reduce the risk of overtraining, a dramatic increase in training volume is not recommended.* Finally, it is important to point out that not all exercises need to be performed with the same number of sets, and that emphasis of higher or lower training volume is related to the program priorities as well as the muscle(s) trained in an exercise movement.

Exercise selection. Both single- (39,193,263) and multiple-joint exercises (107,112,147,238) have been shown to be effective for increasing muscular strength in the targeted muscle groups. Multiple-joint exercises (e.g., bench

press, squat) are more neurally complex (35) and have generally been regarded as most effective for increasing overall muscular strength because they enable a greater magnitude of weight to be lifted (240). Single-joint exercises (e.g., leg extension, arm and leg curls) have typically been used to target specific muscle groups, and may pose a lesser risk of injury because of the reduced level of skill and technique involved. *It is recommended that both exercise types be included in a resistance training program with emphasis on multiple-joint exercises for maximizing muscle strength and closed kinetic chain movement capabilities in novice, intermediate, and advanced individuals.*

Free weights and machines. In general, weight machines have been regarded as safer to use and easy to learn, and allow the performance of some exercises that may be difficult with free weights (e.g., leg extension, lat pull down) (73). In essence, machines help stabilize the body and limit movement about specific joints involved in synergy and focus the activation to a specific set of prime movers (73). Unlike machines, free weights may result in a pattern of intra- and intermuscular coordination that mimics the movement requirements of a specific task. *For novice to intermediate training, it is recommended that the resistance training program include free-weight and machine exercises. For advanced strength training, it is recommended that emphasis be placed on free-weight exercises, with machine exercises used to complement the program needs.*

Exercise order. The sequencing of exercises significantly affects the acute expression of muscular strength (225). Considering that multiple-joint exercises have been shown to be effective for increasing muscular strength, maximizing performance of these exercises may be necessary for optimal strength gains. This recommendation includes performance of these exercises early in the training session when fatigue is minimal. In addition, the muscle groups trained each workout may effect the order. Therefore, recommendations for sequencing exercises for novice, intermediate, and advanced strength training include:

- When training all major muscle groups in a workout: *large muscle group exercises before small muscle group exercises, multiple-joint exercises before single-joint exercises, or rotation of upper and lower body exercises.*
- When training upper body muscles on one day and lower body muscles on a separate day: *large muscle group exercises before small muscle group exercises, multiple-joint exercises before single-joint exercises, or rotation of opposing exercises (agonist-antagonist relationship).*
- When training individual muscle groups: *multiple-joint exercises before single-joint exercises, higher intensity exercises before lower intensity exercises.*

Rest periods. The amount of rest between sets and exercises significantly affects the metabolic (153), hormonal (149,150,152), and cardiovascular (67) responses to an acute bout during resistance exercise, as well as performance of subsequent sets (147) and training adaptations (203,214). It has been shown that acute resistance exercise performance may be compromised with short (i.e., 1 min) rest periods (147). Longitudinal resistance training studies have shown greater strength increases with long versus short rest periods between sets (e.g., 2–3 min vs 30–40 s) (203,214). These data demonstrate the importance of recovery during optimal strength training. It is important to note that rest period length will vary on the basis of the goals of that particular exercise (i.e., not every exercise will use the same rest interval). Muscle strength may be increased using short rest periods but at a slower rate, thus demonstrating the need to establish goals (i.e., the magnitude of strength improvement sought) prior to selecting a rest interval. *For novice intermediate, and advanced training, it is recommended that rest periods of at least 2–3 min be used for multiple-joint exercises using heavy loads that stress a relatively large muscle mass (e.g., squat, bench press). For assistance exercises (those exercises complementary to core exercise including exercises on machines, e.g., leg extension, leg curl), a shorter rest period length of 1–2 min may suffice.*

Velocity of muscle action. The velocity of muscular contraction used to perform dynamic muscle actions affects the neural (55,96,97), hypertrophic (123), and metabolic (14) responses to resistance exercise. Studies examining isokinetic resistance exercise have shown strength increases specific to the training velocity with some carryover above and below the training velocity (e.g., $30°·s^{-1}$) (69). Several investigators have trained individuals between 30 and $300°·s^{-1}$ and reported significant increases in muscular strength (41,60,123,133,144,182,191,250). It appears that training at moderate velocity ($180–240°·s^{-1}$) produces the greatest strength increases across all testing velocities (133). Data obtained from isokinetic resistance training studies support velocity specificity and demonstrate the importance of training at fast, moderate, and slow velocities to improve isokinetic force production across all testing velocities (69).

Dynamic constant external resistance (so-called isotonic) training poses a different stress when examining training velocity. Significant reductions in force production are observed when the intent is to perform the repetition slowly. In interpreting this, it is important to note that two types of slow-velocity contractions exist during dynamic resistance training: unintentional and intentional. *Unintentional* slow velocities are used during high-intensity repetitions in which either the loading and/or fatigue are responsible for limiting the velocity of movement. One study has shown that during a 5 RM bench press set, the concentric phase for the first three repetitions was approximately 1.2–1.6 s in duration, whereas the last two repetitions were approximately 2.5 and 3.3 s, respectively (183). These data demonstrate the impact of loading and fatigue on repetition velocity in individuals performing each repetition maximally.

Intentional slow-velocity contractions are used with submaximal loads where the individual has greater control of the velocity. It has been shown that concentric force production was significantly lower for an intentionally slow velocity (5 s concentric, 5 s eccentric) of lifting compared

with a traditional (moderate) velocity with a corresponding lower neural activation (139). These data suggest that motor unit activity may be limited when intentionally contracting at a slow velocity. In addition, the lighter loads required for slow velocities of training may not provide an optimal stimulus for strength enhancement in resistance-trained individuals, although some evidence does exist to support its use as a component part of the program in the beginning phases of training for highly untrained individuals (254). It has recently been shown that when performing a set of 10 repetitions using a very slow velocity (10 s concentric, 5 s eccentric) compared with a slow velocity (2 s concentric, 4 s eccentric), a 30% reduction in training load was necessary, which resulted in significantly less strength gains in most of the exercises tested after 10 wk of training (137). Compared with slow velocities, moderate (1–2 s concentric: 1–2 s eccentric) and fast (< 1 s concentric, 1 s eccentric) velocities have been shown to be more effective for enhanced muscular performance (e.g., number of repetitions performed, work and power output, volume) (156,188) and for increasing the rate of strength gains (116). Recent studies examining training at fast velocities with moderately high loading have shown this to be more effective for advanced training than traditionally slower velocities (132,189). *For untrained individuals, it is recommended that slow and moderate velocities be used initially. For intermediate training, it is recommended that moderate velocity be used for strength training. For advanced training, the inclusion of a continuum of velocities from unintentionally slow to fast velocities is recommended for maximizing strength. It is important to note that proper technique is used for any exercise velocity in order to reduce any risk of injury.*

Frequency. Optimal training frequency (the number of workouts per week) depends on several factors such as training volume, intensity, exercise selection, level of conditioning, recovery ability, and the number of muscle groups trained per workout session. Numerous resistance training studies have used frequencies of 2–3 alternating d·wk^{-1} in previously untrained individuals (28,41,50,119). This has been shown to be an effective initial frequency (20), whereas 1–2 d·wk^{-1} appears to be an effective maintenance frequency for those individuals already engaged in a resistance training program (89,184). In a few studies, a) 3 d·wk^{-1} was superior to 1 (176) and 2 d·wk^{-1} (88); b) 4 d·wk^{-1} was superior to 3 (125); c) 3 d·wk^{-1} was superior to 1 (207); and d) 3–5 d·wk^{-1} was superior to 1 and 2 d·wk^{-1} (82) for increasing maximal strength. *Therefore, it is recommended that novice individuals train the entire body 2–3 d·wk^{-1}.*

It appears that progression to intermediate training does not necessitate a change in frequency for training each muscle group, but may be more dependent on alterations in other acute variables such as exercise selection, volume, and intensity. Increasing training frequency may enable greater specialization (e.g., greater exercise selection and volume per muscle group in accordance with more specific goals). Performing upper-body exercises during one workout and lower-body exercises during a separate workout (upper/lower-body split) or training specific muscle groups (split routines) during a workout are common at this level of training in addition to total-body workouts (69). Similar increases in strength have been observed between upper/lower- and total-body workouts (30). *It is recommended that for progression to intermediate training, a similar frequency of 2–3 d·wk^{-1} continues to be used for total-body workouts. For those individuals desiring a change in training structure (e.g., upper/lower-body split, split workout), an overall frequency of 3–4 d·wk^{-1} is recommended such that each muscle group is trained 1–2 d·wk^{-1} only.*

Optimal frequency necessary for progression during advanced training varies considerably. It has been demonstrated that football players training 4–5 d·wk^{-1} achieved better results than those who trained either 3 or 6 d·wk^{-1} (121). Advanced weightlifters and bodybuilders use high-frequency training (e.g., 4–6 d·wk^{-1}). The frequency for elite weightlifters and bodybuilders may be even greater. Double-split routines (two training sessions per day with emphasis on different muscle groups) are common during training (111,264), which may result in 8–12 training sessions·wk^{-1}. Frequencies as high as 18 sessions·wk^{-1} have been reported in Olympic weightlifters (264). The rationale for this high-frequency training is that frequent short sessions followed by periods of recovery, supplementation, and food intake allow for high-intensity training via maximal energy utilization and reduced fatigue during exercise performance (69). One study reported greater increases in muscle CSA and strength when training volume was divided into two sessions per day as opposed to one (100). Elite power lifters typically train 4–6 d·wk^{-1} (69). It is important to note that not all muscle groups are trained per workout using a high frequency. Rather, each major muscle group may be trained 2–3 times·wk^{-1} despite the large number of workouts. *It is recommended that advanced lifters train 4–6 d·wk^{-1}. Elite weightlifters and bodybuilders may benefit from using very high frequency (e.g., two workouts in 1 d for 4–5 d·wk^{-1}), so long as appropriate steps are taken to optimize recovery and minimize the risk of overtraining.*

MUSCULAR HYPERTROPHY

It is well known that resistance training induces muscular hypertrophy (129,170,232). Muscular hypertrophy results from an accumulation of proteins, through either increased rate of synthesis, decreased degradation, or both (23). Recent developments have shown that protein synthesis in human skeletal muscle increases following only one bout of vigorous weight training (201,202). Protein synthesis peaks approximately 24 h after exercise and remains elevated from 2–3 h after exercise up through 36–48 h after exercise (81,162,202). It is unclear whether resistance training increases synthesis of all cellular proteins or only the myofibrillar proteins (201,264). The types of protein synthesized may have direct impact on various designs of resistance training programs (e.g., body building vs strength training) (264).

Several other factors have been identified that contribute to the magnitude of muscle hypertrophy. Fast-twitch muscle fibers typically hypertrophy to a greater extent than slow-twitch fibers (6,115,170). Muscle lengthening has been shown to reduce protein catabolism and increase protein synthesis in animal models (85). Mechanical damage resulting from loaded eccentric muscle actions is a stimulus for hypertrophy (16,80,161,173) that is somewhat attenuated by chronic resistance training (80). Nevertheless, it has not been shown that muscle damage is a requirement for hypertrophy. This tissue remodeling process has been shown to be significantly affected by the concentrations of testosterone, growth hormones, cortisol, insulin, and insulin-like growth factor-1, which have been shown to increase during and following an acute bout of resistance exercise (1,145,146,150,152,171,211,232).

The time course of muscle hypertrophy has been examined during short-term training periods in previously untrained individuals. The nervous system plays a significant role in the strength increases observed in the early stages of adaptation to training (186). However, by 6–7 wk of training, muscle hypertrophy becomes evident (201), although changes in the quality of proteins (232), fiber types (232), and protein synthetic rates (201) take place much earlier. From this point onward, there appears to be an interplay between neural adaptations and hypertrophy in the expression of strength (217). Less muscle mass is recruited during resistance training with a given intensity once adaptation has taken place (204). These findings indicate that progressive overloading is necessary for maximal muscle fiber recruitment and, consequently, muscle fiber hypertrophy. Advanced weightlifters have shown strength improvements over a 2-yr period with little or no muscle hypertrophy (112), indicating an important role for neural adaptations at this high level of training for these competitive lifts. It appears that this interplay is highly reflective of the training stimulus involved and suggests that alterations in program design targeting both neural and hypertrophic factors may be most beneficial for maximizing strength and hypertrophy.

Program Design Recommendations for Increasing Muscle Hypertrophy

Muscle action. *Similar to training for strength, it is recommended that both concentric and eccentric muscle actions be included for novice, intermediate, and advanced resistance training.*

Loading and volume. Numerous types of resistance training programs have been shown to stimulate muscle hypertrophy in men and women (43,233). Resistance training programs targeting muscle hypertrophy utilize moderate to very heavy loads and are typically high in volume (146). These programs have been shown to initiate a greater acute increase in testosterone and growth hormone than high-load, low-volume programs with long (3-min) rest periods (150,152). Total work, in addition to the forces developed, has been implicated for gains in muscular hypertrophy (189,226,230). This has been supported, in part, by greater hypertrophy associated with high-volume, multiple-set programs compared with low-volume, single-set programs in resistance-trained individuals (147,154,165). Traditional strength training (high load, low repetition, long rest periods) has produced significant hypertrophy (96,247); however, it has been suggested that the total work involved with traditional strength training may not maximize hypertrophy (264). *For novice and intermediate individuals, it is recommended that moderate loading be used (70–85% of 1 RM) for 8–12 repetitions per set for one to three sets per exercise. For advanced training, it is recommended that a loading range of 70–100% of 1 RM be used for 1–12 repetitions per set for three to six sets per exercise in periodized manner such that the majority of training is devoted to 6–12 RM and less training devoted to 1–6 RM loading.*

Exercise selection and order. Both single- and multiple-joint exercises have been shown to be effective for increasing muscular hypertrophy (39,147). The complexity of the exercises chosen has been shown to affect the time course of muscle hypertrophy such that multiple-joint exercises require a longer neural adaptive phase than single-joint exercises (35). Less is understood concerning the effect of exercise order on muscle hypertrophy. However, it appears that the recommended exercise sequencing guidelines for strength training may also apply for increasing muscle hypertrophy. *It is recommended that both single- and multiple-joint exercises be included in a resistance training program in novice, intermediate, and advanced individuals, with the order similar to that recommended in training for strength.*

Rest periods. Rest period length has been shown to significantly affect muscular strength, but less is known concerning hypertrophy. One study reported no significant difference between 30, 90, and 180 s in muscle girth, skinfolds, or body mass in recreationally trained men over 5 wk (214). Short rest periods (1–2 min) coupled with moderate to high intensity and volume have elicited the greatest acute anabolic hormone response to resistance exercise in comparison with programs utilizing very heavy loads with long rest periods (150,152). Although not a direct assessment of muscle hypertrophy, the acute hormonal responses have been regarded potentially more important for hypertrophy than chronic changes (171). *It is recommended that 1- to 2-min rest periods be used in novice and intermediate training programs. For advanced training, rest period length should correspond to the goals of each exercise or the training phase such that 2- to 3-min rest periods may be used with heavy loading for core exercises and 1- to 2-min rest periods may be used for all other exercises of moderate to moderately high intensity.*

Repetition velocity. Less is known concerning the effect of repetition velocity on muscle hypertrophy. It has been suggested that higher velocities of movement pose less of a stimulus for hypertrophy than slow and moderate velocities (247). It does appear that the use of different velocities of contraction is warranted for long-term improvements in muscle hypertrophy for advanced training. *It is recommended that slow to moderate velocities be used by novice- and intermediate-trained individuals. For advanced training, it is recommended*

that slow, moderate, and fast repetition velocities be used depending on the load, repetition number, and goals of the particular exercise.

Frequency. The frequency of training depends on the number of muscle groups trained per workout. Frequencies of 2–3 d·wk^{-1} have been effective in novice and intermediate men and women (43,119,232). Higher frequency of training has been suggested for advanced hypertrophy training. However, only certain muscle groups are trained per workout with a high frequency. *It is recommended that frequencies similar to strength training be used when training for hypertrophy during novice, intermediate, and advanced training.*

MUSCULAR POWER

The expression and development of power is important from both a sports performance and a lifestyle perspective. By definition, more power is produced when the same amount of work is completed in a shorter period of time, or when a greater amount of work is performed during the same period of time. Neuromuscular contributions to maximal muscle power include 1) maximal rate of force development (RFD) (105), 2) muscular strength at slow and fast contraction velocities (134), 3) stretch-shortening cycle (SSC) performance (25), and 4) coordination of movement pattern and skill (223,263). Several studies have shown improved power performance following a traditional resistance training program (3,18,37,260,261). Yet, the effectiveness of traditional resistance training methods for developing maximal power has been questioned because this type of training tends to only increase maximal strength at slow movement velocities rather than improving the other components contributing to maximal power production (93). Thus, alternative resistance training programs may prove to be more effective. A program consisting of movements with high power output using relatively light loads has been shown to be more effective for improving vertical jump ability than traditional strength training (105,106). It appears that heavy resistance training with slow velocities of movement leads primarily to improvements in maximal strength, whereas power training (utilizing light to moderate loads at high velocities) increases force output at higher velocities and RFD (106). However, it is important to simultaneously train for strength over time to provide the basis for optimal power development (13).

Heavy resistance training may actually decrease power output unless accompanied by explosive movements (22). The inherent problem with traditional weight training is that the load is decelerated for a considerable proportion (24–40%) of the concentric movement (54,198). This percentage increases to 52% when performing the lift with a lower percentage (81%) of 1 RM lifted (54) or when attempting to move the bar rapidly in an effort to train more specifically near the movement speed of the target activity (198). Ballistic resistance exercise (explosive movements that enable acceleration throughout the full range of motion) has been shown to limit this problem (196,197,261). One such ballistic resistance exercise is the loaded jump squat. Loaded jump squats with 30% of 1 RM (134,187,189) have been shown to increase vertical jump performance more than traditional back squats and plyometrics (261). These results indicate the importance of minimizing the deceleration phase when maximal power is the training goal.

Exercise selection and order. Multiple-joint exercises have been used extensively for power training. The inclusion of total-body exercises (e.g., power clean, push press) is recommended, as these exercises have been shown to require rapid force production (77). These exercises do require additional time for learning, and it is strongly recommended that proper technique be stressed for novice and intermediate training. Critical to performance of these exercises is the quality of effort per repetition (maximal velocity). *The use of predominately multiple-joint exercises performed with sequencing guidelines similar to strength training is recommended for novice, intermediate, and advanced power training.*

Loading/volume/repetition velocity. Considering that resistance training program design has been effective for improving muscular strength and power in novice- and intermediate-trained individuals, *it is recommended that a power component consisting of one to three sets per exercise using light to moderate loading (30–60% of 1 RM) for three to six repetitions performed not to failure be integrated into the intermediate strength training program. Progression for power enhancement uses various loading strategies in a periodized manner. Heavy loading (85–100% of 1 RM) is necessary for increasing the force component of the power equation and light to moderate loading (30–60% of 1 RM) performed at an explosive velocity is necessary for increasing fast force production. A multiple-set (three to six sets) power program integrated into a strength training program consisting of one to six repetitions in periodized manner is recommended for advanced power training.*

Rest periods and frequency. *The recommendations for rest period length and training frequency for power training are similar to those for novice, intermediate, and advanced strength training.*

LOCAL MUSCULAR ENDURANCE

Local muscular endurance has been shown to improve during resistance training (11,124,164,165,175,242). More specifically, submaximal local muscular and high-intensity endurance (also called strength endurance) have been investigated. Traditional resistance training has been shown to increase absolute muscular endurance (the maximal number of repetitions performed with a specific pretraining load) (11,124,147), but limited effects are observed in relative local muscular endurance (endurance assessed at a specific relative intensity, or percentage of 1 RM) (169). Moderate- to low-resistance training with high repetitions has been shown to be most effective for improving absolute and relative local muscular endurance (11,124). A relationship exists between increases in strength and local muscle endurance such that strength

training alone may improve local muscular endurance to a certain extent. However, specificity of training produces the greatest improvements (11,243). Training to increase local muscular endurance implies the individual 1) performs high repetitions (long-duration sets) and/or 2) minimizes recovery between sets (11).

Exercise selection and order. Exercises stressing multiple or large muscle groups have elicited the greatest acute metabolic responses during resistance exercise (14,220,246). Metabolic demand is an important stimulus concerning the adaptations within skeletal muscle necessary to improve local muscular endurance (increased mitochondrial and capillary number, fiber type transitions, buffering capacity). The sequencing of exercises may not be as important in comparison with strength training, as fatigue is a necessary component of endurance training. *It is recommended that both multiple- and single-joint exercises be included in a program targeting improved local muscular endurance using various sequencing combinations for novice, intermediate, and advanced training.*

Loading and volume. Light loads coupled with high repetitions (15–20 or more) have been shown to be most effective for increasing local muscular endurance (11,243). However, moderate to heavy loading (coupled with short rest periods) is also effective for increasing high-intensity and absolute local muscular endurance (11,175). High-volume programs have been shown to be superior for endurance enhancement (119,147,165,243), especially when multiple sets per exercise are performed (147,165,175). *For novice and intermediate training, it is recommended that relatively light loads be used (10–15 repetitions) with moderate to high volume. For advanced training, it is recommended that various loading strategies be used for multiple sets per exercise (10–25 repetitions or more) in periodized manner.*

Rest periods. The duration of rest intervals during resistance exercise appears to affect muscular endurance. It has been shown that bodybuilders (who typically train with high volume and short rest periods) demonstrate a significantly lower fatigue rate in comparison with power lifters (who typically train with low to moderate volume and longer rest periods) (153). These data demonstrate the benefits of high-volume, short-rest-period workouts for improving local muscular endurance. *It is recommended that short rest periods be used for endurance training (i.e., 1–2 min for high-repetition sets (15–20 repetitions or more), and less than 1 min for moderate (10–15 repetitions) sets.*

Frequency. *The recommended frequency for local muscular endurance training is similar to that for hypertrophy training.*

Repetition velocity. Studies examining isokinetic exercise have shown that a fast training velocity (i.e., $180°·s^{-1}$) is more effective than a slow training velocity (i.e., $30°·s^{-1}$) for improving local muscular endurance (4,182). Thus, fast contraction velocities are recommended for isokinetic training. However, it appears that both fast and slow velocities are effective for improving local muscular endurance during dynamic constant external resistance training. Two effective strategies used to prolong set duration are 1) moderate repetition number using an intentionally slow velocity, and 2) high repetition number using moderate to fast velocities. Intentionally slow velocity training with light loads (5 s concentric, 5 s eccentric and slower) places continued tension on the muscles for an extended period and is more metabolically demanding than moderate and fast velocities (14). However, it is difficult to perform a large number of repetitions using intentionally slow velocities. *It is recommended that intentionally slow velocities be used when a moderate number of repetitions (10–15) are used. If performing a large number of repetitions (15–25 or more) is the goal, then moderate to faster velocities are recommended.*

MOTOR PERFORMANCE

The effect of resistance training on various motor performance skills has been investigated (3,45,121,237). The importance of improved motor performance resulting from resistance training has implications not only for the training of specific athletic movements but also the performance of activities of daily living (i.e., balance, stair climbing). The principle of "specificity" is important for improving motor performance, as the greatest improvements are observed when resistance training programs are prescribed that are specific to the task or activity. *The recommendations for improving motor performance are similar to those for strength and power training (discussed in previous sections).*

Vertical jump. Force production has correlated positively to vertical jump height (27,168,205,255). This relationship between jumping ability and muscular strength/power in exercises with high speeds of movement is consistent with the angular velocity of the knee joint during the vertical jump (53). Several studies have reported significant improvements in vertical jump following resistance training (3,13,238). Multiple-joint exercises such as the Olympic style lifts have been suggested to improve jumping ability (77,262). The high velocity and joint involvement of these exercises, and their ability to integrate strength, power, and neuromuscular coordination, demonstrate a direct carryover to improving jump performance. Some studies (105,261) have reported significant improvements in jump height using light loads (< 60% of 1 RM), which supports the theory of high-velocity, ballistic training. Other reports suggest that increases in vertical jump height can be achieved while using higher intensities (> 80% of 1 RM) of training (3,262). Multiple-set resistance training programs have been shown to be superior for improving vertical jump performance in comparison with single-set training programs (147). Resistance training programs of 5–6 d·wk^{-1} elicit greater vertical jump improvements (2.3–4.3%) than programs of 3–4 d·wk^{-1} (0–1.2%) in resistance-trained Division 1AA college football players (121). The inclusion of plyometric training (explosive form of exercise involving various jumps) in combination with resistance training has been shown to be most effective for improving jumping ability (3). *It is recommended that multiple-joint exercises be performed*

using a combination of both heavy and light to moderate loading (using fast repetition velocity) with moderate to high volume in periodized fashion 4–6 d·wk^{-1} for maximal progression in vertical jumping ability.

Sprint speed. Force production is related to sprint performance (5,10,229) and appears to be a better indicator of speed when strength testing is performed at isokinetic velocities greater than 180°·s^{-1} (200). Absolute strength increases can improve the force component of the power equation. However, increasing maximal strength does not appear to be highly related to reducing sprint time (12). Strength training has only produced small, nonsignificant reductions (< 1%) in sprint times (44,76,121). When strength and sprint training are combined, significant improvements in sprinting speed are observed (45). The inclusion of high-velocity movements is paramount for improving sprint speed (45). *It is recommended that the combination of traditional heavy resistance and ballistic resistance exercise (along with other training modalities such as sprints and plyometrics) be included for progression in sprinting ability.*

Sport-specific activities. The importance of resistance training for other sport-specific activities has been demonstrated (36,154). The importance of strength and ballistic resistance training for the kicking limb of soccer players (210), throwing velocity (70,120,157,174,199), shot put performance (36), and tennis service velocity (154) has been demonstrated.

GENERAL-TO-SPECIFIC MODEL OF PROGRESSION

There have been a limited number of studies that examined different models of progression over long-term resistance training. Most resistance training studies are short term (6–24 wk) and have used predominantly untrained individuals. Little is known about longer training periods. Resistance-trained individuals have shown a slower rate of progression (83,107,112,221). Advanced lifters have demonstrated a complex cyclical pattern of training variation to optimize performance (107,112). It appears that resistance training progression occurs in an orderly manner, from a basic program design initially to a more specific design with higher levels of training when the rate of improvement becomes slower. For example, a general program used by a novice individual will most likely increase muscle hypertrophy, strength, power, and local muscular endurance simultaneously. However, this same program will not have the same effect in a trained individual (strength, hypertrophy, local muscular endurance, or power would have to be trained specifically). *Therefore, it is recommended that program design progress from simple to complex during the progression from novice, intermediate, and advanced training.*

PROGRESSION MODELS FOR RESISTANCE EXERCISE IN HEALTHY, OLDER ADULTS

Long-term progression in resistance training in healthy, older adults is brought about by chronically manipulating the acute program variables. However, caution must be taken with the elderly population as to the rate of progression. Furthermore, each individual will respond differently to a given resistance training program on the basis of his or her current training status, past training experience, and the individual response to the training stress (94). The design of a quality resistance training program for the older adult should attempt to improve the quality of life by enhancing several components of muscular fitness (56). Programs that include variation, gradual progressive overload, specificity, and careful attention to recovery are recommended (2).

Muscular strength and hypertrophy are crucial components of quality of life. As life expectancy increases, the decline in muscle strength associated with aging becomes a matter of increasing importance. Optimizing strength to meet and exceed performance goals is important to a growing number of older adults who wish to live a fit, active, independent lifestyle. Resistance training to improve muscle hypertrophy is instrumental in limiting sarcopenia. Numerous studies have investigated the effects of resistance training on muscular strength and size in older adults and have shown that both increase as long as basic requirements of intensity and volume are met (2,29,34,56,65,74,75,99,101,103,108,151). The basic health/fitness resistance training program recommended by the ACSM for the healthy adult (8) has been an effective starting point in the elderly population (63).

When the older adult's long-term resistance training goal is progression towards higher levels of muscular strength and hypertrophy, evidence supports the use of variation in the resistance training program (94,101,103,151). Nevertheless, variation may take place with any of the previously mentioned variables (e.g., exercise selection, order, intensity, volume, rest periods, frequency). Studies have shown significant improvements in muscular strength regardless of age (2,56,65,74,75,185). It is important that progression be introduced into this population at a very gradual pace, as the potential for strength adaptation appears high (2). *Recommendations for improving muscular strength and hypertrophy in older adults support the use of both multiple- and single-joint exercises (perhaps machines initially with progression to free weights with training experience) with slow to moderate lifting velocity, for one to three sets per exercise with 60–80% of 1 RM for 8–12 repetitions with 1–2 min of rest in between sets.*

The ability to develop muscular power diminishes with age (64,101). An increase in power enables the older adult to improve performance in tasks that require a rapid rate of force development (17), including a reduced risk of accidental falls. There is support for the inclusion of resistance training specific for power development for the healthy older adult (99,101,103,151). Muscle atrophy, especially in fast fibers, is most likely attributable to a combination of aging and very low physical activity levels (57,61,160) and is associated with considerable decreases in muscle strength and power (74,98,99,103). The decreases in maximal power have been shown to exceed those of maximal

TABLE 1. Summary of resistance training recommendations: an overview of different program variables needed for progression with different fitness levels.

	Muscle Action	Selection	Order	Loading	Volume	Rest Intervals	Velocity	Frequency
Strength			For Nov, Int, Adv:			For Nov, Int, Adv:		
Nov.	ECC & CON	SJ & MJ ex.	Large < small	60–70% of 1RM	1–3 sets, 8–12 reps	2–3 min. for core	S, M	2–3×/week
Int.	ECC & CON	SJ & MJ ex.	MJ > SJ	70–80% of 1RM	Mult. Sets, 6–12 reps	1–2 min. for others	M	2–4×/week
Adv.	ECC & CON	SJ & MJ ex. – emphasis: MJ	HI < LI	1RM – PER.	Mult. Sets, 1–12 reps – PER.		US-F	4–6×/week
Hypertrophy			For Nov, Int, Adv:			For Nov, Int, Adv:		
Nov.	ECC & CON	SJ & MJ ex.	Large < small	60–70% of 1RM	1–3 sets, 8–12 reps	1–2 min.	S, M	2–3×/week
Int.	ECC & CON	SJ & MJ ex.	MJ > SJ	70–80% of 1RM	Mult. Sets, 6–12 reps	1–2 min.	S, M	2–4×/week
Adv.	ECC & CON	SJ & MJ	HI < LI	70–100% of 1RM with emphasis on 70–85% – PER	Mult. Sets, 1–12 reps with emphasis on 6–12 reps – PER	2–3 min. – VH; 1–2 min. – L-MH	S, M, F	4–6×/week
Power		For Nov, Int, Adv:	For Nov, Int, Adv:	For Nov, Int, Adv:		For Nov, Int, Adv:		
Nov.	ECC & CON	Mostly MJ	Large < small	Heavy loads (>80%) – strength; Light (30–60%) – velocity – PER	Train for strength	2–3 min. for core	M	2–3×/week
Int.	ECC & CON		Most complex < least complex; HI < LI		1–3 sets, 3–6 reps	1–2 min. for others	F	2–4×/week
Adv.	ECC & CON				3–6 sets, 1–6 reps – PER		F	4–6×/week
Endurance			For Nov, Int, Adv:			For Nov, Int, Adv:	For Nov, Int, Adv:	
Nov.	ECC & CON	SJ & MJ ex.	Variety in sequencing is recommended	50–70% of 1RM	1–3 sets, 10–15 reps	1–2 min for high rep sets	S – MR	2–3×/week
Int.	ECC & CON	SJ & MJ ex.		50–70% of 1RM	Mult. Sets, 10–15 reps or more	<1 min for 10–15 reps	M – HR	2–4×/week
Adv.	ECC & CON	SJ & MJ		50–80% of 1RM – PER	Mult. Sets, 10–25 reps or more – PER			4–6×/week

ECC, eccentric; CON, concentric; Nov., novice; Int., intermediate; Adv., advanced; SJ, single-joint; MJ, multiple-joint; ex., exercises; HI, high intensity; LI, low intensity; 1RM, 1-repetition maximum; PER, periodized; VH, very heavy; L-MH, light-to-moderately-heavy; S, slow; M, moderate; US, unintentionally slow; F, fast; MR, moderate repetitions; HR, high repetitions.

muscle strength (26,98,99,103,179,228). Power development programs for the elderly may help optimize functional abilities as well as have secondary effects on other physiological systems (e.g., connective tissue) (17). On the basis of available evidence, it appears prudent to include high-velocity (nonballistic), low-intensity movements to maintain structure and function of the neuromuscular system. *The recommendations for increasing power in healthy older adults include 1) training to improve muscular strength as previously discussed, and 2) the performance of both single- and multiple-joint exercises (machine-based initially progressing to free weights) for one to three sets per exercise using light to moderate loading (40–60% of 1 RM) for 6–10 repetitions with high repetition velocity.*

Improvements in local muscular endurance in the older adult may lead to an enhanced ability to perform submaximal work and recreational activities. Studies examining the development of local muscular endurance in the older adult are limited. It has been shown that local muscular endurance may be enhanced by circuit weight training (78), strength training (124), and high-repetition, moderate-load programs (11,243) in younger populations. Considering that local muscular endurance improvements are attained with low to moderate loading, it appears that *similar recommendations may apply to the aged as well (e.g., low to moderate loads performed for moderate to high repetitions (10–15 or more) with short rest intervals).*

CONCLUSION

Progression of a resistance training program is dependent on the development of appropriate and specific training goals. An overview can be seen in Table 1. It requires the prioritization of training systems to be used during a specific training cycle to achieve desired results. Resistance training progression should be an "individualized" process of exercise prescription using the appropriate equipment, program design, and exercise techniques needed for the safe and effective implementation of a program. Trained and competent strength and conditioning specialists should be involved with this process in order to optimize the safety and design of a training program. Whereas examples and guidelines can be presented, ultimately the good judgment, experience, and educational training of the exercise professionals involved with this process will dictate the amount of training success. Nevertheless, many exercise prescription options are available in the progression of resistance training to attain goals related to health, fitness, and physical performance.

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