# Prescription of resistance training for health and disease

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**ABSTRACT**

FEIGENBAUM, M. S. and M. L. POLLOCK. Prescription of resistance training for health and disease. *Med. Sci. Sports Exerc.*, Vol. 31, No. 1, pp. 38–45, 1999. When prescribed appropriately, resistance training is effective for developing fitness, health, and for the prevention and rehabilitation of orthopedic injuries. Because resistance training is an integral component in the comprehensive health program promoted by the major health organizations (e.g., American College of Sports Medicine, American Heart Association, American Association of Cardiovascular and Cardiopulmonary Rehabilitation, Surgeon General's Office), population-specific guidelines have recently been published. The current research indicates that, for healthy persons of all ages and many patients with chronic diseases, single set programs of up to 15 repetitions performed a minimum of 2 $d \cdot wk^{-1}$ are recommended. Each workout session should consist of 8–10 different exercises that train the major muscle groups. Single set programs are less time consuming and more cost efficient, which generally translates into improved program compliance. Further, single set programs are recommended for the above-mentioned populations because they produce most of the health and fitness benefits of multiple set programs. The goal of this type of program is to develop and maintain a significant amount of muscle mass, endurance, and strength to contribute to overall fitness and health. Patients with chronic diseases (e.g., arthritis) may have to limit range of motion for some exercises and use lighter weights with more repetitions. **Key Words:** RESISTANCE TRAINING, EXERCISE PRESCRIPTION

As shown in this symposium on "Resistance Training for Health and Disease," resistance training is well established as an effective method for developing musculoskeletal strength and is prescribed for fitness and the prevention and rehabilitation of orthopedic injuries (3,6–8,26,50). More recently, resistance training has been considered as a modality used for health purposes (55). Recognizing that various segments of the population may have special limitations (i.e., cardiac, frailty, and/or orthopedic complications), major health organizations including the American College of Sports Medicine (ACSM) (6,7), the American Heart Association (AHA) (27), the American Association for Cardiovascular and Pulmonary Rehabilitation (AACVPR) (3), and the Surgeon General (55) have developed resistance exercise guidelines appropriate for various groups. In recent years, resistance training program guidelines have been developed specifically for elderly persons (50) and patients with cardiovascular disease (3,7,27) as well as for healthy sedentary and physically active adults (6,7). Table 1 summarizes the guidelines, standards, and position statements for exercise prescription for resistance training established by various health organizations. The importance of a well-rounded program including aerobic endurance exercise and resistance training is well recognized, but the purpose of this paper will focus on the latter component. A brief history, the scientific basis for resistance exercise prescription as outlined in the recommended guidelines for the various segments of the population, and the implications for future research in the area of resistance training will be addressed.

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## HISTORICAL PERSPECTIVE: RESISTANCE TRAINING GUIDELINES

As outlined by Carpenter and Nelson (17) in this symposium series, resistance training was not recommended for rehabilitation or athletic performance until the 1950s and 1960s or for adult fitness programs until the 1970s. The evolution of formal guidelines can be traced to the post World War II era, when army physician DeLorme incorporated heavy progressive resistance exercises in rehabilitation programs designed for orthopedically disabled veterans (20). DeLorme and Watkins (21) emphasized the use of heavy resistance and a low number of repetitions to develop muscular strength, and light resistance and a high number of repetitions to develop muscular endurance. As a result of the improved recovery from injuries/accidents and increased strength and muscle mass, resistance training gained formal recognition in the medical community. Studies conducted during the 1950s and 1960s began manipulating and evaluating training volume variables (sets, repetitions, frequency of training, intensity, and rest periods) (10–12,16,40,45,58,59), the results from which formulate the basis for many of the current resistance exercise guidelines.

TABLE 1. Standards, guidelines, and position statements regarding strength training.

| | Sets; RM | No. of Exercises[a] | Frequency |
|---|---|---|---|
| Healthy sedentary adults | | | |
| 1998 ACSM Position Stand (6) | 1 set; 8–12 RM | 8–10 | 2–3 d·wk$^{-1}$ |
| 1998 ACSM Guidelines (7)[b] | 1 set; 8–12 RM | 8–10 | 2 d·wk$^{-1}$ minimum |
| 1996 Surgeon General's Report (55) | 1–2 sets; 8–12 RM | 8–10 | 2 d·wk$^{-1}$ |
| Elderly persons | | | |
| Pollock et al. (50) | 1 set; 10–15 RM | 8–10 | 2 d·wk$^{-1}$ minimum |
| Cardiac patients | | | |
| 1995 AHA Exercise Standards (27) | 1 set; 10–15 RM | 8–10 | 2–3 d·wk$^{-1}$ |
| 1995 AACVPR Guidelines (3) | 1 set; 12–15 RM | 8–10 | 2–3 d·wk$^{-1}$ |

Note. AHA, American Heart Association; AACVPR, American Association of Cardiovascular and Pulmonary Rehabilitation; RM, repetition maximum.
[a] Minimum one exercise per major muscle group, e.g., chest press, shoulder press, triceps extension, biceps curl, pull-down (upper back), lower back extension, abdominal crunch/curl-up, quadriceps extension, leg curls (hamstrings), calve raise.
[b] ACSM (7): guidelines developed for healthy, sedentary, and low-risk diseased populations.
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In the 1960s and 1970s, Cureton (19) and others (31) promoted the importance of a well-rounded program including aerobic endurance exercise and resistance training for adult fitness programs. During the same time period, a growing body of epidemiological research indicated a strong link between aerobic endurance activities and the prevention of cardiovascular disease (28,37,46). These research findings, in addition to the publication of *Aerobics* (18), Shorter winning the 1972 Olympic marathon, and the development of Masters Track and Field (first national meet in 1971), popularized aerobic endurance exercise. Unfortunately, health and fitness became synonymous with aerobic exercise and the perceived need for muscular strength and endurance training appeared to decline.

In 1978, ACSM issued its original position statement entitled "The Recommended Quantity and Quality of Exercise for Developing and Maintaining Fitness in Healthy Adults" (4). Reflecting the trends of the time, the focus of the statement was on establishing exercise guidelines for developing and maintaining cardiorespiratory fitness and body composition. The lack of research quantifying the amount of resistance training needed for the average adult was the main reason for its omission in the 1978 ACSM statement, not because it was felt unimportant (personal communication, M. L. Pollock, May, 1993). It was and remains the policy of the ACSM that position stands must be accompanied by research documentation. Unfortunately, the omission of resistance training guidelines was interpreted as a lack of importance. In 1980, the American Alliance for Health, Physical Education, Recreation, and Dance (AAHPERD) published its new *Health Related Fitness Test Manual* (1). The manual excluded upper body strength test items, implying their lack of importance.

In the early 1980s, health clubs and fitness/wellness centers recognized the impact of resistance training on athletic performance and general fitness. By the mid-1980s, the medical community had begun to recognize the potential health value of resistance training on functional capacity and other health-related factors (e.g., bone health, basal metabolism, weight control, and low back health). At this time, research concerning resistance training and its quantification for the average participant intensified. In 1989, AAHPERD added upper body strength training and testing as an integral component in their Physical Best Program (43). In 1990, ACSM (5) recognized the importance of the comprehensive fitness program and added a resistance training component to the 1978 Position Statement. As mentioned earlier, most major health organizations currently recommend resistance training as part of a comprehensive exercise program for health and fitness (Table 1). Thus, from 1965 to 1995, Cureton's (19) concept of a comprehensive fitness program had come full circle.

## SCIENTIFIC BASIS FOR RESISTANCE EXERCISE PRESCRIPTION

The effectiveness of a resistance training program is dependent upon several factors including frequency, volume of training (sets × repetitions × resistance), and mode of training (free weight vs variable resistance machines; dynamic (i.e., isotonic, isokinetic) vs isometric exercises; concentric vs eccentric contractions) (26,29). When prescribing an resistance exercise program, the clinician or fitness instructor must decide what constitutes an optimal balance of these factors to maximize benefits and needs to consider the individual's current age, health status, fitness level, rationale for strength development, and personal goals. Programs prescribed for competitive athletes that often include exercises designed specifically to improve the development of explosive power (i.e., clean and jerk, snatch, plyometrics) are usually not appropriate for sedentary middle-aged adults, elderly persons, or patients with chronic disease(s). The major health organizations recognized the need for developing resistance exercise guidelines for specific segments of the population (Table 1). Although these guidelines provide the basis for prescribing individualized exercise programs, the basic components common to all resistance exercise programs provide the framework for

TABLE 2. The results from studies comparing strength gains found using single or multiple sets of resistance exercise.

| Reference | Sex | Age | N | Exercise | $d \cdot wk^{-1}$ | Duration | Sets × RM | % Increase |
|---|---|---|---|---|---|---|---|---|
| Berger (10) | M | C | 177 | Bench press | 3 | 12 wk | 1 × 6/10 | 22.4 |
| | | | | | | | 2 × 6/10 | 21.8 NS |
| | | | | | | | 3 × 6/10 | 25.3[a] |
| Silvester et al. (52) | M | C | 48 | Biceps curl | 3 | 8 wk | 1 × 10–12 | 24.6 |
| | | | | | | | 3 × 6 | 26.2 NS |
| Stowers et al. (54) | M | C | 28 | Squat | 2 | 7 wk | 1 × 10 | 16.1 |
| | | | | | | | 3 × 10 | 21.1 NS |
| | | | | Bench press | | | 1 × 10 | 8.0 |
| | | | | | | | 3 × 10 | 10.6 NS |
| Westcott (56) | M/F | 35 | 44 | Nautilus circuit[b] | 3 | 4 wk | 1 × 10 | 11.2[b] |
| | | | | | | | 2 × 10 | 10.8[b]NS |
| Westcott et al. (57) | M/F | 40 | 77 | Dips/Chin-ups | 3 | 10 wk | 1 × 5/10/15 | 4.8[c] |
| | | | | | | | 2 × 5/10/15 | 4.1[c]NS |
| | | | | | | | 3 × 5/10/15 | 5.2[c]NS |
| Pollock et al. (49) | M/F | 26 | 78 | Cervical extension | 2 | 12 wk | 1 × 8–12 | 40.9 |
| | | | | | | | 2 × 8–12 | 43.5 NS |
| Graves et al. (33) | M/F | 31 | 110 | Lumbar extension | 1 | 12 wk | 1 × 8–12 | 19.0 |
| | | | | | | | 2 × 8–12 | 16.0 NS |
| Starkey et al. (53) | M/F | 35 | 49 | Knee extension | 3 | 14 wk | 1 × 8–12 | 30.1 |
| | | | | | | | 3 × 8–12 | 26.8 NS |
| | | | | Knee flexion | 3 | 14 wk | 1 × 8–12 | 18.7 |
| | | | | | | | 3 × 8–12 | 17.7 NS |

C, college undergraduates; NA, data not available; NS, no significant differences vs. one set.

[a] $P < 0.05$; 3 sets > 1 set.

[b] Nautilus circuit—average strength increase of five exercises: leg extension, leg curl, torso pullover, arm extension, arm curl.

[c] Data indicate the average increase in the number of dips and chin-ups combined.

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resistance exercise prescription, regardless of the intended population.

**Repetition maximum (RM).** One common factor in all effective strength training and rehabilitation programs is the inclusion of at least one set of the maximal or near-maximal number of repetitions possible for each exercise performed (26,29). The amount of weight to be used should be based on a percentage of the maximum amount of weight that can be lifted one time, generally referred to as a one-repetition maximum (1-RM). The maximum number of repetitions performed before fatigue prohibits the completion of an additional repetition, is a function of the weight load used, is referred to as a repetition maximum (RM), and generally reflects the intensity of the exercise. Consequently, a weight load that produces fatigue on the third repetition is termed a three-repetition maximum (3-RM) and corresponds to approximately 85% of the weight that could be lifted for a 1-RM. The number of repetitions performed to fatigue is an important consideration in designing a resistance training protocol, with the greatest strength gains appearing to result from resistances yielding 4- to 10-RM (26,42). Increasing the number of repetitions to 12- to 20-RM by decreasing the relative amount of resistance will favor increases in muscular endurance (26). In this regard it appears that the intensity of resistance training is the most important factor for developing muscular strength (8,42), while the total training volume (sets × repetitions × resistance) is more important for the development of muscular endurance and muscle mass (26,44,52,55). While the term "high-intensity" resistance training is usually reserved for 1-RM to 6-RM training loads, programs that emphasize exercising with a resistance that allow 8–12 repetitions are traditionally classified as "moderate intensity." Moderate intensity programs are usually recommended for most of the adult nonathletic populations including programs designed for adult fitness, health maintenance, and orthopedic rehabilitation. Moderate intensity programs recommended for cardiac patients and the elderly and more frail persons use 10/12 to 15 repetitions to fatigue.

**Single versus multiple sets.** The volume of training is a product of the number of sets performed for each exercise, the number of repetitions completed within each set, and the amount of weight (resistance) lifted. Although three sets of 6–12 repetitions performed 3 $d \cdot wk^{-1}$ is a typical exercise prescription for many resistance training programs, the optimal number of sets of an exercise to develop muscular strength remains controversial. It is surprising that there is a lack of well-controlled studies comparing single versus multiple set resistance training programs. Table 2 summarizes the results from resistance training studies comparing the volume of training using a variety of muscle groups. As depicted in Table 2, only one study has found a multiple set protocol to elicit greater strength gains than a single set (10), whereas the majority of studies indicate there is not a significant difference (33,44,49,52,53,56,57). The results of Berger's study (10), from which originated the basis for prescribing three sets of 6–10 repetitions, indicated that three sets of 6 to 10 repetitions was superior to one or two sets with similar repetitions following 12 wk of bench press exercise performed 3 $d \cdot wk^{-1}$. When comparing Berger's ANCOVA data, the groups started with a 1-RM bench press of 56.6 kg and finished with 69.3 kg (22.4% increase; 1 set group), 68.9 kg (21.8% increase; 2 set group), and 70.9 kg (25.3% increase; 3 set group). Although there was a statistically significant difference, the magnitude between the groups training with one set versus three sets was small (2.9%). Furthermore, no studies, including the Berger study, indicate that for the first 3–4 months of an resistance training program two sets are superior to one set. Recently, a study conducted by Starkey et al. (53) concluded that one set of moderate intensity resistance training (approximately 10 repetitions to volitional fatigue) was as effective as three sets (14 wk, 3 $d \cdot wk^{-1}$) for increasing knee extension and knee flexion dynamic strength and isometric torque and muscle thickness in previously untrained adults.

With the exception of the Berger study (10), the literature supports the recommendation of prescribing single set programs performed to fatigue and indicates that quality (intensity) and not the quantity (volume) of resistance training may be the most important factor for developing muscular strength in sedentary persons (44,52,54). Despite the variety of muscle groups tested (pectorals, biceps, lumbar extensors, quadriceps, etc.), most studies have produced similar results (Table 2). It should be noted that most of the studies described were conducted over a 4- to 20-wk period, and longer duration studies may show greater strength gains with multiple set programs. However, the existing literature clearly indicates that for the first 3–4 months of resistance training, single set programs are equally effective as multiple set programs for improving muscular strength in previously untrained persons.

In addition, the amount of time required to complete a single set program is substantially less than one-half the time required to complete multiple set protocols. Messier and Dill (44) reported that the time required to complete a three-set free weight resistance training program averaged 50 min compared to the 20 min for a one-set group. This time efficiency should generally translate into improved exercise program compliance. Considering the similarities in strength gains for single and multiple set programs, single set programs are recommended because they are less time consuming, more cost efficient, and produce similar health and fitness benefits in the untrained person (43,46).

**Frequency of training.** The frequency of training for a muscle group is also an important component of a resistance training program design (15,22,26,30,32). The rest period must be sufficient to allow for muscular recuperation and development and to prevent overtraining. However, too much rest between training sessions can result in detraining. A 48-h rest period between concurrent training sessions is generally recommended (26), which corresponds with a 3 $d \cdot wk^{-1}$ frequency of training guideline for individual muscle groups. Although 3 $d \cdot wk^{-1}$ of resistance exercise is generally recommended for maximal strength gains, research indicates that isolated muscle groups are unique in their trainability and adaptability to resistance training (22,32,51). Table 3 summarizes the results from resistance training studies comparing frequency of training using a variety of muscle groups.

Two studies evaluating the effects of frequency of training have shown that four or more training sessions per week produced optimal strength gains in several muscle groups (30,36). Using the standard bench press exercise, Gillam (30) indicated that training 5 $d \cdot wk^{-1}$ over a 7-wk period was superior to 1, 2, 3, or 4 $d \cdot wk^{-1}$ training regimens. Interestingly, training 3 or 4 $d \cdot wk^{-1}$ produced similar results which were significantly greater than those obtained by the groups training 1 or 2 $d \cdot wk^{-1}$. Hunter (36) and Henderson (34) also found that increasing the frequency of bench press training to 4 and 3 $d \cdot wk^{-1}$, respectively, produced greater strength gains than lesser frequency protocols. In contrast, Berger (13) found that bench pressing either 2 or 3 $d \cdot wk^{-1}$ produced similar strength gains over the course of 12 wk. Similar findings have also been reported for studies evaluating strength gains in the lower limb muscles. Braith et al. (15) found 3 $d \cdot wk^{-1}$ to be superior to 2 $d \cdot wk^{-1}$ in increasing quadriceps (knee extension) strength and an earlier study by Barham (9) showed that performing the squat exercise 3 $d \cdot wk^{-1}$ was as effective as 5 $d \cdot wk^{-1}$, and that both training frequencies were superior to squatting 2 $d \cdot wk^{-1}$.

While the chest, arms, and legs may require a training frequency of 3 $d \cdot wk^{-1}$ or more to develop optimal strength gains, additional studies suggest that the muscles supporting the spine (i.e., lumbar extensors) and smaller muscles of the torso may respond as well with fewer training sessions per week. For example, Graves et al. (32) found no significant differences in dynamic and isometric strength generated by isolated lumbar extensor muscles among groups training 1, 2, or 3 $d \cdot wk^{-1}$ for 20 wk. When assessing cervical rotation strength, Leggett et al. (39) found that training frequencies of 2 and 3 $d \cdot wk^{-1}$ were superior to 1 $d \cdot wk^{-1}$ or 1 day every 2 wk over a 12-wk training period. Pollock et al. (49) indicated that training 2 $d \cdot wk^{-1}$ is superior to 1 $d \cdot wk^{-1}$ for increasing cervical extension strength, but because training 3 $d \cdot wk^{-1}$ was not evaluated, no inferences can be made in this regard. As for the muscles involved in torso rotation, DeMichele et al. (22) concluded that the 2 $d \cdot wk^{-1}$ training frequency obtained better adherence and equal strength gains compared with 3 $d \cdot wk^{-1}$; both of these groups elicited greater improvements than those that trained 1 $d \cdot wk^{-1}$.

Based on the findings of these studies, it is clear that there is no single optimal frequency of resistance training for all muscle groups. Whether the differences in the time course of strength gains occurring in isolated muscle groups result from variations in neural integration, muscle morphology, autoregulation, or other mechanisms warrants further investigation. Although clinicians and other health professionals must consider the specific needs of individual participants, particularly those who are frail or with orthopedic limitations, the conservative frequency of training of a minimum of 2 $d \cdot wk^{-1}$ guideline seems appropriate (Table 3). Participants who have time and want to achieve more benefits may choose to weight train 3 $d \cdot wk^{-1}$. In addition, when