

Prescription of Resistance Training for Healthy Populations

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Abstract

Although there are well documented protective health benefits conferred by regular physical activity, most individuals of all ages are not physically active at a level for sufficient maintenance of health. Consequently, a major public health goal is to improve the collective health and fitness levels of all individuals. The American College of Sports Medicine (ACSM) and other international organisations have established guidelines for comprehensive exercise programmes composed of aerobic, flexibility and resistance-exercise training. Resistance training is the most effective method available for maintaining and increasing lean body mass and improving muscular strength and endurance.

Furthermore, there is an increasing amount of evidence suggesting that resistance training may significantly improve many health factors associated with the prevention of chronic diseases. These health benefits can be safely obtained by most segments of the population when prescribed appropriate resistance-exercise programmes. Resistance-training programmes should be tailored to meet the needs and goals of the individual and should incorporate a variety of exercises performed at a sufficient intensity to enhance the development and maintenance of muscular strength and endurance, and lean body mass. A minimum of 1 set of 8 to 10 exercises (multi-joint and single joint) that involve the major muscle groups should be performed 2 to 3 times a week for healthy participants of all ages. More technical and advanced training including periodised multiple set regimens and/or advanced exercises may be more appropriate for individuals whose goals include maximum gains in strength and lean body mass. However, the existing literature supports the guidelines as outlined in this paper for children and adults of all ages seeking the health and fitness benefits associated with resistance training.

Daily physical exertion and participation in exercise programmes incorporating endurance exercise and resistance training have been shown to reduce the risk of several chronic diseases (e.g. cor-

onary heart disease, obesity, diabetes mellitus, osteoporosis).^[1] However, despite the protective health benefits, most individuals of all ages are not physically active.^[2] Among children and adolescents

aged 6 to 17 years, less than half exercise at a level considered vigorous enough to achieve health and fitness benefits. Furthermore, approximately one-half of males and two-thirds of females aged 12 to 21 years do not participate regularly in resistance-training activities (i.e. push-ups, curl-ups, weight training) which may, in part, explain why less than half of today's youth can not perform a single pull-up.^[2-4] With regard to young and middle-aged adults, the 1996 Surgeon General's Report on Physical Activity and Health^[2] indicated that only 22% of adults exercise on a regular basis and that 25% lead an essentially sedentary lifestyle. Finally, elderly adults often experience age-, inactivity- and disease/disability-associated declines in lean body mass and functional capacity, which could be largely offset with regular participation in resistance-training programmes.^[5]

Consequently, the general perception among the major health organisations is that most individuals of all ages are below the activity and fitness levels needed for optimal protection against chronic disease. Not surprisingly, a major public health goal is to improve the collective health and fitness levels of all individuals. The American College of Sports Medicine (ACSM) and other national and international organisations have established guidelines for exercise programmes designed to improve the health and fitness of the predominantly sedentary population (table I).

Resistance training, also known as strength- or weight-training, is well established as an effective method for developing musculoskeletal fitness and is currently prescribed by many major health organisations for improving health and fitness levels, athletic performance and/or for the prevention and rehabilitation of orthopaedic injuries.^[6,7,9-14] Further-

Table I. Standards, guidelines and position statements regarding physical activity for adults

Reference	Frequency	Intensity	Duration	Mode	Resistance training	Flexibility training
Healthy/sedentary adults						
1998 ACSM Position Stand ^[6]	3-5 d/wk	55/65-90% HR _{max} or 40/50-85% VO _{2max} or HR _{max} reserve	20-60 min continuous	Aerobic activities	1 set 8-12 reps; 8-10 exer.; major muscle groups; 2 d/wk	Static and dynamic major muscle groups 2-3 d/wk
2000 ACSM Guidelines ^[7]	3-5 d/wk	55/65-90% HR _{max} or 40/50-85% VO _{2max} or HR _{max} reserve	20-60 min continuous; 20-30 min minimum	Aerobic activities (expanded)	1 set 8-12 reps; 8-10 exer.; major muscle groups; 2 d/wk	Static and dynamic major muscle groups 2-3 d/wk
1995 CDC/ACSM Public Health Statement ^[9]	Daily	Moderate	Accumulate 30 min/d	Health promotion activities	Addressed, not specified	
Elderly persons						
Pollock et al. ^[9]	3-5 d/wk	50-85% VO _{2max} or 40-80% HR _{max} reserve	30-60 min continuous	Low-impact aerobic activities	1 set 8; 12 reps; 8-10 exer.; major muscle groups; 2 d/wk	
Cardiac patients						
1995 AHA Exercise Standards ^[10]	Minimum 3 d/wk	50-60% VO _{2max} or HR _{max} reserve	Minimum 30 min	Health promotion activities	1 set 10-15 reps; 8-10 exer.; 2-3 d/wk	
1999 AACVPR Guidelines ^[11]	3-5 d/wk	50-60% VO _{2max} or HR _{max} reserve	30-45 min continuous/intermittent (expanded)	Aerobic activities	1 set 10-15 reps; major muscle groups; 2-3 d/wk	

AACVPR = American Association of Cardiovascular and Pulmonary Rehabilitation; **ACSM** = American College of Sports Medicine; **AHA** = American Heart Association; **CDC** = Centers for Disease Control and Prevention; **d** = days; **exer.** = exercises; **HR_{max}** = maximum heart rate; **reps** = repetitions; **VO_{2max}** = maximal oxygen uptake; **wk** = week.

more, participation in a resistance-training programme has been shown to reduce the rate-pressure product when lifting any given load.^[13] Thus, strength training may decrease cardiac demands during performance of daily activities such as carrying groceries or lifting moderate-to-heavy objects.^[15] Higher levels of strength are accompanied by a greater capacity to perform activities of daily living by improving functional status, the maintenance of independence and the prevention of disability.^[16] Until recently, the effects of resistance training on long-term health status and the role resistance training may play in preventing chronic diseases have been largely overlooked. An increasing amount of evidence suggests that resistance training plays a significant role in improving many health factors associated with the prevention of chronic diseases (see table II).^[1,17] These health benefits can be safely obtained by most segments of the population when prescribed appropriate resistance-exercise programmes.^[18] When prescribing a resistance-exercise regimen, the clinician, coach or fitness instructor should consider the individual's current health and fitness status, goals, access to appropriate equipment and time available for training. Training programmes prescribed for competitive athletes which often include exercises designed specifically to improve the development of explosive power (i.e. Olympic lifts, plyometrics) are generally inappropriate for children, untrained adults, elderly persons or patients with chronic disease(s).

Several major health organisations have recognised the need for developing resistance-exercise guidelines for specific segments of the population (table I). This paper provides fundamental resistance-training programme guidelines for healthy nonathletic populations ranging in age from the pre-pubescent to the elderly. Furthermore, this review allows the reader to make comparisons across the age ranges and provides information regarding the progression of the exercise programme once an initial level of fitness is achieved.

1. Overview of Resistance-Training Guidelines

Resistance training is the most effective method available for maintaining and increasing lean body mass and improving muscular strength and endurance. These improvements are developed by utilising the progressive overload principle (i.e. gradually increasing the stress placed upon the body during training). Progressive overload may be introduced into a resistance-training programme by increasing the frequency or duration of activity, altering repetition speed, rest periods or by increasing the resistive load and volume. A consistent over-

Table II. Comparison of the effects of aerobic endurance training to resistance training on health and fitness variables (from Pollock & Vincent,^[1] with permission)

Variable	Aerobic exercise	Resistance exercise
Bone mineral density	↑↑	↑↑
Risk of falls	↔↓	↓
Osteoarthritis	↓↔	↓
% fat	↓↓	↓
LBM	↔	↑↑
Strength	↔	↑↑↑
Local muscle endurance	↑↑	↑↑↑
Glucose metabolism		
Insulin response to glucose challenge	↓↓	↓↓
Basal insulin levels	↓	↓
Insulin sensitivity	↑↑	↑↑
Serum lipids		
HDL	↑↑	↑↔
LDL	↓↓	↓↔
Resting heart rate	↓↓	↔
Stroke volume	↑↑	↔
Blood pressure at rest		
Systolic	↓↓	↔
Diastolic	↓↓	↓↔
VO _{2max}	↑↑↑	↑
Endurance time	↑↑↑	↑↑
Physical function	↑↑	↑↑↑
Independent living/mobility	↑↑	↑↑↑
Basal metabolism	↑	↑↑

HDL = high-density lipoprotein; **LBM** = lean body mass; **LDL** = low-density lipoprotein; **VO_{2max}** = maximal oxygen uptake; **% fat** = percentage body fat; ↑ = increase; ↑↑ = marked increase; ↑↑↑ = very marked increase; ↓ = decrease; ↓↓ = marked decrease; ↔ = no change.

load will result in strength development, but maximal or near maximal loads (greater intensity) and/or increased volumes of training will elicit greater improvements.^[13,19] The intensity of an exercise, or the amount of resistance used, is often estimated as the percentage of the 1 repetition maximum (1RM). The term RM refers to the maximal number of times a load can be lifted using good form and technique. Loads greater than 50% of the 1 RM have been shown to increase muscular strength in previously untrained individuals;^[20-22] however, more intense training is often required to produce further adaptations in experienced lifters.^[23,24] Training volume is the product of the number of sets performed for each exercise and the number of repetitions performed in each set.^[25] Training volume has been shown to affect neural,^[23,24] hypertrophic,^[26] metabolic,^[27] hormonal responses^[28,29] and adaptations to resistance training.

The intensity and volume of exercise can be manipulated by varying the weight load, the number of repetitions and sets completed, the rest interval between sets and exercises, or combinations thereof. The question remains as to the optimal intensity and volume that are sufficient to elicit a training effect (physiological and/or psychosocial), yet do not deter programme compliance and/or result in an increased risk of injury. Specificity in resistance training refers to the idea that the adaptations to training are specific to the stimulus applied. Although there is some carryover in the training effects, the physiological adaptations to training are specific to the muscle actions involved,^[30] muscles trained, range of motion of the movement,^[31] and the energy systems utilised.^[32,33]

1.1 Number of Repetitions

Muscular strength and power are best developed by using heavier weights (that require maximum or near maximum tension development) with few repetitions, whereas muscular endurance is enhanced by using lighter weights with a greater number of repetitions. To some extent, both muscular strength and endurance are developed under each condition,

but each loading scheme favours a more specific type of neuromuscular development.^[13,19] Thus, 8 to 12 repetitions/set are generally recommended to elicit improvements in both muscular strength and endurance as well as muscle hypertrophy.^[6,7,13] Orthopaedic injury may occur in older (>65 years) and/or more frail participants when performing efforts to volitional fatigue using a high-intensity, low-to-moderate RM training regimen. Therefore, the completion of 10 to 15 repetitions or RM are generally recommended for this population.^[6,7,12]

1.2 Number of Sets

Three or more sets of 6 to 12 repetitions per exercise performed 3 days/week as part of a periodised programme is a traditional resistance-exercise prescription for many high school, collegiate and professional athletic programmes. Periodisation is the systematic process of planned variations in a resistance-training programme over a specified training cycle.^[14] Specifically, varying the volume and intensity of the exercise has been shown to be vital for the optimisation of the training adaptation in athletes.^[34] However, the minimal and optimal number of sets required to elicit significant gains in health parameters is substantially less for nonathletes.^[35] Unfortunately, there is a lack of well-controlled long-term clinical trials reported in the literature comparing single versus multiple-set resistance-training programmes.

The existing resistance-training guidelines recommended by the ACSM,^[6,7] American Heart Association (AHA)^[10] and American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR)^[11] regarding the number of sets to be performed are clearly directed at adult fitness and clinical populations, and reflect the empirical research conducted to determine the minimal and optimal levels of exercise needed to induce health and fitness-related adaptations. Part of the rationale for the current guidelines is that the time efficiency of single-set programmes often translates into improved programme compliance since exercise-programme sessions that last longer than 1 hour are associated

with higher dropout rates.^[36,37] Considering the similarities in strength gains for single and multiple-set programmes during the initial training period, single-set programmes are recommended for healthy nonathletes and clinical populations^[18] because they are less time consuming, more cost efficient and appear to produce comparable health and fitness benefits.

1.3 Frequency of Training

The frequency of training, the number of training sessions per week, is also an important component of a resistance-exercise prescription.^[13,38] The rest period must be sufficient to allow for muscular recuperation and development while alleviating the potential for overtraining; however, extended periods between sessions can result in detraining. Training frequency depends on several factors including the number of muscle groups trained per workout session, level of conditioning, exercise intensity, volume and duration. A 48 hour rest period between concurrent training sessions is generally recommended,^[6,13] which corresponds to a 3 days/week frequency of training guideline for individual muscle groups. Although clinicians and coaches must consider the specific needs and goals of individual participants (i.e. time needed to recover from a training session), the conservative frequency of training guideline of a minimum of 2 days/week is appropriate. The 2 days/week programme also appears to elicit 80 to 90% of the strength benefits that are achieved with more frequent programmes in the initially untrained person.^[38] Interestingly, the ongoing benefits conferred by resistance training can apparently be maintained by performing once a week and even once every other week sessions of resistance training.^[39,40] Participants who have the time and want to achieve even greater benefits may choose to train 3 days/week. However, the minimum of 2 days/week frequency guideline allows more time for recuperation, is less time consuming and thus may enhance adherence.

1.4 Modality of Exercise

Muscular strength and endurance can be developed by means of static (isometric) or dynamic (isotonic or isokinetic) exercises. Although each type of training has its advantages and limitations, dynamic resistance exercises are generally recommended as they best mimic activities of daily living. From a safety standpoint, variable resistance machines with incremental weight stacks are generally recommended.^[41] Furthermore, machines generally require less time compared with free-weight exercises, allowing the participant additional time to pursue complementary aerobic activities and flexibility exercises. However, free-weight exercises more often mimic the movement requirements of specific tasks and allow proprioceptive feedback in a manner more similar to athletic movements and activities of daily living.^[42] Moreover, free weights are often less expensive and may offer more variety in a resistance-training programme leading to greater programme adherence. Both single- and multiple-joint exercises are effective for increasing muscular strength and both should be incorporated into the resistance-training programme.^[23,43,44] Single-joint exercises are more often used to isolate specific muscle groups whereas multi-joint exercises are generally regarded as most effective for increasing overall muscle strength.

The ability to complete a comprehensive exercise programme within 45 to 60 minutes, 2 to 3 days/week, should facilitate increased programme compliance while inducing favourable adaptation and improvement in multiple organ systems (i.e. cardiorespiratory, musculoskeletal, endocrine, immune). For safety and time allotment considerations, most resistance-training programmes should incorporate a combination of variable resistance equipment, free weights and traditional calisthenics and flexibility exercises. Intensity should start low and progress slowly, allowing time for physiologic adaptation. Exercises should be rhythmical, performed at a moderate-to-slow controlled speed, through a pain-free range of motion, with a normal breathing pattern during the lifting movements.

Heavy resistance exercise can cause dramatic acute increases in both systolic and diastolic blood pressure, especially when a Valsalva manoeuvre is evoked, and is generally not recommended for populations with chronic diseases.^[45,46] If a 1RM test is administered for the purposes of assessing muscular strength at the beginning of a resistance-training programme, then 30 to 40% of the 1RM for the upper body and 50 to 60% of the 1RM for the hips and legs should be used as the starting weight for the initial exercise training session.

Although greater percentages of the 1RM are often initially used in a research setting, it is our opinion that the recommendations presented here provide the novice exerciser with the opportunity to learn proper form and technique, demonstrate how to progress the intensity of the exercise, and provide for immediate success and reduce muscle soreness. All of which may lead to increased programme adherence. When the participant can comfortably lift the weight for 12 repetitions using good form and perceive it to be light to somewhat hard [12 to 13 on the Borg Rating of Perceived Exertion (RPE) scale],^[47] 5% can be added to the next training session. Although completing 1 set of 8 to 12 repetitions at a comfortably hard level (RPE = 12 to 13) is the initial goal, the healthy participant may strive to progress to a higher intensity (RPE = 15 to 17; very hard). Since the level of intensity is an important factor for attaining a maximal benefit, exercising with greater effort gives the best results. At this higher level of training, progression to a heavier weight should occur every 1 to 2 weeks. If an individual can not lift the weight a minimum of 8 times then the weight should be reduced for the next training session.

2. Guidelines for Initially Untrained Adults

The current recommendation for the initially untrained adult is 1 set of 8 to 12 repetitions to volitional fatigue of 8 to 10 exercises performed 2 to 3 times/week for individuals under 50 years of age, and the same regimen using 10 to 15 repeti-

tions for persons older than 50 years of age.^[6] Research suggests that 80 to 90% of strength gains can be elicited using this regimen during the initial training period (i.e. up to the first 4 months) compared with higher volume programmes. The rationale for the current recommendations regarding resistance-training programme guidelines have been reviewed previously.^[25,35,36]

For healthy untrained adults, it appears that multiple-set programmes provide little, if any, additional stimulus for improving the rate of physiological adaptations during the initial training period when compared with single-set programmes. For example, Starkey et al.^[48] compared the effects of 1 set versus 3 sets of high-intensity leg extension and leg flexion exercises on isometric muscular strength and muscle thickness following a 14-week training period. Muscular strength improved significantly and similarly for both groups for the exercises tested. Ultrasound measurements of muscle thickness made from 10 representative sites on the anterior and posterior thigh revealed comparable and significant improvements for both groups. In contrast to the training regimens recommended for initially untrained adults, there is compelling evidence for the multiple-set paradigm using periodisation regimens for the more serious lifter/athlete whose goal is to maximise muscle size and strength.^[14] However, there is increasing evidence that most individuals who engage in resistance-training regimens are more likely to adhere to the current ACSM recommendations in which resistance training is but one component of a comprehensive exercise programme.^[36,37]

3. Guidelines for Recreational Weight Lifters

In previously sedentary individuals, increases in muscle strength are readily attained and are mediated by neural adaptations as well as a gradual increase in muscle hypertrophy.^[49] The ACSM position stand^[6] reported an average improvement in muscular strength of 25 to 30% for sedentary young and middle aged men and women during the first 6

months of resistance training. Although studies have shown continued increases in strength with added weeks of training up to 2 years, the magnitude of improvement is less and tends to plateau after 3 to 6 months.^[13,50] Critics of the current guidelines for resistance training suggest that once initial fitness has been achieved, multiple sets are required to achieve greater physiological adaptation and improvement. Presumably, the additional improvements in performance conferred by multiple-set programmes would surpass the time advantages of single-set training regimens. However, recent studies suggest that single-set programmes are efficacious and lead to similar improvements in muscular fitness compared with multiple-set nonperiodised programmes in recreational weight lifters.

Recreational weight lifters are those individuals with resistance-training experience whose training goals are improved health and muscular fitness (i.e. muscular strength, endurance and body composition). As opposed to the goals of most athletes, these individuals exercise primarily for the associated aesthetic outcomes, improved performance and stamina in recreational activities and activities of daily living, and overall health and well-being. Hass et al.^[37] investigated the effects of increasing training volume from 1 set to 3 sets on muscular strength, muscular endurance, and body composition in long-term recreational weight lifters. At the end of the 13-week training protocol, the results showed that performing additional sets of high intensity resistance exercise did not lead to significantly greater improvements in muscular strength, muscular endurance or body composition compared with training using a single set when part of a comprehensive exercise programme. Both the 1-set and 3-set groups experienced significant and similar improvements with the 3-set group demonstrating only a 2% greater increase in strength. Interestingly, all of the participants who dropped out of the study were from the multiple-set group.

In a similar study, Ostrowski et al.^[51] reported that 1 set per exercise was as effective as 2 and 4 sets for improving muscular size, strength and up-

per body power in recreational weight lifters with several years of training experience. Considering the similarities in improvements between single-set and multiple-set nonperiodised training, a single set of 8 to 12 repetitions appears to represent a valid and efficient method for continued development of muscular fitness in recreational lifters. This is important for individuals who desire the health and fitness benefits associated with a comprehensive programme but may not have the time to devote to multiple-set training regimens.

The potential for strength development and the magnitude and time course of neuromuscular adaptations may differ in novice versus experienced weight lifters. However, by systematically varying the resistance-training programme by changing the number of repetitions and the type of exercises performed, significant gains may be achieved.^[13] Recreational weight lifters should incorporate these variations into the recommended guideline of performing 1 set of a minimum of 8 to 10 exercises (multi-joint and single joint) that focus on the major muscle groups performed 2 to 3 times/week for continued improvement in musculoskeletal fitness.

4. Guidelines for Prepubescents and Adolescents

Children and adolescents can safely improve their health and fitness levels if appropriate resistance-training guidelines are followed.^[52-54] These adaptations include increases in muscular strength and endurance, improvements in blood lipid profiles and body composition, enhanced motor performance, and a reduction in the incidence of injury.^[54] Socialisation and mental discipline as well as more favourable attitudes towards physical activity in general can also be fostered through participation in resistance-training programmes.^[55,56] The American Academy of Paediatrics,^[57] the ACSM^[7] and the National Strength and Conditioning Association (NSCA)^[53] support the participation of children in supervised weight-training programmes. The general recommendation is to develop a basic resistance-training regimen that does not exceed 20

to 40 minutes per session, 2 to 3 times/week, performed in a well supervised environment.^[13] With regard to training volume, the NSCA recommends that children should perform at least 1 set of 6 to 15 repetitions on a variety of upper and lower body exercises incorporating both isolated and multi-joint exercises.^[53]

Recognising that upper body strength is declining in boys and girls,^[2-4] resistance-training exercises for the upper body should be emphasised for both genders. The initial intensity of these programmes should be comfortably tolerable but become more challenging as the child matures physically and psychologically. Child-size machines should be used whenever possible though bodyweight-resisted and partner-assisted exercises are viable alternatives. Pads and boards may be used to adapt standard size equipment if care is taken to ensure proper body alignment.^[53]

Recently, researchers evaluated a wide array of training regimens (i.e. choice/order of exercises, manipulating volume and intensity) to determine the potential benefits for prepubescents and adolescents. Although higher intensity loads with fewer repetitions lead to greater improvements in strength in adults, this does not appear to be the case in prepubescents. Faigenbaum and colleagues^[52] compared low-repetition high-load versus high-repetition moderate-load intensity of single-set training in 5- to 12-year-old boys and girls. The investigators concluded that in the beginning stages of a resistance-exercise programme, children should perform a single set of 13 to 15 repetitions per exercise. This recommendation was based not only on the greater gains in muscular strength, but also on the observation that this repetition-load scheme provided each child with an opportunity to succeed and appreciate his/her accomplishments during training.^[52]

5. Guidelines for the Elderly

Aging is a complex process involving many variables (e.g. lifestyle factors, genetics, chronic disease development) that interact with one another and greatly influence quality of life.

Physiological changes that occur with aging are variable and include reductions in muscle mass and muscular strength (sarcopenia), muscle power, elasticity of connective tissue, balance and flexibility.^[58-61] These changes impinge on the functional performance required for independent living and contribute to increased frailty and fracture risk.^[61,62] Falls are a major source of morbidity and mortality in the elderly, accounting for 90% of hip fractures^[63,64] and subsequent healthcare costs of about 1.3 billion and \$US10 billion dollars (1998 value) in the UK^[65] and US,^[66] respectively. Regular exercise including resistance training has been shown to be an effective mode to circumvent age-related changes in the musculoskeletal system and may be one way of preventing falls and fall-related fractures. Research studies indicate that resistance training is an effective intervention against sarcopenia,^[67,68] increases endurance performance,^[69] normalises blood pressure in those with high normal values,^[70] reduces insulin resistance,^[71] decreases body fatness,^[72] increases metabolic rate,^[73] reduces the loss of bone mineral density with age,^[74] reduces risk factors for falls^[75] and may reduce pain and improve function in those with rheumatoid and osteoarthritis.^[76] However, caution must be taken with respect to the resistance-programme guidelines in this population, particularly for those with hypertension, arthritis and cardiovascular disease.^[12]

The ACSM exercise prescription guidelines^[6,7] for young and middle-aged adults are also appropriate for the elderly, with slight but distinct differences in application.^[6,9] Because of the natural course of age-related physiological decline, the exercise regimen should begin at lower intensities, progress slowly and utilise variable resistance machines with incremental weight stacks to help ensure the safety of the participants. The exercise sessions should begin at a lower intensity level (10 to 15 repetitions per set) and progress more slowly (every 2 to 4 weeks) than programmes designed for younger adults (every 1 to 2 weeks), allowing time for adaptation.^[9] If a 1RM test is administered, the initial training weight should be 30 to 40% of the maximum.^[9]

This type of training regimen has been consistently reported to offset the age- and disease/disability-associated declines in strength and musculoskeletal mass while improving functional capacity, which in turn, can enhance an individual's quality of life.^[12,77] This benefit alone provides the rationale for incorporating resistance training in exercise programmes for healthy persons of all ages, as well as for those with chronic diseases.

The recommended resistance-training guidelines for the elderly have been shown to significantly improve musculoskeletal fitness and cardiovascular health. In a recent study, Vincent et al.^[78] demonstrated that 1 set of resistance training is an effective means for improving peak oxygen uptake (22% increase), treadmill time to exhaustion (26% increase), stair climbing ability (6.5% decrease in time to ascend flight of stairs) and protection from oxidative stress in elderly men and women aged 60 to 85 years. Muscular strength increased an average of 17% whereas local muscular endurance increased by 71% for the upper body and 46% for the lower body following 6 months of training. A reduced susceptibility to oxidative stress has also been associated with reductions in muscle fatigue, cardioprotective benefits and a reduced risk of cardiac events.^[79,80]

Muscle power involves a combination of muscular strength and speed and is a common component of many activities of daily living. In the elderly, there appears to be a greater loss in muscular power than muscular strength.^[81] Recent research has indicated that losses in muscle power are associated with decreases in functional ability including decreased capacity to climb stairs and the ability to stand up from a chair.^[82] Thus, there is support for the inclusion of resistance training specific to power development for the healthy older adult.^[83,84] Once the individual has progressed beyond the initial stages of the exercise regimen (3 to 6 months), the performance of both single- and multiple-joint exercises using light to moderate loading (40 to 60% of 1RM) with high repetition velocity should be included. The progression of the resistance-

training programmes to include greater intensity (80% 1RM) and more advanced periodised regimens have also been shown to be effective and safe for the elderly when performed in a supervised programme.^[67,83,84] However, it is our opinion that the progression to these types of programmes should be decided on an individual basis, should occur only after the participant has reached a level of fitness, and when participation occurs in a supervised setting.

6. Conclusion

Physical inactivity is associated with increased susceptibility to chronic diseases and a reduced quality of life. Consequently, major health organisations have established guidelines for comprehensive exercise programmes designed to improve the health and fitness status of individuals of all ages, with resistance training being an integral component. Resistance-training programmes should incorporate a variety of exercises (calisthenics, machines and free weights) performed at a sufficient intensity to enhance the development and maintenance of muscular strength and endurance and lean body mass. A minimum of 1 set of 8 to 10 exercises involving the major muscle groups should be performed 2 to 3 times/week for healthy participants of all ages. Periodised multiple-set regimens and/or advanced exercises may be more appropriate for individuals whose goals include maximum gains in strength, lean body mass and athletic performance. However, the existing literature supports the guidelines as outlined in this paper for children and adults of all ages seeking the health and fitness benefits associated with resistance training.

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