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Acsm Position Stand: The Recommended Quantity And Quality Of Exercise For Developing And Maintaining Cardiorespiratory And Muscular Fitness, And Flexibility In Healthy Adults

ACSM Position Stand: The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in Healthy Adults

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Author Information

This pronouncement was reviewed for the American College of Sports Medicine by members-at-large, the Pronouncements Committee, and by Jack Wilmore, Ph.D., Steve Blair, P.E.D., William Haskell, Ph.D., and William Kraemer, Ph.D.

The position stand replaces the 1990 ACSM position paper of similar title (3).

Abstract

ACSM Position Stand on The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in Adults. *Med. Sci. Sports Exerc.,* Vol. 30, No. 6, pp. 975-991, 1998. The combination of frequency, intensity, and duration of chronic exercise has been found to be effective for producing a training effect. The interaction of these factors provide the overload stimulus. In general, the lower the stimulus the lower

the training effect, and the greater the stimulus the greater the effect. As a result of specificity of training and the need for maintaining muscular strength and endurance, and flexibility of the major muscle groups, a well-rounded training program including aerobic and resistance training, and flexibility exercises is recommended. Although age in itself is not a limiting factor to exercise training, a more gradual approach in applying the prescription at older ages seems prudent. It has also been shown that aerobic endurance training of fewer than 2 $d \cdot wk^{-1}$, at less than 40-50% of $V\dot{O}_2R$, and for less than 10 min^{-1} is generally not a sufficient stimulus for developing and maintaining fitness in healthy adults. Even so, many health benefits from physical activity can be achieved at lower intensities of exercise if frequency and duration of training are increased appropriately. In this regard, physical activity can be accumulated through the day in shorter bouts of 10-min durations.

In the interpretation of this position stand, it must be recognized that the recommendations should be used in the context of participant's needs, goals, and initial abilities. In this regard, a sliding scale as to the amount of time allotted and intensity of effort should be carefully gauged for the cardiorespiratory, muscular strength and endurance, and flexibility components of the program. An appropriate warm-up and cool-down period, which would include flexibility exercises, is also recommended. The important factor is to design a program for the individual to provide the proper amount of physical activity to attain maximal benefit at the lowest risk. Emphasis should be placed on factors that result in permanent lifestyle change and encourage a lifetime of physical activity.

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INTRODUCTION

Many people are currently involved in cardiorespiratory fitness and resistance training programs and efforts to promote participation in all forms of physical activity are being developed and implemented [242]. Thus, the need for guidelines for exercise prescription is apparent. Based on the existing evidence concerning exercise prescription for healthy adults and the need for guidelines, the American College of Sports Medicine (ACSM) makes the following recommendations for the quantity and quality of training for developing and maintaining cardiorespiratory fitness, body composition, muscular strength and endurance, and flexibility in the healthy adult:

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Cardiorespiratory Fitness and Body Composition

1. Frequency of training: 3-5 $d \cdot wk^{-1}$.

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2. Intensity of training: 55/65%-90% of maximum heart rate (HR_{max}), or 40/50%-85% of maximum oxygen uptake reserve ($V\dot{O}_2R$) or HR_{max} reserve (HRR).1 The lower intensity values, i.e., 40-49% of $V\dot{O}_2R$ or HRR and 55-64% of HR_{max}, are most applicable to individuals who are quite unfit.

3. Duration of training: 20-60 min of continuous or intermittent (minimum of 10-min bouts accumulated throughout the day) aerobic activity. Duration is dependent on the intensity of the activity; thus, lower-intensity activity should be conducted over a longer period of time (30 min or more), and, conversely, individuals training at higher levels of intensity should train at least 20 min or longer. Because of the importance of "total fitness" and that it is more readily attained with exercise sessions of longer duration and because of the potential hazards and adherence problems associated with high-intensity activity, moderate-intensity activity of longer duration is recommended for adults not training for athletic competition.

4. Mode of activity: any activity that uses large muscle groups, which can be maintained continuously, and is rhythmical and aerobic in nature, e.g., walking-hiking, running-jogging, cycling-bicycling, cross-country skiing, aerobic dance/group exercise2 (213), rope skipping, rowing, stair climbing, swimming, skating, and various endurance game activities or some combination thereof.

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Muscular Strength and Endurance, Body Composition, and Flexibility

1. Resistance training: Resistance training should be an integral part of an adult fitness program and of a sufficient intensity to enhance strength, muscular endurance, and maintain fat-free mass (FFM). Resistance training should be progressive in nature, individualized, and provide a stimulus to all the major muscle groups. One set of 8-10 exercises that conditions the major muscle groups 2-3 $d \cdot wk^{-1}$ is recommended. Multiple-set regimens may provide greater benefits if time allows. Most persons should complete 8-12 repetitions of each exercise; however, for older and more frail persons (approximately 50-60 yr of age and above), 10-15 repetitions may be more appropriate.

2. Flexibility training: Flexibility exercises should be incorporated into the overall fitness program sufficient to develop and maintain range of motion (ROM). These exercises should stretch the major muscle groups and be performed a minimum of 2-3 $d \cdot wk^{-1}$. Stretching should include appropriate static and/or dynamic techniques.

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RATIONALE AND RESEARCH BACKGROUND

Introduction

The questions, "How much exercise is enough?" and "What type of exercise is best for developing and maintaining fitness?" are frequently asked. It is recognized that the term "physical fitness" is composed of a variety of characteristics included in the broad categories of cardiorespiratory fitness, body composition including regional fat distribution, muscular strength and endurance, and flexibility. In this context, fitness is defined as the ability to perform moderate-to-vigorous levels of physical activity without undue fatigue and the capability of maintaining this capacity throughout life (251). It is also recognized that the adaptive response to training is complex and includes peripheral, central, structural, and functional factors (10). Although many such variables and their adaptive responses to training have been documented, the lack of sufficient in-depth and comparative data relative to frequency, intensity, and duration of training makes them inadequate to use as models for quantifying

benefits. Thus, with respect to the above questions, fitness in this position stand is limited mainly to changes in cardiorespiratory fitness as measured by maximum oxygen uptake ($V\dot{O}_{2max}$), lactate threshold (LT), and metabolic fitness (see below); muscular strength and endurance; and body composition, which includes total body mass, fat mass (FM), FFM, and regional fat distribution. Furthermore, the rationale and research background used for this position stand will be divided into programs for cardiorespiratory fitness and weight control, muscular strength and endurance, and flexibility

Fitness and health benefits of exercise. Since the original position statement was published in 1978, an important distinction has been made between physical activity as it relates to health versus fitness. This relationship has been further defined since the 1990 revised stand [3]. It has been pointed out that the quantity and quality of exercise needed to attain health-related benefits may differ from what is recommended for fitness benefits. It is now clear that lower levels of physical activity (particularly intensity) than recommended by this position stand may reduce the risk for certain chronic degenerative diseases and improve metabolic fitness and yet may not be of sufficient quantity or quality to improve $V\dot{O}_{2max}$ [13,28,54-56,105,106,145,178]. The term metabolic fitness was introduced by Després et al. [52,53] to describe the state of metabolic systems and variables predictive of the risk of diabetes and cardiovascular disease which can be favorably altered by increased physical activity or regular endurance exercise without the requirement of a training-related increase in $V\dot{O}_{2max}$. The ACSM recognizes the potential health benefits of regular exercise performed more frequently and for a longer duration but at a lower intensity than recommended in the previous editions of this position stand, i.e., 40-49% of $V\dot{O}_2R$ and HRR or 55-64% of HR_{max} [20,52,53,105,149,178,179,232]. Accordingly, it has addressed the issue concerning the proper amount of physical activity necessary to derive health benefits in various chronic diseases, e.g., coronary heart disease [5], hypertension [4], osteoporosis [6], and obesity and weight control [2]. The ACSM has also developed a statement on "Physical Activity and Public Health" with the Centers for Disease Control and Prevention [181]. Other important statements on physical activity and health have been recently published by the National Institutes of Health [172], American Heart Association [76], and the Office of the Surgeon General [242].

Thus, the ACSM now views exercise/physical activity for health and fitness in the context of an exercise dose continuum. That is, there is a dose response to exercise by which benefits are derived through varying quantities of physical activity ranging from approximately 700-2000 plus kilocalories of effort per week [76,147,179,181,242]. Many significant health benefits are achieved by going from a sedentary state to a minimal level of physical activity; programs involving higher intensities and/or greater frequency/durations provide additional benefits [242,248]. Although the fitness paradigm that is recommended in this ACSM position stand is adaptable to a broad cross-section of the healthy adult population, it is clearly designed for the middle-to-higher end of the exercise/physical activity continuum.

Need for standardization of procedures and reporting results. Despite an abundance of information available concerning the training of the human organism, the lack of standardization of testing protocols and procedures, of methodology in relation to training procedures and experimental design, and of a preciseness in the documentation and reporting of the quantity and quality of training prescribed make interpretation difficult [185,199,247,251]. Interpretation and comparison of results are also dependent on the initial level of fitness [44,94,171,219,223], length of time of the training regimen [29,77,187,189,199,222], and specificity of the testing and training [10,75,191,199,216]. For example, training studies using subjects with varied levels of $V\dot{O}_{2max}$, total body mass, and FM indicate that changes occur in relation to their initial values [21,166,219,223]; i.e., the lower the initial $V\dot{O}_{2max}$, the larger the percentage of improvement found; and the higher the FM, the

greater the reduction in total body mass and FM. Also, data evaluating trainability with age, comparison of the different intensities and volumes of effort, and comparison of the trainability of men and women may have been influenced by the initial fitness levels.

Because improvement in the fitness variables discussed in this position stand continues over many months of training [29,44,128,199,215,222], it is reasonable to believe that short-term studies conducted over a few weeks have certain limitations. Middle-aged sedentary and older participants may take several weeks to adapt to the initial rigors of training and thus need a longer adaptation period to get the optimal benefit from a program. For example, Seals et al. [222] exercise trained 60- to 69-yr-olds for 12 months. Their subjects showed a 12% improvement in $V\dot{O}_{2max}$ after 6 months of moderate intensity walking training. A further 18% increase in $V\dot{O}_{2max}$ occurred during the next 6 months of training when jogging was introduced. How long a training experiment should be conducted is difficult to determine and depends upon the purpose of the study. To evaluate the efficacy of various intensities, frequencies, and durations of exercise on fitness variables, a 15- to 20-wk length may be an adequate minimum standard. To evaluate health-related variables may take longer. However, to evaluate the time course of adaptations to training, and to correlate changes in one variable with those of another, shorter training programs may suffice. Although it is difficult to control exercise training experiments for more than 1 yr, there is a need to study this effect. Lower doses of exercise may improve $V\dot{O}_{2max}$ and metabolic fitness, and control or maintain body composition, but at a slower rate. However, long-term exercise training studies that compare various training models (volume, frequency, duration, intensity) are few in number or not available, especially when considering the metabolic component of fitness.

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Exercise Prescription for Cardiorespiratory Fitness and Weight Control

Exercise prescription is based upon the frequency, intensity, and duration of training, the mode of activity (aerobic in nature, e.g., listed under no. 4 above), and the initial level of fitness. Within this framework, the total volume of training becomes an important reference for improving fitness. In evaluating these factors, the following observations have been derived from studies conducted for up to 6-12 months with endurance training programs.

Improvement in $V\dot{O}_{2max}$ is directly related to frequency [7,11,85,111-113,187,224,225,247], intensity [7,11,42,46,94,95,111-113,117,127,224,247], and duration [7,46,104,151,166,177,224,237,239,247,252] of training. Depending upon the quantity and quality of training, improvement in $V\dot{O}_{2max}$ ranges from 10% to 30% [15,46,47,82,95,100,103,111-113,148,151,170,185,188,199,220,222,224,229,247,252,257]. These studies show that a minimum increase in $V\dot{O}_{2max}$ of 10-15% is generally attained in programs that meet the above-stated guidelines. Although increases in $V\dot{O}_{2max}$ greater than 30% have been shown, they are usually associated with large losses of total body mass and FM, in cardiac patients, or in persons with a very low initial level of fitness. Also, as a result of leg fatigue or a lack of motivation, persons with low initial fitness may have spuriously low initial $V\dot{O}_{2max}$ values. Klissouras et al. [141] and Bouchard [27] have shown that human variation in the trainability of $V\dot{O}_{2max}$ is important and related to one's genetic makeup as well as current activity status. That is, there is a genetically determined pretraining status of the trait and capacity to adapt to physical training. Thus, physiological results should be interpreted with respect to both genetic variation and the quality and quantity of training performed.

The lactate threshold (LT) is an important indicator of cardiorespiratory endurance [16,202,245]. The LT has been variously

defined, but generally may be thought of as the highest $V\dot{O}_2$ that can be maintained without a sustained rise in blood lactate [245]. For most untrained individuals, the LT occurs between 40% and 60% of $V\dot{O}_{2max}$ [16,202]. Exercise below the LT may be considered light-to-moderate (rating of perceived exertion (RPE), 10-13) [24]. Exercise above the LT may be considered hard-to-very hard (RPE, 14-18), depending upon the degree to which the $V\dot{O}_2$ exceeds the LT [63]. For exercise intensities well above the LT (≥85% $V\dot{O}_{2max}$), blood lactate concentration rises continuously, and exercise tolerance is compromised [245].

The LT can be increased independently of $V\dot{O}_{2max}$ and is correlated strongly with endurance capacity [154,245]. The LT can be improved rapidly in response to training (10-20%) and appears to be increased by both moderate- and high-intensity exercise training, as well as by both continuous and intermittent exercise [154,202]. Perceived exertion at the LT does not change with endurance training despite the fact that the LT occurs at a higher power output, and absolute and relative $V\dot{O}_{2max}$. Thus, RPE appears more closely linked with blood lactate than $\%V\dot{O}_{2max}$ after training [60].

Intensity and duration. Intensity and duration of training are interrelated, with total volume of training accomplished being an important factor in improvement in fitness [32,44,82,134,137,185,188,189,195,220,223,247]. Although more comprehensive inquiry is necessary, present evidence suggests that, when exercise is performed above the minimum intensity threshold, the total volume of training (kcal) accomplished is an important factor in fitness development [31,44,188,220,223] and maintenance [193]. That is, improvement will be similar for activities performed at a lower intensity-longer duration compared with higher intensity-shorter duration if the total energy cost of the activities is similar. This same total kcal concept appears to be acceptable whether the activity program is continuous or intermittent, i.e., shorter exercise bouts (minimum of 10 min) that are accumulated throughout the day [48,68,124]. Higher-intensity exercise is associated with greater cardiovascular risk [228] and orthopaedic injury [186,199] and lower adherence to training than lower-intensity exercise [59,160,186,217]. Therefore, programs emphasizing moderate intensity training with longer duration are recommended for most adults, because a high proportion of the adult population is both sedentary and has at least one risk factor for cardiovascular disease [242].

The RPE also may influence adherence to an exercise program [60,62]. Though no experimental investigations have directly tested the effects of RPE on adoption or maintenance of physical activity, several studies suggest an interaction between RPE and preferred levels of exercise intensity during both acute [61] and chronic exercise [139]. In a 1-yr randomized exercise trial with middle-aged sedentary adults [139], adherence to home-based exercise was similar between groups assigned to moderate (60-73% peak HR) or high (74-88% peak HR) exercise intensities. However, the authors reported that each group selected intensities during the year which regressed toward a common intensity level accompanied by a mean daily exercise RPE of 11.7 to 13.1 (somewhat hard). Other studies conducted with treadmill walking/running or cycling [60] suggest that people prefer to exercise at an intensity approximating 60-65% of $V\dot{O}_{2max}$ regardless of their activity history, whereas trained distance runners prefer an intensity of 75% $V\dot{O}_{2max}$. The RPE at these intensities typically approximates 12-14. Perceived exertion may be especially useful as an adjunct for aerobic exercise prescription where relative heart rates can underestimate relative oxygen uptake by 5-15%.

Intensity threshold. The minimal training intensity threshold for improvement in $V\dot{O}_{2max}$, and the LT is approximately 40-50% of $V\dot{O}_2R$ or HRR (55-65% of the HR_{max}) [117,127]. It should be noted that the ACSM is now relating HRR to $V\dot{O}_2R$ rather than a percentage of $V\dot{O}_{2max}$. Using $V\dot{O}_2R$ improves the accuracy of the

relationship, particularly at the lower end of the intensity scale [153,180,235,236]. It is incorrect to relate HRR to a level of $V\dot{O}_2$ that starts from zero rather than a resting level. This change makes this document more scientifically accurate but should have no effect on the practitioner who is using the HRR method for exercise prescription.

The ACSM has also increased the estimated difference between the $\%V\dot{O}_2R$ (%HRR) to the $\%HR_{max}$ from 10% to 15% difference for the light and moderate intensity categories (see Table 1). This is based on research from Londeree and Ames [153] and others [180,235,236] that show that the HR_{max} method actually underestimates the $V\dot{O}_2R$ by approximately 15%. The underestimation may be larger or smaller depending on age and intensity of exercise.

Table 1
Image Tools

The decrease in the minimal intensity to 40% of $V\dot{O}_2R$ (HRR) and 55% of HR_{max} represents a change in the ACSM recommendation and more clearly recognizes that the minimal threshold for improving fitness/health is quite variable at the lower end of the intensity scale. Initial level of fitness greatly effects this minimal threshold [42,134,159,219,223]. The person who has a very low level of fitness can achieve a significant training effect with a training heart rate as low as 40-50% of HRR, whereas persons with higher fitness levels require a higher training stimulus [58,94,224,247]. The 50% of HRR represents a heart rate of approximately 130-135 beats·min^{-1} for young persons. As a result of the age-related decrease in HR_{max}, the absolute heart rate to achieve this threshold is inversely related to age and can be as low as 105-115 beats·min^{-1} for older persons [58,100,222].

Classification of exercise intensity. The classification of exercise intensity and its standardization for exercise prescription based on a 20- to 60-min training session has been confusing, misinterpreted, and often taken out of context. One of the most quoted exercise classification systems is based on the energy expenditure (kcal·min^{-1}·kg^{-1}) of industrial tasks [67, 132]. The original data for this classification system were published by Christensen [37] in 1953 and were based on the energy expenditure of working in the steel mill for an 8-h d. The classification of industrial and leisure-time tasks by using absolute values of energy expenditure has been valuable for use in the occupational and nutritional setting [1]. Although this classification system has broad application in medicine and, in particular, in making recommendations for weight control and job placement, it has little or no meaning for preventive and rehabilitation exercise training programs unless adapted for age and regimens lasting up to 60 min. To extrapolate absolute values of energy expenditure for completing an industrial task based on an 8-h workday to 20- to 60-min regimens of exercise training does not make sense. For example, walking and jogging/running can be accomplished at a wide range of speeds; thus, the relative intensity becomes important under these conditions. Because the endurance training regimens recommended by ACSM for nonathletic adults are geared for 60 min or less of physical activity, the system of classification of exercise training intensity shown in Table 1 is recommended [242]. The use of a realistic time period for training and an individual's relative exercise intensity makes this system amenable to young, middle-aged, and elderly participants, as well as patients with a limited exercise capacity [7,196,199,242]. Since some professionals, especially in the quantification of epidemiological data, use multiples of resting metabolic equivalents (METs) for classification of exercise intensity, these values have been included in Table 1. See Ainsworth et al. [1] for a compendium listing more than 500 activities by their MET values. Although these absolute values seem reasonable, more information to validate the values at the older age ranges is needed.

Table 1 also describes the relationship between relative exercise intensity based on percent HR_{max}, percentage of HRR or percentage of $V\dot{O}_2R$, and the corresponding RPE [24,199,209]. The use of heart

rate as an estimate of intensity of training is the common standard [7,196,199,209].

The use of RPE has become a valid tool in the monitoring of intensity in exercise training programs [63,196,199,209]. It has been shown to correlate well with blood lactate, heart rate, pulmonary ventilation, and the $\dot{V}O_2$ responses to exercise [209]. The RPE is generally considered an adjunct to heart rate in monitoring relative exercise intensity, but once the relationship between heart rate and RPE is known, RPE can be used in place of heart rate [36,199]. This would not be the case in certain patient populations in which a more precise knowledge of heart rate may be critical to the safety of the participant.

Only about 15% of U.S. adults participate in physical activities with sufficient intensity and regularity to meet minimum ACSM recommendations for the improvement or maintenance of fitness [242]. Moreover, the dropout rate for adult fitness programs for healthy adults approximates 25-35% across 10-20 wk [186]; the rate is only partly explainable by injury [200]. Behavioral interventions designed to increase physical activity have reported better adherence when the intensity of physical activity was estimated as 50% of aerobic capacity or lower [64]. However, increases in physical activity after such interventions have been similar regardless of frequency or duration of physical activity. One study [124] found increased self-reports of physical activity over a period of 20 wk when overweight women achieved 40 min of daily walking in multiple 10-min bouts compared with a single 40-min bout each day. However, weight loss, increased aerobic fitness, and energy expenditure estimated by an accelerometer were comparable between the two conditions.

Frequency. The amount of improvement in $\dot{V}O_{2max}$ increases with frequency of training, but the magnitude of change is smaller and tends to plateau when frequency of training is increased above 3 $d \cdot wk^{-1}$ [85,185,247]. The value of the added improvement in $\dot{V}O_{2max}$ that occurs with training more than 5 $d \cdot wk^{-1}$ is minimal to none [111-113,161,185], yet the incidence of injury increases disproportionately [19,194]. Training of less than 2 $d \cdot wk^{-1}$ does not generally result in a meaningful increase in $\dot{V}O_{2max}$ [46,85,177,185,224,247]. The optimal training frequency for improving the LT and metabolic fitness are not known and may or may not be similar to that for improving $\dot{V}O_{2max}$.

Mode. If frequency, intensity, and duration of training are similar (total kcal expenditure), the training adaptations appear to be independent of the mode of aerobic activity [152,177,191,195]. Therefore, a variety of endurance activities, e.g., those listed above under number 4, may be used to derive comparable $\dot{V}O_{2max}$ and body composition training effects. Even so, exercise mode would favor a specific effect to the muscle group(s) being used, e.g., arm cranking: arms and shoulders; cycling: thighs (quadriceps); and jogging/walking: calf, hamstrings, and gluteals [38,140]. Thus, cross-training that emphasizes the use of a variety of large muscle groups (activities) may be beneficial to achieving a more well-rounded training effect.

Endurance activities that require running and jumping are considered high-impact types of activity and generally cause significantly more debilitating injuries to beginning as well as long-term exercisers than do low impact and nonweight-bearing type activities [19,34,138,176,186,188,194,200,203,208]. The relationship between mode of activity and injury risk is particularly evident in elderly persons who are overweight and in unfit women [34,126,200]. Beginning joggers have increased foot, leg, and knee injuries when training is performed more than 3 $d \cdot wk^{-1}$ and longer than 30-min duration per exercise session [194]. High-intensity interval training (run-walk) compared with continuous jogging training was also associated with a higher incidence of injury [186,195]. Thus, caution should be taken when recommending this type of activity for the beginning exerciser. Orthopaedic injuries as related to overuse increase linearly in runners/joggers when performing this activity

[19,203]. Several studies have shown that women who are beginning an exercise program have more orthopaedic injuries of the lower extremities than men when participating in high-impact exercise [34,126,200]. These injury rates appear to be approximately twofold higher in younger women compared with men and as much as fourfold higher in older women compared with older men. Although more information is necessary to confirm the exact mechanism for this difference, it appears that the lack of muscle mass in the lower limbs and greater Q angle3 for women make them more susceptible to injury. Also, being unfit, overweight, and having a previous injury are related to increased incidences of additional injury in both men and women [19,126,203,243]. Although not yet confirmed, the participation in resistance training before initiating moderate- to high-impact activities may attenuate this problem. Thus, there is a need for more inquiry into the effect that different types of activities, the quantity and quality of exercise and the rate of progression in training have on injuries over short-term and long-term participation.

Resistance training should not be considered as a primary means of training for developing $V\dot{O}_{2max}$, but it has significant value for increasing muscular strength and endurance, FFM, and physical function [50,72-74,89,167,250]. Studies evaluating circuit weight training (weight training conducted almost continuously with moderate weights, using 10-15 repetitions per exercise with no more than 15-30 s of rest between bouts of activity) show an average improvement in $V\dot{O}_{2max}$ of 6% [86-88,121,165,254]. Circuit weight training when interspersed with short bouts (1-2 min) of running has shown a greater than 15% increase in $V\dot{O}_{2max}$ [90]. Thus, circuit weight training is not recommended as the only activity used in exercise programs for developing $V\dot{O}_{2max}$ or metabolic fitness.

Although resistance training exercise can only elicit slight to modest increases in $V\dot{O}_{2max}$, it does improve muscular strength and endurance and physical function [74,89,110]. For example, Hickson et al. [110] had subjects perform heavy-resistance exercise primarily designed to strengthen the quadriceps muscle. After 10 wk of training, submaximal endurance time on a cycle ergometer increased 47%, yet $V\dot{O}_{2max}$ increased only 4%. These results have important implications because many leisure and occupational tasks require lifting, moving, or carrying a constant load. Because the magnitude of the pressor response to resistance exercise is proportionate to the percentage of maximal voluntary contraction (MVC) [157], as well as the muscle mass involved [157,168], an increase in strength will result in a participant working at a lower percentage of MVC for a given load.

Age. Age in itself does not appear to be a deterrent to aerobic endurance or resistance training [73,100,207,210]. The relative increase in $V\dot{O}_{2max}$ consequent to endurance training in the elderly is similar to that reported in middle-aged and younger adults [12,15,100,103,144,164,170,192,226,227], and there appears to be no gender difference in the response to training [100,144,174]. Although some earlier studies showed a lower training effect in elderly participants [17,57], this lower value was primarily attributed to an inadequate training stimuli (intensity and/or duration of training) [17,57], too short a training program, or both [17,57,222]. Older participants may need longer periods of time to progress and adapt to endurance training exercise [222], but this has not been confirmed by all investigators [169]. Variability in ages and initial fitness levels of the participants and the quantity and quality of training make the interpretation of these results difficult; further inquiry of the rate of change in cardiorespiratory and metabolic fitness in the middle-aged and elderly is needed. Improvements in LT have also been demonstrated in the elderly with both short- and long-term training programs [16,154].

Although $V\dot{O}_{2max}$ decreases and total body mass and FM increase with age, evidence suggests that those trends can be favorably altered with endurance training [33,128-131,199,207,240]. The reduction in $V\dot{O}$ that occurs with aging has varied widely in the

literature, ranging from 0% to 34% per decade [33,66,107,130,131,174,211]. After 25-30 yr of age, sedentary adults generally experience a 9-15% reduction in $V\dot{O}_{2max}$ per decade. Although this decline may be attenuated in endurance-trained athletes to approximately 5% per decade [33,66,133,197,240], this value has not been confirmed in recent longitudinal studies [101,201,241]. The earlier assumption was based on short-term study (<10 yr) or cross-sectional data [49,107]. Current longitudinal data (20-plus yr of follow-up) on endurance trained individuals, some who were still competitive at the elite level, show an ~10-15% decrease in $V\dot{O}_{2max}$ per decade [101,201,241]. Follow-up studies in which participants continued training at a similar level for 10 yr or more showed maintenance of cardiorespiratory fitness [9,129,131,197]. The consensus from these long-term studies is that it was difficult for highly trained individuals to continue their high intensity training at the same level for 10-20 yr; thus, $V\dot{O}_{2max}$ is significantly reduced, but their values track at a higher level than aged-matched sedentary persons [101,201,241]. Thus, lifestyle and injury and health status play a significant role in the maintenance of training and fitness and the reduction of disability [9,71,129,131,197]. More inquiry into the relationship of long-term training (quantity and quality), for both competitors and noncompetitors, and physiological function with increasing age is necessary before more definitive statements can be made.

Muscular strength and FFM decline with age, although there is variability in the rate of decline in various muscle groups [118,210]. There is a decrement in muscle strength of approximately 30% between the ages of 20 and 75 yr in both men and women, with much of the loss in strength occurring after the age 50 yr and after menopause [10,184,210], although estrogen replacement therapy can attenuate this loss in women [184,210]. There are few data available on strength and FFM decline in persons older than 75 yr of age, but after the age of 80 yr, it appears that both strength and FFM decline at a greater rate than previously described for persons 50-75 yr of age [210]. Longitudinal studies examining the relationship between physical activity levels, muscle strength, FFM, and aging are not generally available, so it is difficult to determine whether resistance training or other physical training alters the loss of strength over time. One study by Pollock et al. [197] showed a 2-kg decline in FFM in older track athletes who maintained their $V\dot{O}_{2max}$ at 10 yr follow-up. At 20 yr follow-up (age, 70.4 ± 8.8 yr), those who participated in a resistance training program maintained their FFM from yr 10-20 [190]. However, numerous studies have demonstrated that significant increases in strength and muscle hypertrophy (FFM) result from resistance training in healthy and frail elderly participants [35,73,74,100,122,162,163,205]. The relative magnitude of the strength increases in the elderly appear to be similar to or greater than for younger subjects, when differences in initial strength are considered [74,81,100,162,210].

Gender difference. There are a number of morphological and physiological differences between men and women that are important relative to fitness and exercise performance [246]. Women have less blood volume, fewer red blood cells, and less hemoglobin, leading to a lower oxygencarrying capacity and capability to increase their arterial-venous O_2 difference. A smaller heart results in a higher resting and submaximal heart rate, lower stroke volume, and oxygen pulse in women. $V\dot{O}_{2max}$ is lower in women than men due primarily to a lower cardiac output. The gender differences in $V\dot{O}_{2max}$ are greatly reduced when corrected for FFM [246]. The distribution of muscle fiber types is similar between the sexes, but women have fewer and smaller muscle fibers. Body composition is significantly different in women compared with men; women have lower FFM and bone mineral density (BMD) and a greater percentage of FM. Even so, when strength is normalized for FFM, gender differences become smaller and disappear in the lower limbs [246,250].

Despite many biological differences, there appear to be no gender differences in the magnitude of improvement in $V\dot{O}_{2max}$ with endurance training [78,84,100,144,161,169,183,220,246], and the effects of training seem unaffected by menstrual status [207,246,250]. Studies of women have generally applied training principles derived from studies of males, and it is clear that women and men engaging in comparable training regimens attain similar improvements in $V\dot{O}_{2max}$ and muscular strength and endurance [100,144,210,246]. Likewise, the relative improvements resulting from resistance training are similar in men and women [45,100,210,233]. Because there are few studies of women that examine the quantity and quality of exercise [38,134,169,231], it is difficult to determine whether the recommendations based on male subjects are optimal for female subjects. Further study of the quality and quantity of both endurance and resistance training in women is needed before more definitive recommendations can be made.

There are some special considerations relative to exercise training in women [22,155,244,246]. Although these factors do not affect the recommendations made in this stand, based on the available evidence, they should be considered in the development of a training program for women. Exercise training can affect the reproductive system of the female [22,155,244]. Menstrual irregularity may result in some women because of exercise training, but the causative factors remain unclear. Fertility does not appear to be influenced by training except in women with oligomenorrhea and anovulation [244]. The latter conditions can occur in active women and may place them at an increased risk for the development of osteoporosis (for more information on this issue see ACSM Position Stand on Osteoporosis and Exercise) [6]. Although there are few studies available, menopause does not appear to alter the $V\dot{O}_{2max}$ or strength responses to exercise training [23,184,207,244]. Further research is needed on the relationship between exercise of various types and reproductive function in women. Pregnancy presents special considerations for exercise training in women which are addressed elsewhere [1a]. As discussed earlier, women appear to be more susceptible to orthopaedic injury when performing high-impact, lower-extremity exercise [34,126,200].

Maintenance of the training effect. To maintain the training effect, exercise must be continued on a regular basis [30,40,80,143,170,212,218]. A significant reduction in cardiorespiratory fitness occurs after 2 wk of detraining [40,212], with participants returning to near pretraining levels of fitness after 10 wk [80] to 8 months of detraining [143]. A loss of 50% of their initial improvement in $V\dot{O}_{2max}$ has been shown after 4-12 wk of detraining [80,135,212]. Those individuals who have undergone years of continuous training maintain some benefits for longer periods of detraining than subjects from short-term training studies [40]. Although stopping training shows dramatic reductions in $V\dot{O}_{2max}$, reduced training shows modest to no reductions for periods of 5-15 wk [30,111-113,212]. Hickson et al., in a series of experiments where frequency [111], duration [112], or intensity [113] of training were manipulated, found that, if intensity of training remained unchanged, $V\dot{O}_{2max}$ was maintained for up to 15 wk when frequency and duration of training were reduced by as much as 2/3. When frequency and duration of training remained constant and intensity of training was reduced by 1/3 or 2/3, $V\dot{O}_{2max}$ was significantly reduced. Similar findings were found in regard to reduced strength training exercise. When strength training exercise was reduced from 3 or 2 $d \cdot wk^{-1}$ to at least 1 $d \cdot wk^{-1}$, strength was maintained for 12 wk of reduced training [96]. Thus, it appears that missing an exercise session periodically or reducing training frequency or duration for up to 15 wk will not adversely affect $V\dot{O}_{2max}$ or muscular strength and endurance as long as training intensity is maintained.

Even though many new studies have given added insight into the proper amount of exercise, investigation is necessary to evaluate the changes in fitness when reducing training loads and dosage in

relation to level of fitness, age, and length of time in training. Also, more information is needed to better identify the minimal level of exercise necessary to maintain fitness.

Weight control and body composition. Physical exercise alone without dieting (caloric restriction) has only a modest effect on total body mass and FM loss [28,54,56,234]. Caloric restriction generally produces the most substantial weight losses compared with exercise alone simply because it is easier to induce a marked energy deficit by the former [28,54,56,234]. The most successful studies in terms of weight loss have been those that combined diet and exercise to optimize the energy deficit [28,234,258,259]. Also, it appears that individuals who combined exercise with their dietary regimens maintain their weight loss more effectively [234]. The reader is referred to ACSM's position stand on weight loss and weight control [2] and a more recent review by Stefanick [234]. Although there is variability in the human response to body composition changes with exercise, total body mass and FM are generally moderately reduced with endurance training programs [199,255], whereas FFM remains constant [185,199,253] or increases slightly [175,262]. For example, Wilmore [255] reported the results of 32 studies that met the ACSM criteria for developing cardiorespiratory fitness and found an average loss in total body mass of 1.5 kg and percent fat of 2.2. Weight loss programs using dietary manipulation that result in a more dramatic decrease in total body mass show reductions in both FM and FFM [2,114,259]. When these programs are conducted in conjunction with exercise training, FFM loss is more modest than in programs using diet alone [114,182]. Programs that are conducted at least 3 $d \cdot wk^{-1}$ [185,187,189,253], of at least a sufficient intensity and duration to expend approximately 250-300 kcal per exercise session (75-kg person)4 are suggested as a threshold level for total body mass and FM loss [44,99,113,185,199]. This generally would require at least 30-45 min of exercise per session for a person of average fitness. An expenditure of 200 kcal per session has also been shown to be useful in weight reduction if the exercise frequency is at least 4 $d \cdot wk^{-1}$ [226]. If the primary purpose of the training program is for weight loss, then regimens of greater frequency and duration of training and moderate intensity are recommended [2,199,234]. Programs with less participation generally show little or no change in body composition [92,138,185,231,239,253,255]. Significant increases in $\dot{V}O_{2max}$ have been reported with 10-15 min of high-intensity training [11,116,166,177,185,224]; thus, if total body mass and FM reduction are not considerations, then shorter-duration, higher-intensity programs may be recommended for healthy individuals at low risk for cardiovascular disease and orthopaedic injury.

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Exercise Prescription for Muscular Strength and Muscular Endurance

The addition of resistance/strength training to the position statement results from the need for a well-rounded program that exercises all the major muscle groups of the body. Thus, the inclusion of resistance training in adult fitness programs should be effective in the development and maintenance of muscular strength and endurance, FFM, and BMD. The effect of exercise training is specific to the area of the body being trained [10,75,216]. For example, training the legs will have little or no effect on the arms, shoulders, and trunk muscles, and *vice versa* [216]. A 10-yr follow-up of master runners who continued their training regimen, but did no upper body exercise, showed maintenance of $\dot{V}O_{2max}$ and a 2-kg reduction in FFM [197]. Their leg circumference remained unchanged, but arm circumference was significantly lower. These data indicate a loss of muscle mass in the untrained areas. Three of the athletes who practiced weight training exercise for the upper body and trunk muscles maintained their FFM. A comprehensive review by Sale [216] documents available information on specificity of training.

Specificity of training was further addressed by Graves et al. [97]. Using a bilateral knee extension exercise, these investigators trained four groups: group A, first half of the ROM; group B, second half of the ROM; group AB, full ROM; and a control group that did not train. The results clearly showed that the training result was specific to the ROM exercised, with group AB getting the best full range effect. Thus, resistance training should be performed through a full ROM for maximum benefit [97,142].

Muscular strength and endurance are developed by the progressive overload principle, i.e., by increasing more than normal the resistance to movement or frequency and duration of activity [50,69,75,109,215]. Muscular strength is best developed by using heavier weights (that require maximum or near maximum tension development) with few repetitions, and muscular endurance is best developed by using lighter weights with a greater number of repetitions [18,69,75,215]. To some extent, both muscular strength and endurance are developed under each condition, but each loading scheme favors a more specific type of neuromuscular development [75,215]. Thus, to elicit improvements in both muscular strength and endurance, most experts recommend 8-12 repetitions per set; however, a lower repetition range, with a heavier weight, e.g., 6-8, repetitions may better optimize strength and power [75]. Because orthopaedic injury may occur in older and/or more frail participants (approximately 50-60 yr of age and above) when performing efforts to volitional fatigue using a high-intensity, low-to-moderate repetition maximum (RM), the completion of 10-15 repetitions or RM is recommended. The term RM refers to the maximal number of times a load can be lifted before fatigue using good form and technique.

Any magnitude of overload will result in strength development, but heavier resistance loads to maximal, or near maximal, effort will elicit a significantly greater training effect [75,109,156,158,215]. The intensity and volume of exercise of the resistance training program can be manipulated by varying the weight load, repetitions, rest interval between exercises and sets, and number of sets completed [75]. Caution is advised for training that emphasizes lengthening (eccentric) contractions, compared with shortening (concentric) or isometric contractions, as the potential for skeletal muscle soreness and injury is increased particularly in untrained individuals [8,125].

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, for healthy adults, dynamic resistance exercises are recommended as they best mimic everyday activities. Resistance training for the average participant should be rhythmical, performed at a moderate-to-slow controlled speed, through a full ROM, and with a normal breathing pattern during the lifting movements. Heavy resistance exercise can cause a dramatic acute increase in both systolic and diastolic blood pressure [150,157], especially when a Valsalva maneuver is evoked.

The expected improvement in strength from resistance training is difficult to assess because increases in strength are affected by the participant's initial level of strength and their potential for improvement [75,102,109,171]. For example, Mueller and Rohmert [171] found increases in strength ranging from 2% to 9% per week depending on initial strength levels. Also, studies involving elderly participants [73,74] and young to middle-aged persons using lumbar extension exercise [198] have shown greater than 100% improvement in strength after 8-12 wk of training. Although the literature reflects a wide range of improvement in strength with resistance training programs, the average improvement for sedentary young and middle-aged men and women for up to 6 months of training is 25-30%. Fleck and Kraemer [75], in a review of 13 studies representing various forms of isotonic training, reported an average improvement in bench press strength of 23.3% when subjects were tested on the equipment with which they were trained and 16.5% when tested on special isotonic or isokinetic ergometers (six studies). These investigators [75] also reported an average increase in leg

strength of 26.6% when subjects were tested with the equipment that they trained on (six studies) and 21.2% when tested with special isotonic or isokinetic ergometers (five studies). Improvements in strength resulting from isometric training have been of the same magnitude as found with isotonic training [29,75,96,97].

In light of the information reported above, the following guidelines for resistance training are recommended for the average healthy adult. A minimum of 8-10 exercises involving the major muscle groups (arms, shoulders, chest, abdomen, back, hips, and legs) should be performed 2-3 $d \cdot wk^{-1}$. A minimum of 1 set of 8-12 RM or to near fatigue should be completed by most participants; however, for older and more frail persons (approximately 50-60 yr of age and above), 10-15 repetitions may be more appropriate. These recommendations for resistance training are based on three factors. First, the time it takes to complete a comprehensive, well-rounded exercise program is important. Programs lasting more than 60 min per session appear to be associated with higher dropout rates [186]. Also, Messier and Dill [165] reported that the average time required to complete 3 sets of a weight-training program was 50 min compared with only 20 min for 1 set. Second, although greater frequencies of training [29,75,91] and additional sets or combinations of sets and repetitions may elicit larger strength gains [18,50,75,109], the difference in improvement is usually small in the adult fitness setting. For the more serious weight lifter (athlete), a regimen of heavier weights (6-12 RM) of 1-3 sets using periodization techniques usually provides greater benefits [75]. Third, although greater gains in strength and FFM can be attained when using heavy weights, few repetitions (e.g., 1-6 RM), and multiple set regimens, this approach may not be suitable for adults who have different goals than the athlete. Finally, from a safety standpoint, these types of programs may increase the risk of orthopaedic injury and precipitation of a cardiac event in middle-aged and older participants [43,199]

Research appears to support the minimal standard that is recommended for the adult fitness/health model for resistance training. A recent review by Feigenbaum and Pollock [72] clearly illustrated that the optimal frequency of training may vary depending on the muscle group. For example, Graves et al. [98] found that 1 $d \cdot wk^{-1}$ was equally as effective in improving isolated lumbar extension strength as training 2 or 3 $d \cdot wk^{-1}$. DeMichele et al. [51] found 2 $d \cdot wk^{-1}$ of torso rotation strength training to be equal to 3 $d \cdot wk^{-1}$ and superior to 1 $d \cdot wk^{-1}$. Braith et al. [29] found that leg extension training 3 $d \cdot wk^{-1}$ elicited a greater effect than exercising 2 $d \cdot wk^{-1}$. Others have found that chest press exercise 3 $d \cdot wk^{-1}$ showed a greater improvement in strength than 1 or 2 $d \cdot wk^{-1}$ [72]. In summary, it appears that 1-2 $d \cdot wk^{-1}$ elicits optimal gains in strength for the spine and 3 $d \cdot wk^{-1}$ for the appendicular skeletal regions of the body. Also, the 2 $d \cdot wk^{-1}$ programs using the arms and legs showed 70-80% of the gain elicited by the regimens using a greater frequency.

In the same review mentioned above, Feigenbaum and Pollock [72] compared eight well-controlled studies and found that no study showed that 2 sets of resistance training elicited significantly greater improvements in strength than 1 set and only one study showed that a 3-set regimen was better than 1 or 2 sets. Berger [18] using the bench press exercise found 3 sets to elicit a 3-4% greater increase in strength ($P < 0.05$) than the 1- or 2-set groups. None of the studies reported were conducted for more than 14 wk; thus, it is possible that various multiple set programs may show greater strength gains when conducted over a longer time span. Program variation may also be an important factor in improving resistance training outcomes but must be verified by additional research [75]. Considering the small differences found in the various programs relating to frequency of training and multiple versus single-set programs, the minimal standard recommended for resistance training in the adult fitness setting seems appropriate for attaining most of the fitness and health benefits desired in fitness and health maintenance programs.

Although resistance training equipment may provide better feedback as to the loads used along with a graduated and quantitative stimulus for determining an overload than traditional calisthenic exercises, calisthenics and other resistive types of activities can still be effective in improving and maintaining muscular strength and endurance [86,109,195].

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Exercise Prescription for Flexibility

The inclusion of recommendations for flexibility exercise in this position stand is based on growing evidence of its multiple benefits including; improving joint ROM and function [120,206] and in enhancing muscular performance [26,256,261]. In addition, although there is a lack of randomized, controlled clinical trials defining the benefit of flexibility exercise in the prevention and treatment of musculoskeletal injuries, observational studies support stretching in both of these applications [65,115].

Stretching exercises increase tendon flexibility through two major effects on the muscle tendon unit, mechanoreceptor mediated reflex inhibition and viscoelastic strain. Increased tension in the musculotendinous unit is detected by proprioceptors in the tendon and muscle (Golgi tendon organ and muscle spindle), which inhibit further agonist muscle contraction and induce relaxation in the antagonist unit. Theoretically, this reflex inhibition prevents excessive strain injury and may account for short-term increases in flexibility immediately after stretching. The actual importance of the proprioceptor effects in flexibility training has been questioned [238]. Recent work has suggested that acute activation of these receptors may lead to transient desensitization of the stretch reflex and increased antagonist muscle excitation [123].

The primary effects of stretching involve the viscoelastic properties of the tendon. Stretching results in both a transient increase in the musculotendon unit length resulting from actin-myosin complex relaxation [230] and a lasting increase through alteration in the surrounding extracellular matrix [238]. In studies using rabbit tendon, equal increases were shown in denervated muscle and fully innervated muscle, supporting the relative importance of this viscoelastic effect over the inhibitory effects of the mechanoreceptors [238].

The most readily appreciated effect of tendon inflexibility is in reduced joint ROM. Aging often results in substantial loss of tendon flexibility and limits in motion [206]. This is related to both biochemical changes in the musculotendinous unit and mechanical factors in the underlying skeletal structure. With aging, collagen solubility declines, probably related to increased tropocollagen crosslinking [119]. These changes result in reduced tensile strength and increased tendon rigidity [173]. Associated age related skeletal changes such as degenerative joint disease and osteophyte formation may further limit motion in the joints. This loss of flexibility can significantly impair an individual's ability to accomplish daily activities and perform exercise. Several studies have examined the impact of declining flexibility and the efficacy of exercise interventions [108,120,206,221,249]. Schenkman et al. [221] demonstrated declining physical performance related to the loss of axial skeleton mobility. Further, these investigators speculated that this decline may be favorably modified through flexibility training [221]. Similarly, improvements in joint ROM have been demonstrated with extremity flexibility programs [119,120,206]. Of note, a study by Girouard and Hurley [93] demonstrated that the improvements in ROM gained by flexibility exercises may be minimized by simultaneous resistance training.

Recent studies have suggested that stretching exercises may enhance muscle performance [26,256,261]. Worrell et al. [261] demonstrated increased peak torque generation in hamstring muscle

with flexibility training. In another study, Wilson et al. [256] reported improved rebound bench-press performance after flexibility training which was attributed to a reduction in the series elastic component stiffness of the upper extremities. These findings are contradicted somewhat by studies on running economy that have demonstrated an inverse correlation with hip flexibility [41].

A relationship between poor flexibility and subsequent injury has been established in several musculotendinous units, including the Achilles tendon [146], plantar fascia [136], and hamstring tendons [83,260]. Similarly, poor flexibility can result in injury to adjacent joints as is seen in the development of lateral patella compression syndrome (patello-femoral dysfunction) as a result of iliotibial band tightness [204]. General stretching programs have been shown to be effective in reducing both the severity and frequency of injuries [65,70,79,83,115,230]. In addition, flexibility exercises are advocated in the treatment of many musculoskeletal injuries to regain ROM and reduce symptoms [65,79,260].

Although the optimal level of flexibility is determined by sport specific and individual factors, several guidelines for developing a general program can be extracted from the available literature. The ideal type and duration of stretching exercise has been the subject of significant debate. The three main types of stretching exercises described are static, proprioceptive neuromuscular facilitation (PNF), and ballistic. As it was originally described, the PNF stretching techniques consist of alternating isometric muscle contraction and passive stretching through a designated series of motions. Ballistic stretching involves repetitive bouncing motions wherein the tendon is rapidly stretched and immediately relaxed. Static exercises slowly stretch the tendon, hold them in the stretched state for a period of time, and then return to the resting length. Many studies have shown PNF to be superior to the other types of exercises in increasing flexibility [39,214]. In their pure form, these exercises are complicated and require an experienced therapist or trainer. Many modified PNF techniques have been described (active/assisted, contract/relax, hold/relax) that can often be done alone or with a partner. Static stretches represent an effective compromise for many individuals [14,249]. In determining the ideal duration of the stretch to achieve increased flexibility, it is apparent that slow rates allow greater stress relaxation and generate lower tensile force on the tendon [238]. Studies have demonstrated that holding the stretch for 10 to 30 s at the point of mild discomfort enhances flexibility without significantly greater benefit from longer durations [14,25,238]. Few studies have examined the optimal number of repetitions required to obtain maximal benefit from stretching exercises. Taylor et al. [238] found that the greatest increase in ROM occurred in the first four repetitions with minimal gains in subsequent stretches. Neither prestretching warm-up or ice application appears to give added benefit over stretching alone in improving flexibility [39,249].

Based on this evidence, the following recommendations for incorporating flexibility exercises into an overall fitness plan are made. A general stretching program that exercises the major muscle/tendon groups (lower extremity anterior chain, lower extremity posterior chain, shoulder girdle, etc) should be developed using static, ballistic, or modified PNF (contract/relax, hold/relax, active/assisted) techniques. Static stretches should be held for 10 to 30 s, whereas PNF techniques should include a 6-s contraction followed by 10- to 30-s assisted stretch. At least four repetitions per muscle group should be completed for a minimum of 2-3 $d \cdot wk^{-1}$.

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[1]Maximum heart rate reserve (HRR) and maximum $V\dot{O}_2$ reserve ($V\dot{O}_2R$) are calculated from the difference between resting and maximum heart rate and resting and maximum $V\dot{O}_2$, respectively. To estimate training intensity, a percentage of this value is added to the resting heart rate and/or resting $V\dot{O}_2$ and is expressed as a percentage of HRR {127} or $V\dot{O}_2R$ {236}. Cited Here...

[2]Aerobic dance refers to a variety of activities such as high- and low-impact aerobics and jazz dancing. The term "group exercise" has been coined to encompass the broad spectrum of these activities, such as, step aerobics, slide board exercise, strength aerobics, and spinning, which are usually performed to music. Cited Here...

[3]The Q angle is usually measured as the angle between a line connecting the anterior superior iliac spine and the midpoint of the patella, and a line between the midpoint of the patella and the tibial tubercle. Cited Here...

[4]Haskell and Haskell et al. {105,106} have suggested the use of 4 kcal·kg^{-1} of body weight of energy expenditure per day for use in exercise programs. The Surgeon General {242} recommends a minimum of 2 kcal·kg^{-1}. Cited Here...

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