Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise

AMERICAN COLLEGE of SPORTS MEDICINE®

POSITION STAND

This pronouncement was written for the American College of Sports Medicine by Carol Ewing Garber, Ph.D., FACSM, (Chair); Bryan Blissmer, Ph.D.; Michael R. Deschenes, Ph.D., FACSM; Barry A. Franklin, Ph.D., FACSM; Michael J. Lamonte, Ph.D., FACSM; I-Min Lee, M.D., Sc.D., FACSM; David C. Nieman, Ph.D., FACSM; and David P. Swain, Ph.D., FACSM.

SUMMARY

The purpose of this Position Stand is to provide guidance to professionals who counsel and prescribe *individualized* exercise to apparently healthy adults of all ages. These recommendations also may apply to adults with certain chronic diseases or disabilities, when appropriately evaluated and advised by a health professional. This document supersedes the 1998 American College of Sports Medicine (ACSM) Position Stand, "The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in Healthy Adults." The scientific evidence demonstrating the beneficial effects of exercise is indisputable, and the benefits of exercise far outweigh the risks in most adults. A program of regular exercise that includes cardiorespiratory, resistance, flexibility, and neuromotor exercise training *beyond* activities of daily living to improve and maintain physical fitness and health is *essential* for most adults. The ACSM recommends that most adults engage in moderate-intensity cardiorespiratory exercise training for ≥30 min·d^{-1} on ≥5 d·wk^{-1} for a total of ≥150 min·wk^{-1}, vigorous-intensity cardiorespiratory exercise training for ≥20 min·d^{-1} on ≥3 d·wk^{-1} (≥75 min·wk^{-1}), or a combination of moderate- and vigorous-intensity exercise to achieve a total energy expenditure of ≥500–1000 MET·min·wk^{-1}. On 2–3 d·wk^{-1}, adults should also perform resistance exercises for each of the major muscle groups, and neuromotor exercise involving balance, agility, and coordination. Crucial to maintaining joint range of movement, completing a series of flexibility exercises for each the major muscle–tendon groups (a total of 60 s per exercise) on ≥2 d·wk^{-1} is recommended. The exercise program should be modified according to an individual's habitual physical activity, physical function, health status, exercise responses, and stated goals. Adults who are unable or unwilling to meet the exercise targets outlined here still can benefit from engaging in amounts of exercise *less than* recommended. In addition to exercising regularly, there are health benefits in concurrently reducing total time engaged in sedentary pursuits and also by interspersing frequent, short bouts of standing and physical activity between periods of sedentary activity, even in physically active adults. Behaviorally based exercise interventions, the use of behavior change strategies, supervision by an experienced fitness instructor, and exercise that is pleasant and enjoyable can improve adoption and adherence to prescribed exercise programs. Educating adults about and screening for signs and symptoms of CHD and gradual progression of exercise intensity and volume may reduce the risks of exercise. Consultations with a medical professional and diagnostic exercise testing for CHD are useful when clinically indicated but are not recommended for universal screening to enhance the safety of exercise.

Key Words: Practice Guidelines, Prescription, Physical Activity, Physical Fitness, Health, Aerobic Exercise, Resistance Exercise, Flexibility Exercise, Neuromotor Exercise, Functional Fitness

0195-9131/11/4307-1334/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0b013e318213fefb

INTRODUCTION

Many recommendations for exercise and physical activity by professional organizations and government agencies have been published since the *sui generis* publications of the American College of Sports Medicine (ACSM) (10,11). The number of recommendations has escalated after the release of the 1995 Centers for Disease Control and Prevention (CDC)/ACSM public health recommendations (280) and the 1996 US Surgeon General's Report (371), and the ostensibly contradictory recommendations between these documents have led to confusion among health professionals, fitness professionals, and the public (32,155). The more recent recommendations of the American Heart Association (AHA) and the ACSM (155,264) and the *2008 Physical Activity Guidelines for Americans* (370) have helped clarify public health recommendations for physical activity, and these are now are incorporated into the current edition of the *ACSM's Guidelines for Exercise Testing and Prescription* (14). The purpose of this Position Stand is to provide scientific evidence-based recommendations to health and fitness professionals in the development of *individualized* exercise prescriptions for apparently healthy adults of all ages. When appropriately evaluated and advised by a health professional (e.g., physician, clinical exercise physiologist, nurse), these recommendations may also apply to persons with certain chronic diseases or disabilities, with modifications required according to an individual's habitual physical activity, physical function, health status, exercise response, and stated goals. The advice presented in this Position Stand is intended principally for adults whose goal is to improve physical fitness and health; adult athletes engaging in competitive sports and advanced training regimens can benefit from more advanced training techniques (13,212,254,255). The evidence statements and summary exercise recommendations derived from the scientific review are found in Tables 1 and 2.

This document updates the scientific evidence published since the 1998 Position Stand (12). Epidemiological studies, randomized and nonrandomized clinical trials, meta-analyses, evidence-based guidelines, consensus statements, and scientific reviews published from 1998 to 2010 were identified through bibliographic searches using common computer search engines (e.g., PubMed, Medline, Google Scholar, IndexCat, PsychArticles, and CINAHL). References cited in the 2008 *Physical Activity Guidelines Advisory Committee Report* (372), the AHA/ACSM public health statements (155,264), and article bibliographies were also reviewed by the writing group.

Interpretation of the available scientific evidence was made by consensus of the writing group members using the evidence rating system of the National Heart Lung and Blood Institute (263) shown in Table 3. Observational studies of physical activity and, to a lesser extent, physical fitness are the primary sources of data supporting the benefits of exercise in reducing the risks of mortality and morbidity, and these studies provided guidance on the recommended patterns and volumes of exercise to gain health and fitness benefits. Randomized clinical trials of exercise training and meta-analyses contributed evidence for the causal effects (effectiveness and efficacy) of exercise training (frequency, intensity, duration, mode, pattern, volume) for improving physical fitness and biomarkers of chronic disease.

The focus of the recommendations in this Position Stand is on *exercise*, which connotes *intentional* physical activity for improving health and fitness. The terms *physical activity* and *physical fitness* are used when these terms more precisely reflect the nature of the scientific evidence that supports the exercise recommendations. The data supporting the benefits of exercise have been derived primarily from observational studies that have evaluated *physical activity*, or less commonly, *physical fitness* (rather than exercise), while the randomized clinical trials center mostly on *exercise*. Exercise, physical activity, and physical fitness are closely related constructs, but they have distinct meanings. Table 4 presents the definitions of these and other common terms used in this Position Stand. All terms used in this document conform with the definitions found in the *Physical Activity Guidelines Advisory Committee Report* (372) and the classifications of cardiovascular diseases (CVD) of the AHA (229).

WHAT ARE THE HEALTH BENEFITS OF PHYSICAL ACTIVITY AND EXERCISE IN ADULTS?

Regular physical activity and exercise are *associated* with numerous physical and mental health benefits in men and

TABLE 1. Summary of the general evidence relevant to the exercise prescription.

	Evidence Statement	Evidence Category
Health benefits	Engaging in regular exercise and reducing sedentary behavior is vital for the health of adults.	A
Reversibility of training effects	Training-induced adaptations are reversed to varying degrees over time upon cessation of a program of regular exercise.	A
Heterogeneity of response	There is considerable variability in individual responses to a standard dose of exercise.	A
Exercise regimen	Cardiorespiratory and resistance exercise training is recommended to improve physical fitness and health.	A
	Flexibility exercises improve and maintain and joint range of movement	A
	Neuromotor exercises and multifaceted activities (such as tai ji and yoga) can improve or maintain physical function, and reduce falls in older persons at risk for falling.	B
	Neuromotor exercises may benefit middle aged and younger adults	D
Exercise adoption and maintenance	Theory-based exercise interventions can be effective in improving adoption and short-term adherence to exercise.	B
	Moderate-intensity exercise and exercise that is enjoyable can enhance the affective responses to exercise, and may improve exercise adherence	B
	Supervision by an experienced health and fitness professional and enhance exercise adherence	C
Risks of exercise	Exercise is associated with an increased risk of musculoskeletal injury and adverse CHD events.	B
	The benefits of exercise far outweigh the risks in most adults.	C
	Warm-up, cool down, flexibility exercise, and gradual progression of exercise volume and intensity may reduce the risk of CVD events and musculoskeletal injury during exercise.	C
	Consultation with a physician and diagnostic exercise testing for CHD may reduce risks of exercise if medically indicated, but are not recommended on a routine basis.	C
	Consultation with a well-trained fitness professional may reduce risks in novice exercisers and in persons with chronic diseases and conditions	D
Preexercise screening	Screening for and educating about the forewarning signs or symptoms of CVD events may reduce the risks of serious untoward events.	C

Table evidence categories: A, randomized controlled trials (rich body of data); B, randomized controlled (limited body of data); C, nonrandomized trials, observational studies; D, panel consensus judgment. From the National Heart Lung and Blood Institute (263).

TABLE 2. Evidence statements and summary of recommendations for the individualized exercise prescription.

	Evidence-Based Recommendation	Evidence Category
Cardiorespiratory (“aerobic”) exercise		
Frequency	≥5 d·wk^{-1} of moderate exercise, or ≥3 d·wk^{-1} of vigorous exercise, or a combination of moderate and vigorous exercise on ≥3–5 d·wk^{-1} is recommended.	A
Intensity	Moderate and/or vigorous intensity is recommended for most adults.	A
	Light- to moderate-intensity exercise may be beneficial in deconditioned persons.	B
Time	30–60 min·d^{-1} (150 min·wk^{-1}) of purposeful moderate exercise, or 20–60 min·d^{-1} (75 min·wk^{-1}) of vigorous exercise, or a combination of moderate and vigorous exercise per day is recommended for most adults.	A
	<20 min·d^{-1} (<150 min·wk^{-1}) of exercise can be beneficial, especially in previously sedentary persons.	B
Type	Regular, purposeful exercise that involves major muscle groups and is continuous and rhythmic in nature is recommended.	A
Volume	A target volume of ≥500–1000 MET·min·wk^{-1} is recommended.	C
	Increasing pedometer step counts by ≥2000 steps per day to reach a daily step count ≥7000 steps per day is beneficial.	B
	Exercising below these volumes may still be beneficial for persons unable or unwilling to reach this amount of exercise.	C
Pattern	Exercise may be performed in one (continuous) session per day or in multiple sessions of ≥10 min to accumulate the desired duration and volume of exercise per day.	A
	Exercise bouts of <10 min may yield favorable adaptations in very deconditioned individuals.	B
	Interval training can be effective in adults.	B
Progression	A gradual progression of exercise volume by adjusting exercise duration, frequency, and/or intensity is reasonable until the desired exercise goal (maintenance) is attained.	B
	This approach may enhance adherence and reduce risks of musculoskeletal injury and adverse CHD events.	D
Resistance exercise		
Frequency	Each major muscle group should be trained on 2–3 d·wk^{-1}.	A
Intensity	60%–70% of the 1RM (moderate to hard intensity) for novice to intermediate exercisers to improve strength.	A
	≥80% of the 1RM (hard to very hard intensity) for experienced strength trainers to improve strength.	A
	40%–50% of the 1RM (very light to light intensity) for older persons beginning exercise to improve strength.	A
	40%–50% of the 1RM (very light to light intensity) may be beneficial for improving strength in sedentary persons beginning a resistance training program.	D
	<50% of the 1RM (light to moderate intensity) to improve muscular endurance.	A
	20%–50% of the 1RM in older adults to improve power.	B
Time	No specific duration of training has been identified for effectiveness.	
Type	Resistance exercises involving each major muscle group are recommended.	A
	A variety of exercise equipment and/or body weight can be used to perform these exercises.	A
Repetitions	8–12 repetitions is recommended to improve strength and power in most adults.	A
	10–15 repetitions is effective in improving strength in middle aged and older persons starting exercise	A
	15–20 repetitions are recommended to improve muscular endurance	A
Sets	Two to four sets are the recommended for most adults to improve strength and power.	A
	A single set of resistance exercise can be effective especially among older and novice exercisers.	A
	≤2 sets are effective in improving muscular endurance.	A
Pattern	Rest intervals of 2–3 min between each set of repetitions are effective.	B
	A rest of ≥48 h between sessions for any single muscle group is recommended.	A
Progression	A gradual progression of greater resistance, and/or more repetitions per set, and/or increasing frequency is recommended.	A
Flexibility exercise		
Frequency	≥2–3 d·wk^{-1} is effective in improving joint range of motion, with the greatest gains occurring with daily exercise.	B
Intensity	Stretch to the point of feeling tightness or slight discomfort.	C
Time	Holding a static stretch for 10–30 s is recommended for most adults.	C
	In older persons, holding a stretch for 30–60 s may confer greater benefit.	C
	For PNF stretching, a 3- to 6-s contraction at 20%–75% maximum voluntary contraction followed by a 10- to 30-s assisted stretch is desirable.	B
Type	A series of flexibility exercises for each of the major muscle–tendon units is recommended.	B
	Static flexibility (active or passive), dynamic flexibility, ballistic flexibility, and PNF are each effective.	B
Volume	A reasonable target is to perform 60 s of total stretching time for each flexibility exercise.	B
Pattern	Repetition of each flexibility exercise two to four times is recommended-	B
	Flexibility exercise is most effective when the muscle is warmed through light to moderate aerobic activity or passively through external methods such as moist heat packs or hot baths.	A
Progression	Methods for optimal progression are unknown.	
Neuromotor exercise training		
Frequency	≥2–3 d·wk^{-1} is recommended.	B
Intensity	An effective intensity of neuromotor exercise has not been determined.	
Time	≥20–30 min·d^{-1} may be needed.	B
Type	Exercises involving motor skills (e.g., balance, agility, coordination, and gait), proprioceptive exercise training, and multifaceted activities (e.g., tai ji and yoga) are recommended for older persons to improve and maintain physical function and reduce falls in those at risk for falling.	B
	The effectiveness of neuromuscular exercise training in younger and middle-aged persons has not been established, but there is probable benefit.	D
Volume	The optimal volume (e.g., number of repetitions, intensity) is not known.	
Pattern	The optimal pattern of performing neuromotor exercise is not known.	
Progression	Methods for optimal progression are not known.	

Table evidence categories: A, randomized controlled trials (rich body of data); B, randomized controlled trials (limited body of data); C, nonrandomized trials, observational studies; D, panel consensus judgment. From the National Heart Lung and Blood Institute (263).

TABLE 3. Evidence categories.

Evidence Category	Sources of Evidence	Definition
A	Randomized controlled trials (RCT; rich body of data)	Evidence is from end points of well-designed RCT (or trials that depart only minimally from randomization) that provide a consistent pattern of findings in the population for which the recommendation is made. Category A therefore requires substantial numbers of studies involving substantial numbers of participants.
B	Randomized controlled trials (limited body of data)	Evidence is from end points of intervention studies that include only a limited number of RCT, *post hoc* or subgroup analysis of RCT, or meta-analysis of RCT. In general, Category B pertains when few randomized trials exist, they are small in size, and the trial results are somewhat inconsistent, or the trials were undertaken in a population that differs from the target population of the recommendation.
C	Nonrandomized trials, observational studies	Evidence is from outcomes of uncontrolled or nonrandomized trials or from observational studies.
D	Panel consensus judgment	Expert judgment is based on the panel's synthesis of evidence from experimental research described in the literature and/or derived from the consensus of panel members based on clinical experience or knowledge that does not meet the above-listed criteria. This category is used only in cases where the provision of some guidance was deemed valuable but an adequately compelling clinical literature addressing the subject of the recommendation was deemed insufficient to justify placement in one of the other categories (A through C).

Evidence categories reprinted with permission from the National Heart Lung and Blood Institute (263).

women. All-cause mortality is delayed by regularly engaging in physical activity; this is also the case when an individual *increases* physical activity by changing from a sedentary lifestyle or a lifestyle with insufficient levels of physical activity to one that achieves recommended physical activity levels (372). Exercise and physical activity decrease the risk of developing CHD, stroke, type 2 diabetes, and some forms of cancer (e.g., colon and breast cancers) (372).

Exercise and physical activity lower blood pressure; improve lipoprotein profile, C-reactive protein, and other CHD biomarkers; enhance insulin sensitivity, and play an important role in weight management (372). Of particular relevance to older adults, exercise preserves bone mass and reduces the risk of falling (264). Prevention of and improvement in mild to moderate depressive disorders and anxiety can occur with exercise (35,155,244,250,305,337,398). A physically active lifestyle enhances feelings of ''energy'' (294), well-being (25,406), quality of life (81,139,302), and cognitive function (203,318,333) and is associated with a lower risk of cognitive decline and dementia (210,281,387,405).

WHAT ARE THE HEALTH BENEFITS OF PHYSICAL FITNESS?

Each component of physical fitness (i.e., cardiorespiratory fitness, muscular strength and endurance (muscular fitness), body composition, flexibility, and neuromotor fitness) conceivably influences some aspect of health. Quantitative data on the relationships between fitness and health are available for only some fitness components, with the most data available on body composition and cardiorespiratory fitness. In the domain of body composition, overall and abdominal obesity are associated with increased risk of adverse health outcomes (12,37,92,301), whereas greater fat-free mass is associated with a lower risk of all-cause mortality (37,160). Higher levels of cardiorespiratory and muscular fitness are each associated with lower risks for poorer health (24,42,75,117,128,189,265,292,339).

Relationships between cardiorespiratory fitness, biological risk factors, and clinical health outcomes tend to parallel those for physical activity: apparently healthy middle-aged and older adults with greater cardiorespiratory fitness at

TABLE 4. Definition of key terms.

Active commuting	Traveling to or from work or school by a means involving physical activity, such as walking, riding a bicycle (324).
Biomarkers	A specific biochemical indicator of a biological process, event, or condition (i.e., disease, aging, etc.) (251).
Cardiometabolic	Factors associated with increased risk of CVD and metabolic abnormalities including obesity, insulin resistance, glucose intolerance, and type 2 diabetes mellitus.
Physical activity	"Any bodily movement produced by skeletal muscles that results in energy expenditure" (64) above resting (basal) levels (371). Physical activity broadly encompasses exercise, sports, and physical activities done as part of daily living, occupation, leisure, and active transportation.
Exercise	"Physical activity that is planned, structured, and repetitive and [that] has as a final or intermediate objective the improvement or maintenance of physical fitness" (64).
Physical fitness	"The ability to carry out daily tasks with vigor and alertness, without undue fatigue and with ample energy to enjoy [leisure] pursuits and to meet unforeseen emergencies" (64). Physical fitness is operationalized as "[a set of] measurable health and skill-related attributes" that include cardiorespiratory fitness, muscular strength and endurance, body composition and flexibility, balance, agility, reaction time and power (1985).
Physical function	The capacity of an individual to carry out the physical activities of daily living. Physical function reflects motor function and control, physical fitness, and habitual physical activity (54,176) and is an independent predictor of functional independence (130), disability (126), morbidity, and mortality (125).
Energy expenditure	The total amount of energy (gross) expended during exercise, *including* the resting energy expenditure (resting energy expenditure + exercise energy expenditure). Energy expenditure may be articulated in METs, kilocalories or kilojoules (342).
MET	An index of energy expenditure. "[A MET is] the ratio of the rate of energy expended during an activity to the rate of energy expended at rest.... [One] MET is the rate of energy expenditure while sitting at rest...by convention, [1 MET is equal to] an oxygen uptake of 3.5 [$mL \cdot kg^{-1} \cdot min^{-1}$]" (370).
MET-minutes	An index of energy expenditure that quantifies the total amount of physical activity performed in a standardized manner across individuals and types of activities (370). Calculated as the product of the number of METs associated with one or more physical activities and the number of minutes the activities were performed (i.e., METs $\times$ minutes). Usually standardized per week or per day. Example: jogging (at ~7 METs) for 30 min on 3 $d \cdot wk^{-1}$: 7 METs $\times$ 30 min $\times$ three times per week = 630 $MET \cdot min \cdot wk^{-1}$.
Sedentary behavior	Activity that involves little or no movement or physical activity, having an energy expenditure of about 1–1.5 METs. Examples are sitting, watching television, playing video games, and using a computer (276).

baseline, and those who improve fitness over time have a lower risk of all-cause and CVD mortality and morbidity (41,213,339,340). A decreased risk of clinical events is also associated with greater cardiorespiratory fitness in individuals with preexisting disease (75,213,247,262,338).

The minimum level of cardiorespiratory fitness required for health benefit may be different for men and women and for older and younger adults. This is because the distribution of cardiorespiratory fitness is different between healthy men and women (14) and a nonlinear decline in cardiorespiratory fitness, which occurs with advancing age when not accompanied by a program of regular exercise (118). Sex- and age-specific norms for cardiorespiratory fitness in apparently healthy adults are available in the *ACSM Guidelines for Exercise Testing and Prescription* (14).

HOW MUCH PHYSICAL ACTIVITY IS NEEDED TO IMPROVE HEALTH AND CARDIORESPIRATORY FITNESS?

What volume of physical activity is needed? Several studies have supported a dose–response relationship between chronic physical activity levels and health outcomes (155,372), such that greater benefit is associated with higher amounts of physical activity. Data regarding the specific quantity and quality of physical activity for the attainment of the health benefits are less clear. Epidemiologic studies have estimated the *volume* of physical activity needed to achieve specific health benefits, typically expressed as kilocalories per week ($kcal{\cdot}wk^{-1}$), MET-minutes per week ($MET{\cdot}min{\cdot}wk^{-1}$), or MET-hours per week ($MET{\cdot}h{\cdot}wk^{-1}$). Large prospective cohort studies of diverse populations (216,237,320,353) clearly show that an energy expenditure of approximately 1000 $kcal{\cdot}wk^{-1}$ of moderate-intensity physical activity (or about 150 $min{\cdot}wk^{-1}$) is associated with lower rates of CVD and premature mortality. This is equivalent to an intensity of about 3–5.9 METs (for people weighing ~68–91 kg) and 10 $MET{\cdot}h{\cdot}wk^{-1}$. Ten MET-hours per week can also be achieved with ≥20 $min{\cdot}d^{-1}$ of vigorous-intensity (≥~6 METs) physical activity performed ≥3 $d{\cdot}wk^{-1}$ or for a total of ~75 $min{\cdot}wk^{-1}$. Previous investigations have suggested that there may be a dose–response relationship between energy expenditure and depression, but additional study is needed to confirm this possibility (25,101).

In the general population, this 1000 $kcal{\cdot}wk^{-1}$ volume of physical activity is accumulated through a combination of physical activities and exercise of varying intensities. Therefore, the *2008 Physical Activity Guidelines for Americans* (370), the 2007 AHA/ACSM recommendations (155,264), and the ACSM guidelines (14) allow for a combination of moderate- and vigorous-intensity activities to expend the requisite weekly energy expenditure. An intriguing observation from several studies is that significant risk reductions for CVD disease and premature mortality begin to be observed at volumes *below* these recommended targets, starting at about *one-half* of the recommended volume (i.e., ~500 $kcal{\cdot}wk^{-1}$) (214,237,320,353). This observation is congruent with the findings from the DREW trial (76) among sedentary, overweight postmenopausal women, which showed that one-half the currently recommended volume of physical activity was sufficient to significantly improve cardiorespiratory fitness.

The available data support a dose–response relationship between physical activity and health outcomes, so it is reasonable to state with respect to exercise, ''some is good; more is better.'' However, the shape of the dose–response curve is less clear, and it is probable that the shape of the curve may differ depending on the health outcome of interest and the baseline level of physical activity of the individual (155).

***How* can studies of physical fitness help to clarify the question of "*How* much physical activity is needed?"** The physical activity dose required to achieve a specific health benefit may be further clarified by equating specific amounts of physical activity to the levels of cardiorespiratory fitness sufficient to confer health benefits. For instance, a study of apparently healthy middle-aged adults (335) showed that all-cause and CVD mortality rates were approximately 60% lower in persons with moderate compared with low cardiorespiratory fitness, estimated from time to fatigue on a treadmill test. The adults of moderate fitness in this study reported a weekly energy expenditure in moderate-intensity physical activity, such as brisk walking on level ground, of ~8–9 $MET{\cdot}h{\cdot}wk^{-1}$. Therefore, a level of cardiorespiratory fitness associated with substantial health benefit seems to be attainable through a dose of exercise or physical activity compatible with the recommendations in this Position Stand and other current publications (14,155,264,370).

WHAT IS THE EFFECT OF EXERCISE TRAINING ON CARDIORESPIRATORY FITNESS AND CARDIOVASCULAR AND METABOLIC DISEASE (CARDIOMETABOLIC) RISK FACTORS?

What is the role of exercise intensity in modifying the responses to exercise? Either moderate- or vigorous-intensity exercise, or both, can be undertaken to meet current exercise recommendations, provided the criterion for total volume of energy expended is satisfied. What is less clear is this: for the same volume of energy expended, is vigorous-intensity exercise associated with additional risk reduction? The data are unclear because most epidemiologic studies examining chronic disease outcomes and randomized clinical trials of exercise training have not taken into account the total volume of energy expended (323). That is, in most studies where benefit is found for vigorous- compared with moderate-intensity exercise, there is also a greater volume of exercise in the vigorous-intensity condition. Thus, it is unclear whether the added benefit is due to the vigorous-intensity *per se* or whether the results simply reflect the additional benefit due to the higher *volume* of energy expended. Nevertheless, there are some reports that support that vigorous-intensity exercise is associated with greater risk reductions for CVD and all-cause mortality compared with moderate-intensity activity of similar energy expended (155).

Exercise intensity *is* an important determinant of the physiological responses to exercise training (12,14,120). Earlier randomized trials did not control for total exercise volume, so the *independent* contributions of volume and intensity were unclear, but more recent studies have supported the greater benefits of vigorous versus moderate exercise. DiPietro et al. (97) found significant improvements in glucose utilization in sedentary older men and women who engaged in vigorous (80% maximal oxygen uptake ($\dot{V}O_{2max}$)) exercise but not in those who performed moderate (65%$\dot{V}O_{2max}$) exercise, although all subjects expended 300 $kcal{\cdot}d^{-1}$ on 4 $d{\cdot}wk^{-1}$. A comprehensive review by Swain (343) concluded that there were greater improvements in $\dot{V}O_{2max}$ with vigorous-intensity exercise training compared with moderate-intensity exercise, when the volume of exercise is held constant. Additional studies support these conclusions (19,97,161,269,313,383).

Is there a threshold intensity of exercise needed to improve cardiorespiratory fitness and to reduce cardiometabolic risk? According to the overload principle of training, exercise below a minimum intensity, or *threshold*, will not challenge the body sufficiently to result in increased $\dot{V}O_{2max}$ and improvements in other physiological parameters (12,14). Evidence for a *minimum* threshold of intensity for benefit is supported in many studies, but not all, and the lack of consistent findings seems to be related to the initial state of fitness and/or conditioning of the subjects (12,345). Swain and Franklin (345) reviewed 18 clinical trials that measured $\dot{V}O_{2max}$ before and after exercise training in 37 training groups and found that subjects with mean baseline $\dot{V}O_{2max}$ values of 40–51 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ (~11–14 METs) seemed to require an intensity of at least 45% oxygen uptake reserve ($\dot{V}O_2R$) to increase $\dot{V}O_{2max}$, but no apparent threshold was found for subjects with mean baseline $\dot{V}O_{2max}$ <40 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ (<11 METs), although ~30%$\dot{V}O_2R$ was the lowest intensity studied. Supporting these findings, a comprehensive review of exercise training in runners determined that ''near maximal'' (i.e., 95%–100%$\dot{V}O_{2max}$) training intensities were needed to improve $\dot{V}O_{2max}$ in well-trained athletes, while 70%–80%$\dot{V}O_{2max}$ seemed to provide a sufficient stimulus in moderately trained athletes (254). Thus, a threshold of exercise intensity may vary depending on fitness level, and it may be difficult to precisely define an exact threshold to improve cardiorespiratory fitness (40,196,214). Additional randomized controlled trials and meta-analyses are needed to explore the threshold phenomenon in populations of varying fitness levels and exercise training regimens because of the interactive effects of exercise volume, intensity, duration, and frequency and individual variability of response.

There are even fewer data available on the existence of a threshold to favorably modify other cardiometabolic risk factors. Two comprehensive reviews by Durstine et al. (102,103) found little evidence for an intensity threshold for changes in HDL cholesterol, LDL cholesterol, or triglycerides, although most studies did not control for exercise volume, frequency, and/or duration and were conducted at intensities ≥40%$\dot{V}O_{2max}$. Similar methodological limitations pertain to studies evaluating blood pressure, glucose intolerance, and insulin resistance (6,284,361). Several studies suggest that exercise intensity does not influence the magnitude of loss of body weight or fat stores (99,266), but these data are also confounded by variability in exercise volume and other factors. Corroborating evidence is provided by a study of sedentary subjects who walked at a self-selected pace with fixed volume (10,000 steps per day on 3 $d{\cdot}wk^{-1}$) and improved lipoprotein profiles and expression of genes involved in reverse lipid transport, without accompanying changes in body weight and total body fat (56). Further, a study of 16 pairs of same-sex twins with discordant physical activity patterns found that greater volumes of exercise were associated with lower total, visceral, liver, and intramuscular body fat, with the active twin having on average 50% less visceral fat and 25% less subcutaneous abdominal fat compared with the inactive twin (221).

The short-term effects of exercise on mental health, particularly depression, may be a function of exercise intensity, although a specific threshold has not been identified. There are some data to suggest that the greatest benefit is conferred through moderate- to vigorous-intensity activity consistent with the recommendations presented in this Position Stand (i.e., ≥~17.5 $kcal{\cdot}kg^{-1}{\cdot}wk^{-1}$; ~1400 $kcal{\cdot}wk^{-1}$) (101).

Does the pattern of exercise training make a difference? Current recommendations advise that moderate-intensity physical activity may be *accumulated* in bouts of ≥10 min each to attain the daily goal of ≥30 $min{\cdot}d^{-1}$ (14,155,264,370). The data supporting a discontinuous exercise pattern come primarily from randomized clinical trials examining short versus long bouts of physical activity in relation to changes in cardiorespiratory fitness, blood pressure, and studies of active commuting (141,151). A comprehensive review (260) concluded that the evidence comparing the effectiveness of long versus short bouts of exercise for improving body composition, lipoproteins, or mental health is meager and inconclusive. Only one study, in men, examined short (≤15 min) versus long bouts of physical activity in relation to chronic disease outcomes, and the findings suggest it is the volume of energy expended that is important rather than the duration of the exercise (215). Durations of exercise <10 min may result in fitness and health benefits, particularly in sedentary individuals (215); however, the data are sparse and inconclusive.

A different accumulation issue relates to a pattern of physical activity sometimes called a ''weekend warrior'' pattern, where a large total volume of physical activity may be accumulated over fewer days of the week than is recommended. There are few studies evaluating this exercise pattern, but existing evidence supports the possibility of benefit, although the risks are unknown. A study of men indicated that the weekend warrior pattern was associated with lower rates of premature mortality, compared with being sedentary, but only among men *without* cardiovascular risk factors (217). These results suggest the possibility that physical activity might be needed on a regular basis to improve the risk profile of men with risk factors. A randomized study (253) showed that previously untrained middle-aged participants who accumulated endurance training on consecutive weekend days attained similar improvements in cardiorespiratory fitness compared with those who completed similar mode, volume ($\sim$1400 kcal$\cdot$wk^{-1}), and intensity (90% of the ventilatory threshold) of training but in a pattern consistent with current recommendations (30 min$\cdot$d^{-1} at 5 d$\cdot$wk^{-1}).

Another pattern of exercise involves varying the exercise intensity within a *single* bout of exercise, termed *interval training*. With interval training, the exercise intensity is varied at fixed intervals during a single exercise bout, which can increase the total volume and/or average exercise intensity performed. A method commonly used in athletes, short-term ($\leq$3 months) interval training has resulted in similar or greater improvements in cardiorespiratory fitness and cardiometabolic biomarkers such as blood lipoproteins, glucose, interleukin-6, and tumor necrosis factor α, and muscle fatty acid transport compared with single-intensity exercise in healthy adults (77,89,142,161,261,351,388) and persons with metabolic, cardiac, or pulmonary disease (28,104,144,313, 383,399). However, a study of healthy untrained men (268) found that interval running exercise was *more* effective than sustained running of similar total duration ($\sim$150 min$\cdot$wk^{-1}) in improving cardiorespiratory fitness and blood glucose concentrations but *less* effective in improving resting HR, body composition, and total cholesterol/HDL ratio. It is clear from these results that additional studies of interval training are needed to more fully elucidate the effects, particularly with respect to varying interval characteristics (e.g., exercise intensity, work interval duration, rest interval duration) and in diverse populations. Nonetheless, these studies show promise for the use of interval training in adults, but the long-term effects and the safety of interval training remain to be evaluated, although no adverse effects have been reported in the literature to date.

A fourth activity pattern that has important implications for health is sedentary behavior, which is an attribute distinct from physical activity (276). Sitting and low levels of energy expenditure are hallmarks of sedentary behavior and encompass activities such as television watching, computer use, and sitting in a car or at a desk (276). Spending long periods of time in sedentary pursuits is associated with elevated risks of CHD mortality (384) and depression (354), increased waist circumference, elevated blood pressure, depressed lipoprotein lipase activity, and worsened chronic disease biomarkers such as blood glucose, insulin, and lipoproteins (158,159,276, 364,390). Sedentariness is detrimental even among individuals who meet current physical activity recommendations (158,276). When sedentary activities are broken up by short bouts of physical activity or standing, attenuation of these adverse biological effects can occur (157). This evidence suggests it is not enough to consider whether an individual engages in adequate physical activity to attain health benefits but also that health and fitness professionals should be concerned about the amount of time clients spend in activities such as television watching and sitting at a desk.

WHAT IS THE EFFECT OF EXERCISE TRAINING ON CARDIORESPIRATORY FITNESS AND CARDIOVASCULAR AND METABOLIC DISEASE (CARDIOMETABOLIC) RISK FACTORS?

Studies substantiating the previous Position Stand (12), the AHA/ACSM statements (155,264), the *2008 Physical Activity Guidelines for Americans* (370), and *ACSM's Guidelines for Exercise Testing and Prescription* (14) clearly demonstrate that exercise of the intensity, duration, and frequency recommended here results in improvements in cardiorespiratory fitness (i.e., $\dot{V}O_{2max}$). Moreover, a plateau in the training effect occurs, whereby additional increases in exercise volume result in little or no additional improvements in $\dot{V}O_{2max}$ (12).

Cardiorespiratory exercise reduces several cardiometabolic disease risk factors, although the magnitude of effect is modest, varies according to individual and exercise program characteristics, and a change in one cardiometabolic risk factor apparently occurs independently of a change in another (271,361,395). Favorable improvements in hypertension, glucose intolerance, insulin resistance, dyslipidemia, and inflammatory markers have been reported in middle-aged and older persons exercising within the volumes and quality of exercise recommended here, even during weight regain (47,102,103,184,260,284,288,310,328,357,358,361, 376,385). The benefits of exercise on cardiometabolic risk factors are acute (lasting hours to days) and chronic, highlighting the value of regular exercise participation on most days of the week (360,388,389). Exercise without dietary modification has a modest effect ($\sim$2%–6%) on short-term ($\leq$6 months) weight loss (99), but favorable changes in associated cardiometabolic risk factors (e.g., visceral abdominal fat, total body fat, and biomarkers) can occur even in the absence of concomitant weight reduction (96,150,195, 288,361), albeit weight loss enhances these improvements (102,103,256,361). Some risk factor changes, such as reduction of LDL and the attenuation of decline in HDL accompanying reduced dietary intake of saturated fat, occur *only* when exercise is combined with weight loss (102,103,361).

What is the effect of varying exercise volumes on the health and fitness of adults? Although epidemiological evidence demonstrates a dose–response *association* between the volume of exercise and health outcomes, randomized clinical trials (RCT) are needed to demonstrate *causal* biological effects. Until recently, few data from RCT were available comparing the effects of different fixed exercise volumes on fitness and biomarkers of disease. Church et al. (76) evaluated the effect of varying exercise volumes at a fixed intensity (50%$\dot{V}O_{2max}$) in sedentary, overweight, or obese postmenopausal women randomized to exercise volumes of 50%, 100%, or 150% of the recommended weekly energy expenditure (4, 8, and 12 kcal·kg^{-1}·wk^{-1}, respectively; or approximately 330, 840, and 1000 kcal·wk^{-1}, respectively). A dose–response effect across the three volumes was observed, and modest improvements in cardiorespiratory fitness (4%–8%) occurred at 6 months at exercise training volumes as low as one-half of the recommended weekly volume. A preliminary report suggests that initial level of fitness may affect the training responses to a set volume of exercise (18), but more definitive evidence is needed before the results of these studies can be generalized to persons of higher fitness levels.

HOW ARE EXERCISE INTENSITY AND VOLUME ESTIMATED?

Most epidemiologic and many laboratory studies providing evidence of the beneficial effects of exercise have classified intensity according to the *absolute* energy demands of the physical activity (323). Measured or estimated measures of absolute exercise intensity include caloric expenditure (kcal·min^{-1}), absolute oxygen uptake (mL·min^{-1} or L·min^{-1}), and METs. These absolute measures can result in misclassification of exercise intensity (e.g., moderate, vigorous) because they do not consider individual factors such as body weight, sex, and fitness level (4,58,173). Measurement—and consequently misclassification—error is greater when using estimated rather than directly measured absolute energy expenditure, and under free-living compared with laboratory conditions (4,58,173). For example, an older person working at 6 METs may be exercising at a vigorous to maximal intensity, while a younger person working at the same absolute intensity will be exercising moderately (173). Therefore, for individual exercise prescription, a *relative* measure of intensity (i.e., the energy cost of the activity relative to the individual's maximal capacity) is more appropriate, especially for older and deconditioned persons (173,264).

There are several commonly used methods of estimating relative exercise intensity during cardiorespiratory exercise: $\dot{V}O_2R$, HRR, percent of the maximum HR (%HR_{max}), %$\dot{V}O_{2max}$, and %MET_{max}. Each of these methods for prescribing exercise intensity has been shown to result in improvements in cardiorespiratory fitness when used for exercise prescription, thence can be recommended when prescribing exercise for an individual (12).

Table 5 shows the approximate classification of exercise intensity using relative and absolute methods commonly used in practice. No studies have compared all of the methods of measurement of exercise intensity simultaneously; therefore, it cannot be assumed that one method of determining exercise intensity is necessarily equivalent to that derived using another method. It is prudent to keep in

TABLE 5. Classification of exercise intensity: relative and absolute exercise intensity for cardiorespiratory endurance and resistance exercise.

	Cardiorespiratory Endurance Exercise											Resistance Exercise
	Relative Intensity				Intensity (%$\dot{V}O_{2max}$) Relative to Maximal Exercise Capacity in METs			Absolute Intensity	Absolute Intensity (MET) by Age			Relative Intensity
Intensity	%HRR or %$\dot{V}O_2R$	%HR_{max}	%$\dot{V}O_{2max}$	Perceived Exertion (Rating on 6–20 RPE Scale)	20 METs %$\dot{V}O_{2max}$	10 METs %$\dot{V}O_{2max}$	5 METs %$\dot{V}O_{2max}$	METs	Young (20–39 yr)	Middle-aged (40–64 yr)	Older (≥65 yr)	% 1RM
Very light	<30	<57	<37	<Very light (RPE < 9)	<34	<37	<44	<2	<2.4	<2.0	<1.6	<30
Light	30–39	57–63	37–45	Very light–fairly light (RPE 9–11)	34–42	37–45	44–51	2.0–2.9	2.4–4.7	2.0–3.9	1.6–3.1	30–49
Moderate	40–59	64–76	46–63	Fairly light to somewhat hard (RPE 12–13)	43–61	46–63	52–67	3.0 to 5.9	4.8–7.1	4.0–5.9	3.2–4.7	50–69
Vigorous	60–89	77–95	64–90	Somewhat hard to very hard (RPE 14–17)	62–90	64–90	68–91	6.0–8.7	7.2–10.1	6.0–8.4	4.8–6.7	70–84
Near-maximal to maximal	≥90	≥96	≥91	≥Very hard (RPE ≥ 18)	≥91	≥91	≥92	≥8.8	≥10.2	≥8.5	≥6.8	≥85

Table adapted from the American College of Sports Medicine (14), Howley (173), Swain and Franklin (344), Swain and Leutholtz (346), Swain et al. (347), and the US Department of Health and Human Services (370).
HR_{max}, maximal HR; %HR_{max}, percent of maximal HR; HRR, HR reserve; $\dot{V}O_{2max}$, maximal oxygen uptake; %$\dot{V}O_{2max}$, percent of maximal oxygen uptake; $\dot{V}O_2R$, oxygen uptake reserve; RPE, ratings of perceived exertion (48).

mind that the relationships among actual energy expenditure, HRR, $\dot{V}O_2R$, $\%HR_{max}$, and $\%\dot{V}O_{2max}$ can vary considerably depending on exercise test protocol, exercise mode, exercise intensity, resting HR, fitness level, age, body composition, and other factors (57,90,185,277,289,315,336). The HRR or $\dot{V}O_2R$ methods may be preferable for exercise prescription because exercise intensity can be underestimated or overestimated when using $\%HR_{max}$ and $\%\dot{V}O_{2max}$ methods (52,57,231,287,342,346). However, the advantage of the HRR or $\dot{V}O_2R$ methods has not been supported by all studies (90,277). The accuracy of the $\%HR_{max}$ and HRR methods may be influenced by the method used to estimate maximal HR. Specialized regression equations for estimating maximal HR (133,147,352,407) are purported to be superior to the commonly used equation of 220 − age for the estimation of maximal HR because influences associated with aging and possible gender differences (133,147,156,352). Although these equations are promising, further study in diverse populations composed of men and women is needed before one or more can be recommended for universal application. Direct measurements of HR and oxygen uptake are recommended for individualized exercise prescription for greater accuracy, but when not feasible, estimation of exercise intensity is acceptable.

MET-minutes per week and kilocalories per minute per week have been used for estimating exercise volume in research, but these quantifications are seldom used for exercise prescription for individuals. Yet, these may be useful in approximating the gross energy expenditure of an individual because of the proliferating evidence supporting the important role of exercise volume in realizing health and fitness outcomes. The METs per minute and kilocalories per week for a wide array of physical activities can be estimated using previously published tables (4,5).

CAN STEPS PER DAY BE USED TO PRESCRIBE EXERCISE?

Pedometers are popular and effective for promoting physical activity (366) and modest weight loss (308), but they provide an inexact index of exercise volume (26,368). They are limited in that the ‘‘quality’’ (e.g., speed, grade, duration) of steps often cannot be determined. A goal of 10,000 steps per day is often cited, but even fewer steps may meet contemporary exercise recommendations (367). For example, recent data from ‘‘America on the Move’’ (27) showed those individuals who reported ‘‘exercising strenuously’’ on 3 $d{\cdot}wk^{-1}$ (duration of exercise not ascertained), a level that probably meets current recommendations, accumulated a mean of 5486 ± 231 SEM steps per day. People reporting 4 $d{\cdot}wk^{-1}$ of ‘‘strenuous exercise’’ accumulated 6200 ± 220 steps per day, and 7891 ± 540 steps per day were reported by those ‘‘exercising strenuously’’ on 6–7 $d{\cdot}wk^{-1}$. In a randomized trial evaluating different doses of physical activity on fitness levels, initially sedentary women who engaged in a new program of physical activity meeting current exercise recommendations averaged about 7000 steps per day (187). Two meta-analyses of pedometer use showed that participants in randomized clinical trials *increased* their daily steps on average by about 2000 steps per day, equal to walking approximately 1 $mile{\cdot}d^{-1}$, and few of the most sedentary subjects achieved the goal of 10,000 steps per day (51,193). In participants with elevated blood pressure, an increase of 2000 steps per day was associated with a modest decrease in systolic blood pressure (~4 mm Hg), independent of changes in body mass index, suggesting that fewer than 10,000 steps per day may provide health benefits. Recent work to determine step count cut points corresponding to moderate-intensity walking demonstrated that 100 steps per minute is a very rough approximation of moderate-intensity exercise (242). Because of the substantial errors of prediction using either step counts or this algorithm to estimate energy expenditure (204,242,368), it may be prudent to use both steps per minute *combined with* currently recommended durations of exercise for exercise prescription (e.g., 100 steps per minute for 30 min per session) (242,368).

WHAT ARE THE BENEFITS OF IMPROVING MUSCULAR FITNESS?

The health benefits of enhancing muscular fitness have become well established during the past decade (392). Higher levels of muscular strength are associated with significantly better cardiometabolic risk factor profiles (188,189), lower risk of all-cause mortality (117,128,265), fewer CVD events (128,353), lower risk of developing functional limitations (54,235), and nonfatal disease (189). At present, there are insufficient prospective data on the dose–response characteristics between muscular fitness and health outcomes or the existence of a threshold for benefit to recommend a minimal level of health-related muscular strength, power, or endurance (31). Apart from greater strength, there is an impressive array of changes in health-related biomarkers that can be derived from regular participation in resistance training, including improvements in body composition (177,178,328), blood glucose levels (66,67,207,327,328), insulin sensitivity (55,199), and blood pressure in persons with prehypertension or stage 1 hypertension (80,328). Accordingly, resistance training may prove to be effective to prevent and treat the ‘‘metabolic syndrome’’ (234).

Importantly, exercise that promotes muscle strength and mass also effectively increases bone mass (bone mineral density and content) and bone strength of the specific bones stressed (201,233,341) and may serve as a valuable measure to prevent, slow—or even reverse—the loss of bone mass in people with osteoporosis (201,233,341). Because muscle weakness has been identified as a risk factor for the development of osteoarthritis, resistance training may reduce the chance of developing musculoskeletal disorder (331). In persons with osteoarthritis, resistance training can reduce pain and disability (39,252).

The mental health benefits associated with resistance training have received less attention than cardiorespiratory exercise. Preliminary work suggests that resistance training may prevent and improve depression and anxiety (65,271,282), increase ''energy'' levels, and decrease fatigue (294). However, these results are inconclusive and require further study.

HOW CAN EXERCISE IMPROVE AND MAINTAIN MUSCULAR FITNESS?

Muscular fitness is composed of the functional parameters of strength, endurance, and power, and each improves consequent to an appropriately designed resistance training regimen. As the trained muscles strengthen and enlarge (hypertrophy), the resistance must be progressively increased if additional gains are to be accrued. To optimize the efficacy of resistance training, the program variables (frequency, intensity, volume, rest intervals) are best tailored to the individual's goals (13).

The focus here is on program design for adults seeking *general or overall* muscular fitness with associated health benefits. Individuals who desire to engage in more advanced or extensive resistance training regimens aimed at achieving maximal muscular strength and hypertrophy are referred to the relevant ACSM Position Stand (13).

What types of exercises improve muscular fitness? Many types of resistance training equipment can effectively be used to improve muscular fitness, including free weights, machines with stacked weights or pneumatic resistance, and even resistance bands. A resistance training program emphasizing dynamic exercises involving concentric (shortening) and eccentric (lengthening) muscle actions that recruit multiple muscle groups (multijoint exercises) is recommended, including exercises targeting the major muscle groups of the chest, shoulders, back, hips, legs, trunk, and arms (13). Single-joint exercises that isolate functionally important muscle groups such as the abdominals, lumbar extensors (lower back), calf muscles, hamstrings, quadriceps, biceps, etc., should also be included. To prevent muscular imbalances, training opposing muscle groups (antagonists), such as the quadriceps and hamstrings, as well as the abdominals and lumbar extensors, is important.

The exercises should be executed using correct form and technique, including performing the repetitions deliberately and in a controlled manner, moving through the full range of motion of the joint, and using proper breathing techniques (i.e., exhalation during the concentric phase and inhalation during the eccentric phase; avoiding the Valsalva maneuver) (13). Training that exclusively features eccentric contractions should be discouraged because severe muscle damage and soreness as well as serious complications such as rhabdomyolisis can ensue (78).

How many sets of exercises are needed? Most individuals respond favorably (e.g., hypertrophy and strength gains) to two to four sets of resistance exercises per muscle group (13,386), but even a single set of exercise may significantly improve muscle strength and size, particularly in novice exercisers (12,13). The target number of sets per muscle group can be achieved with a single exercise or by using a combination of more than one exercise movement (e.g., two sets of shoulder press and two sets of lateral raises).

What duration of rest intervals between sets and intensity is appropriate to improve muscular fitness? For a general fitness program, rest intervals of 2–3 min are most effective for achieving the desired increases in muscle strength and hypertrophy (13). Robust gains in both hypertrophy and strength result from using a resistance equivalent to 60%–80% of the individual's one-repetition maximal (1RM) effort (386). For novice through intermediate strength trainers, a load of 60%–70% of the 1RM is recommended (i.e., moderate to hard intensity), while experienced exercisers may work at ≥80% of the 1RM (i.e., hard to very hard intensity) (13). The selected resistance should permit the completion of 8–12 repetitions per set—or the number needed to induce muscle fatigue but not exhaustion. For people who wish to focus on improving muscular endurance, a lower intensity (i.e., <50% of 1RM; light to moderate intensity) can be used to complete 15–25 repetitions per set, with the number of sets not to exceed two (59). Table 5 shows the relative intensities for resistance training.

How often should resistance training be performed? Meta-analyses show that optimal gains in muscle function and size can occur with training two to three times per week (285,306,386). This can be effectively achieved with ''whole body'' training sessions completed two to three times a week or by using a ''split-body'' routine where selected muscle groups are trained during one session and the remaining muscle groups in the next. A rest period of 48 to 72 h between sessions is needed to optimally promote the cellular/molecular adaptations that stimulate muscle hypertrophy and the associated gains in strength (36).

Are there differences in resistance training recommendations according to individual characteristics? The resistance training recommendations described here are appropriate for men and women of virtually all ages (1,386). Older, very deconditioned, or frail individuals initiating a resistance training regimen, may begin with lower resistance, perhaps 40%–50% of 1RM (i.e., very light to light intensity), along with a greater number of repetitions (i.e., 10–20) (110). After achieving an acceptable level of muscular conditioning, older and frail persons can increase the resistance and perform the exercises as detailed above (110). Because some studies indicate that the risk of accidental falls and resultant bone fractures is more closely related to a decline in muscular power than strength, it has been suggested that resistance training for the older person should emphasize the development of power (46,71). Research has shown that completing three sets of 8–12 repetitions at a very light to moderate intensity (20%–50% of 1RM) effectively increases strength and power and improves balance in older persons (93,274). Although encouraging, additional studies are needed to provide definitive guidelines regarding exercise prescription for power training in older individuals.

HOW CAN MEASURES OF PERCEIVED EXERCISE INTENSITY AND AFFECTIVE VALENCE BE USED?

Instruments that measure perceived effort and the pleasantness of exercise (i.e., affective valence), including the Borg RPE scales (48,267), the OMNI scales (311,312,373), the Talk Test (283), and the Feeling Scale (152) can be used to modulate or refine the prescribed exercise intensity of both cardiorespiratory and resistance exercise, with the most data available on the cardiorespiratory exercise. However, the evidence is insufficient to support using these methods as a *primary* method of exercise prescription. The RPE scales (48,267) and the modality-specific (i.e., walking, cycling,) OMNI scales (311,312,373) have been used most extensively and demonstrate moderate to strong validity compared with other measures of cardiorespiratory exercise intensity (i.e., $\%\dot{V}O_{2max}$, $\%HR_{max}$, blood lactate concentrations) (72,179), although the strength of these relationships may differ depending on the characteristics of the exercise (72). The OMNI resistance exercise scale has reasonable concurrent validity compared with the RPE scale (208,311). The Talk Test (283) is moderately associated with cardiorespiratory exercise intensity (e.g., ventilatory threshold, HR, oxygen uptake, and blood lactate) in some (53,121,283) but not all studies (316). Measures of the pleasantness/unpleasantness of exercise (i.e., affective valence) hold promise as a means to regulate and monitor exercise intensity because they can accurately identify the transition across the lactate threshold during cardiorespiratory exercise (106,108). The Feeling Scale (152), one measure of affective valence, seems to be an effective way for an individual to self-regulate exercise intensity, particularly during walking exercise (314).

WHAT ARE THE BENEFITS OF FLEXIBILITY EXERCISE?

Although joint flexibility decreases with aging, flexibility can be improved across all age groups (12,15,95,127,264). Joint range of motion is improved transiently after flexibility exercise, chronically after approximately 3–4 wk of regular stretching at a frequency of at least two to three times a week (94,95,146,202,295,300), and it may improve in as few as 10 sessions with an intensive program (145). Flexibility exercises may enhance postural stability and balance (83), particularly when combined with resistance exercise (38). No consistent link has been shown between regular flexibility exercise and a reduction of musculotendinous injuries, prevention of low back pain, or DOMS (9,116,163,248,355,401).

How can exercise be used to improve and maintain muscular fitness? The goal of a flexibility program is to develop range of motion in the major muscle–tendon groups in accordance with individualized goals. Certain performance standards discussed below enhance the effectiveness of flexibility exercises.

What types of exercise can improve flexibility? Several types of flexibility exercises can improve range of movement. Ballistic methods or ''bouncing'' stretches use the momentum of the moving body segment to produce the stretch (402). Dynamic or slow movement stretching involves a gradual transition from one body position to another, and a progressive increase in reach and range of motion as the movement is repeated several times (249). Static stretching involves slowly stretching a muscle/tendon group and holding the position for a period (i.e., 10–30 s). Static stretching can be active or passive (397). Active static stretching involves holding the stretched position using the strength of the agonist muscle, as is common in many forms of yoga. In passive static stretching, a position is assumed while holding a limb or other part of the body with or without the assistance of a partner or device (such as elastic bands or a barre). Proprioceptive neuromuscular facilitation (PNF) methods take several forms but typically involve an isometric contraction of the selected muscle–tendon group followed by a static stretching of the same group (i.e., contract–relax) (299,322).

Do similar benefits result from the various types of flexibility exercise? Ballistic stretching, when properly performed, increases flexibility similarly to static stretching, and may be considered for individuals engaging in activities that involve ballistic movements, such as basketball (85,209,232,400,402). PNF and static stretching elicit greater gains in joint range of motion than dynamic or slow movement stretching (22,95,202,270). PNF may produce slightly larger gains in flexibility of some joints compared with other techniques, but it is less practical because of the need for a partner (322). However, one comparative review reported that range of motion improvements of 5°–20° occurred after 3–10 wk of hamstring stretching irrespective of whether static or PNF techniques were performed (95).

How long should a stretch be held? Holding a stretch for 10–30 s at the point of tightness or slight discomfort enhances joint range of motion, with little apparent benefit resulting from longer durations (21,95). Older persons may realize greater improvements in range of motion with longer durations (30–60 s) of stretching (115). A 20%–75% maximum contraction held for 3–6 s followed by a 10- to 30-s assisted stretch is recommended for PNF techniques (45,114,322).

How many repetitions of stretching exercises are needed? Repeating each flexibility exercise two to four times is effective, with enhancement of joint range of motion occurring during 3–12 wk (21,95,264). The goal is to attain 60 s of total stretching time per flexibility exercise by adjusting duration and repetitions according to individual needs. For example, 60 s of stretch time can be met by two 30-s stretches or four 15-s stretches (95).

How often should stretching exercise be performed? Performing flexibility exercises $\geq$2–3 d·wk^{-1} is effective (95,203), but greater gains in joint range of motion are accrued with daily flexibility exercise (115, 145,146,293,299,394).

What types of flexibility exercises should be performed? A series of exercises targeting the major muscle–tendon units of the shoulder girdle, chest, neck, trunk, lower back, hips, posterior and anterior legs, and ankles are recommended. For most individuals, this routine can be completed within 10 min.

When should stretching be performed? Flexibility exercise is most effective when the muscle temperature is elevated through light-to-moderate cardiorespiratory or muscular endurance exercise or passively through external methods such as moist heat packs or hot baths, although this benefit may vary across muscle–tendon units (29,249,326).

Stretching exercises can have a negative effect on subsequent muscle strength and power and sports performances, particularly when strength and power are important (248,396). However, limited evidence is available about the effects of stretching programs of different durations and types (e.g., passive vs dynamic) on exercise activities with varying characteristics, particularly in individuals who are exercising for improving fitness. Further research is needed before making universal recommendations concerning the timing of stretching in association with other exercise activities. Nonetheless, based on the available evidence, whenever possible, persons engaging in a general fitness program should perform flexibility exercise after cardiorespiratory or resistance exercise—or alternatively—as a stand-alone program. For most persons, a dynamic, cardiorespiratory endurance exercise warm-up is superior to flexibility exercise for enhancing cardiorespiratory or resistance exercise (especially with high duration and repetitions) performance (29,124, 248,249,326). A pre-event warm-up that includes both cardiorespiratory and flexibility exercise has benefits for specific recreational sports such as dancing (143).

WHAT ARE THE BENEFITS OF NEUROMOTOR EXERCISE TRAINING?

Neuromotor exercise training, sometimes called functional fitness training, incorporates motor skills such as balance, coordination, gait, and agility, and proprioceptive training. Multifaceted physical activities such as tai ji (tai chi), qigong, and yoga involve varying combinations of neuromotor exercise, resistance exercise, and flexibility exercise. Neuromotor exercise training is beneficial as part of a comprehensive exercise program for older persons, especially to improve balance, agility, muscle strength, and reduce the risk of falls (38,181,194,224,264,350,369). Tai ji, the most widely studied neuromotor activity, and exercises incorporating balance and agility can be effective in improving balance, agility, motor control, proprioception, and quality of life (69,74,131, 132,181,205,222,223,230,363,375,378). Agility and balance training may reduce the risk of falling and fear of falling (194,226,227) and probably reduce the number of falls, although more definitive evidence is needed to confirm this finding (153,227,228,230,236,264,404).

Few studies have evaluated the benefits of neuromotor exercise training in younger adults. The only English-language study of tai ji in middle-aged adults reported improvements in balance (363). Limited evidence suggests that exercises involving balance and agility may reduce anterior cruciate injury (165,350) and reduce recurrent ankle injury in men and women athletes (174). Definitive recommendations as to whether neuromotor exercise is beneficial in young and middle-aged adults cannot be made owing to a paucity of data, although there *may* be benefit, especially if participating in physical activities requiring agility, balance, and other motor skills. More data are needed in all age groups to elucidate the specific health-related changes resulting from such training and to determine the effectiveness of various exercise types and doses (i.e., frequency, duration, and intensity) and training programs.

What quality and quantity of neuromotor exercise are needed? The frequency and duration of neuromotor exercise training to accrue health and fitness benefits are uncertain because there is variability in the quality of available studies, the types, duration, and frequency of neuromotor exercise used; there is inconsistent length of the training programs, and no standardized outcome measures have been used (138,264,404). Further confounding the interpretation of the results, many studies have combined resistance, cardiorespiratory, and/or flexibility training with neuromotor exercise (138,404). Development of some degree of proficiency in activities, such as balance training and tai ji, may also be important with respect to achieving improvements in physical function and in outcomes such as falls (404). Studies that have resulted in improvements have mostly used training frequencies of $\geq$2–3 d·wk^{-1} with exercise sessions of $\geq$20–30 min in duration, for a total of $\geq$60 min of neuromotor exercise per week; however, more research is needed before any definitive recommendations can be made. There is no available evidence concerning the number of repetitions of exercises needed, the intensity of the exercise, or optimal methods for progression.

HOW DOES THE EXERCISE TRAINING RESPONSE VARY BETWEEN INDIVIDUALS?

The magnitude of effect of a particular training regimen can vary significantly among individuals, and there are some exercisers who may not respond as expected (49,330). Multiple factors are associated with variation in training effects across individuals, including the characteristics of the training regimen, environmental conditions, and numerous individual factors, such as habitual physical activity, fitness level, physiological and genetic variability, and social and psychological factors (12,33,197,239,298). Age and sex seemingly have little influence on the variability of response to exercise training (49,134,393), but this is not universally reported (104,220).

HOW MUCH EXERCISE IS NEEDED TO MAINTAIN THE BENEFICIAL EFFECTS OF EXERCISE TRAINING?

When physical conditioning is stopped or reduced, training-induced cardiorespiratory, metabolic, musculoskeletal, and neuromotor adaptations are reversed to varying degrees over time (63,135,349,358,379,380,381). The level of fitness, age, length of time in training, habitual physical activity, the muscle groups involved, and genetic factors add to this variability (49,154,393).

Because individuals may not always be able to adhere to their exercise regimens, an important question remains, ''Once enhanced fitness has been achieved, does an individual have to train at the same exercise volume to maintain these adaptations?'' It seems that if an occasional exercise session is missed, or if the training volume becomes reduced, $\dot{V}O_{2max}$ will not be adversely affected. A series of studies in trained athletes (88,166–168,240,309) found that decreasing the volume, frequency, and/or or intensity of exercise training had little or only modest influence on $\dot{V}O_{2max}$ over periods of several months. Even so, many physiological changes occur as soon as 1–2 wk after cessation of exercise training, whereas continuing to exercise at reduced volume may attenuate these changes (44,191, 332,377). Unfavorable alterations in HR variability, endothelial function, blood lipoproteins, glucose tolerance, insulin sensitivity, body composition, and inflammatory markers such as interleukin 6 have been reported after cessation of exercise training (332,358,377,379,380,381,393). A study of more than 6000 runners followed for 7.4 yr (393) determined that the magnitude of increase in abdominal adiposity associated with a reduction in training depended on the magnitude of the reduction in training volume in a dose-dependent manner. Although these results cannot be completely generalized for everyone, they do suggest that more exercise is required to *improve* cardiorespiratory fitness and cardiometabolic health than is required to *maintain* these improvements.

Resistance training–induced improvements in muscle strength and power reverse quickly with complete cessation of exercise, although neuromuscular and functional changes seem to be maintained for a longer period (63,112,113,162, 191). Muscular strength, functional performance, and metabolic health indicators may be maintained by as little as a single session per week of moderate- to hard-intensity exercise (112,113,365,393). Intensity seems to be an important component of maintaining the effects of resistance training (112).

Improvements in joint range of motion reverse within 4–8 wk on cessation of stretching exercise, although there are variable responses among muscle–tendon groups (115,145,146,200,394). There is a paucity of data on the effects of reducing the frequency or duration of stretching exercise, although a recent report showed that individuals who reduced participation in stretching exercise from daily to 2–3 $d \cdot wk^{-1}$ maintained joint range of motion (297). Data on the reversibility of the effects of neuromotor exercise are likewise limited.

Another important question relevant to the maintenance of the training effect is, ''Can training effects be attained by training other limbs?'' After endurance training of one limb or a set of limbs, most of the improvements in cardiorespiratory fitness occur in the trained limbs, with small improvements elicited in untrained limbs (i.e., specificity of training) (34,290,348). Arm training has little effect on the deterioration in metabolic response to leg exercise, which occurs with cessation of leg training (34,279,290). However, a cross-education or cross-training effect can occur in an untrained ipsilateral (opposite) limb after resistance training of the opposite limb and in the arms with leg training (and vice versa) (3,174,175,219,258,259). The cross-education effect results from adaptations in neuromotor control rather than skeletal muscle adaptations (62,218). A meta-analysis by Munn et al. (258) reported modest improvements in strength (~8%) in the untrained contralateral limb, a level that was approximately 25% of the strength improvement in the trained limb (62). The cross-education effects of training one limb are seemingly greater when the dominant limb is trained (and the effects transferred to the nondominant limb) rather than vice versa (111). There are no available data on the health benefits of contralateral exercise training.

HOW CAN BEHAVIOR BE IMPROVED TO ENHANCE EXERCISE ADOPTION AND ADHERENCE?

Despite the benefits of exercise, a large proportion of adults fail to achieve the recommended levels of physical activity (69,148,149). Exemplifying the problem, walking is the most popular physical activity identified by adults (329), but fewer than 7% of those whose primary exercise is walking are doing so with the frequency, duration, and intensity to meet contemporary physical activity recommendations (296). Numerous nonmodifiable sociodemographic and neighborhood environmental characteristics are associated with exercise behavior (307), but in this Position Stand, the focus is on *modifiable* factors associated with individual exercise behavior. The role of individual choice, preference, and enjoyment is emphasized in the exercise prescription, particularly because individuals can achieve current recommendations in many ways (391).

How do exercise intensity, mode, duration, and frequency influence exercise behavior? Public health efforts promoting moderate-intensity exercise after the release of the CDC/ACSM statement (280), and US Surgeon General's report (371) were initiated because of the belief that the promotion of moderate-intensity exercise would lead to greater adoption and adherence to exercise (273), but widespread adoption of moderate-intensity activity in the population has not yet occurred (70). A meta-analysis by Rhodes et al. (307) reported that factors related to the exercise prescription, including duration, frequency, intensity, and volume, have little or very small effects on exercise adherence. However, there is other evidence suggesting that individuals are somewhat more likely to adhere to moderate-intensity compared with vigorous-intensity exercise (91,190, 197,307,314). This effect may be moderated by previous exercise behavior so that individuals with previous exercise experience may respond more favorably to vigorous exercise, whereas habitually inactive people adopting exercise may be better suited to—and self-select—moderate-intensity exercise (17,35,107,319). Nonetheless, it is *reasonable* to prescribe moderate-intensity activity to enhance adoption and adherence, particularly in novice exercisers.

How do exercise mode and program format affect exercise behavior? Mode of exercise (i.e., aerobic vs resistance exercise, walking vs running) has no or very minimal effect on adherence to exercise (307). Supervision by an experienced exercise leader can, on the other hand, enhance adherence (87,319). Structured, supervised programs and unsupervised, home-based programs can increase exercise behavior, and there seems to be no differences in adherence to home-based and traditional exercise programs (86,100,307), although some studies have found an advantage for home-based exercise (91,131,183). Community-based interventions and those incorporating program components such as brief advice, the use of pedometers, telecommunications, and group support effectively increase walking duration by 30–60 min in previously inactive persons (51,272). Unfortunately, few data exist on the long-term effects of such interventions (30). Even if the long-term adherence between structured, supervised programs and home-based exercise programs is similar, cost-effectiveness analyses support the promotion of home-based programs (317,321).

There have been few systematic studies about who adopts and maintains resistance training programs (73,84,91, 246,319) or flexibility or neuromotor exercise (119), so it is difficult to make specific recommendations about how to enhance adoption and maintenance of these modes of exercise. Limited evidence suggests that enhancing desires for strength and feelings of empowerment, previous exercise experience, and supervision by an experienced instructor may increase adoption and adherence of resistance training among older adults (304,319).

How do affective responses to exercise influence exercise behavior? Individuals are often advised to select an activity they enjoy for exercise because of an inherent belief that persons are more likely to adopt and maintain a behavior they enjoy (382). Limited evidence suggests that pleasant affective responses to exercise (i.e., how enjoyable or pleasant is the exercise) may enhance future exercise behavior and vice versa (50,198,206, 239,391). More negative affect is reported when exercising above the ventilatory threshold (17,108,278). Thus, prescribing exercise at an intensity below the ventilatory threshold may enhance affective responses to exercise (225) and improve exercise adherence and/or maintenance. Exercise environments with engaging distractions (e.g., music, an instructor, television, scenery) may also ameliorate affective experiences (and adherence), but additional confirmation is needed (16,245).

What types of individual interventions are effective in improving exercise adoption and maintenance and reducing sedentary behavior? Although trials of physical activity counseling by physicians have demonstrated equivocal effectiveness, leading the US Preventive Services Task Force to conclude, ''the evidence is insufficient to recommend for or against behavioral counseling in primary care settings to promote physical activity'' (105). Other medical and voluntary health associations have adopted the position that health providers should make physical activity counseling a part of routine patient visits because of the extensive benefits of physical activity (180). However, there is evidence that brief counseling by health care professionals can increase exercise adoption when it incorporates established counseling strategies and techniques from individual behavioral programs described below (2,140,180,286,403).

Several scientific reviews have shown that individualized, tailored behavioral programs can enhance the adoption and short-term adherence to exercise (169,190,239). Exercise programs conducted in diverse populations in a variety of settings have been effective in promoting short-term increases in physical activity when they are based on health behavior theoretical constructs (23), are individually tailored (239), and use behavioral strategies such as goal setting, social support, reinforcement, problem solving, and relapse prevention (190). Individually tailored interventions delivered using various modalities including print (43), telephone, Internet/computer (374), and group counseling (303) can be effective in enhancing exercise adoption but are at best marginally effective for increasing exercise maintenance. Despite the well-documented problems with long-term adherence and exercise dropout (98), few data exist regarding the factors associated with maintaining exercise behavior (238,257). Successful interventions to improve exercise maintenance have incorporated continued contact and social support (68) and access to home exercise equipment (182). Dual interventions in children and adolescents targeting sedentary behavior *and* physical activity have been effective in reducing sedentary behavior and increasing physical activity (109). There is a dearth of interventions targeting sedentary behavior in adults, but the work in children supports the possibility of successfully intervening in adults. Further research on exercise maintenance and the development of behavioral theory is needed to understand not only how to assist individuals in initiating exercise, reducing sedentary behavior, but also how people can *maintain* that activity over their lifetime (238,276,321).

WHAT ARE RISKS ASSOCIATED WITH EXERCISE AND HOW CAN THEY BE REDUCED?

Although regular exercise helps to protect against and treat aging-related chronic diseases, the risk of CHD and musculoskeletal complications increase transiently during strenuous physical activity compared with the risk at other times (362). Musculoskeletal injury is the most common exercise-related complication (7,8,171,172,192). Overweight and obese adults have engaged in greater volumes of exercise than those recommended here without adverse sequelae, suggesting that this level of activity can be sustained safely (99,129).

The type and intensity of the exercise seem to be more important factors in the incidence of injury, with the volume of exercise performed apparently of lesser importance (7,8,171,172,186,393). Walking and moderate-intensity physical activities are associated with a very low risk of musculoskeletal complications (61,82,171,291), whereas jogging, running, and competitive sports are associated with increased risk of injury (79,116,172,243). Sports-related mortality among adult athletes reflects the popular sporting events engaged in by a population (170,334). For example, in countries where soccer is popular, deaths during that sport are more common. Unaccustomed exercise demands, especially during the initial weeks of a physical conditioning regimen, often result in muscle soreness, musculoskeletal injury, and attrition (12). Rhabdomyolisis associated with exercise is an uncommon, but serious, disorder resulting from damage to the skeletal muscle that can cause acute kidney failure, cardiac arrhythmias, and even death (78). The risk of rhabdomyolisis is increased in both experienced and novice exercisers who undertake *unaccustomed* eccentric exercise, particularly under hot ambient conditions (78).

Commonly used methods to reduce musculoskeletal injury and complications, such as the warm-up and cool-down, stretching, and gradual progression of volume and intensity, seem to be helpful at least under some circumstances, but controlled studies substantiating the effectiveness of these methods are insufficient (9,123,124,164,248,355).

Acute myocardial infarction and sudden cardiac death can be triggered by *unaccustomed vigorous* physical exertion, particularly in sedentary men and women with subclinical or known CHD, and when concomitant chronic diseases and medical conditions and/or superimposed environmental stressors are involved (362). However, this risk decreases with increasing volumes of *regular* exercise (362). Running, racquet sports, and strenuous sports activity seem to be associated with a greater incidence of CVD events than other activities (362).

Population studies have shown that forewarning signs or symptoms often precede exercise-related CHD events, but individuals and their health care providers may ignore or inadequately evaluate these, especially in habitually active persons (362). Careful evaluation of exercisers for warning signs and symptoms, and informing both novice and regular exercisers about common signs and symptoms of CHD disease and how to respond to them may reduce the risk of untoward CHD events (362).

Using a well-designed health assessment or medical history questionnaire (e.g., Physical Activity Readiness Questionnaire (PAR-Q)) to identify conditions, signs, symptoms, and risk factors that are associated with an increased risk of CVD events during and after exercise may be useful and effective (60,325,356). Additional evidence for this approach comes from the Behavior Change Consortium (275), which reported on screening procedures and complications from 11 physical activity interventions in more than 5500 middle-aged and older persons. The studies used minimal (e.g., health questionnaires such as the PAR-Q, measurement of blood pressure and pulse) or more extensive screening (e.g., medical examination) procedures, but no study reported a serious CHD event, suggesting that the former can be highly effective. Few data support the role of routine diagnostic exercise testing as an effective method for reducing the risk of exercise-related CHD events (122,137,211,362). Consultation with a medical professional and diagnostic exercise testing should be performed as medically indicated based on signs and symptoms of disease and according to clinical practice guidelines (20,122,136,241).

There are no randomized studies demonstrating the effectiveness of supervision by a well-trained fitness professional in reducing the risks of exercise, but the low risk of exercise-related complications in medically supervised exercise programs (14,359) supports the likelihood of benefit, particularly for novice exercisers who are at an elevated risk for exercise-related complications.

CONCLUSIONS

The ACSM recommends a comprehensive program of exercise including cardiorespiratory, resistance, flexibility, and neuromotor exercise of sufficient volume and quality as outlined in this document for apparently healthy adults of all ages. Reducing total time spent in sedentary pursuits and interspersing short bouts of physical activity and standing between periods of sedentary activity should be a goal for all adults, irrespective of their exercise habits. Exercise performed in this manner improves physical and mental health and/or fitness in most persons. However, a program of exercise that does not include all exercise components or achieves less than the recommended volumes (intensity, duration, and frequency) of exercise is likely to have benefit, particularly in habitually inactive persons. The exercise prescription is best adjusted according to individual responses because of the considerable individual variability in the response to a program of exercise. Exercise is beneficial only if a person engages in it. To this end, focusing on individual preferences and enjoyment and incorporating health behavior theory and behavior change strategies into exercise counseling and programs can enhance adoption and short-term maintenance of regular exercise, and these form an essential component of exercise counseling and programs. Effective strategies to reduce the musculoskeletal and CVD risks of exercise include screening for and educating about prodromal signs and symptoms of cardiovascular disease in novice and habitual exercisers, consultation with a health professional and diagnostic exercise testing as medically indicated, and attention to several elements of the exercise prescription including warming up, cooling down, a gradual progression of exercise volume and intensity, and proper training technique. The supervision of an experienced fitness professional can enhance adherence to exercise and likely reduces the risk of exercise in those with elevated risk of adverse CHD events. Adults, especially novice exercisers and persons with health conditions or disabilities, likely can benefit from consultation with a well-trained fitness professional.

The authors have no conflict of interest.

The authors base this revision on the painstaking efforts of members of the writing groups for the 1978, 1990, and 1998 versions of this Position Stand, who summarized in a clear and concise manner the latest scientific research with specific reference to application. The authors especially recognize the legacy of Dr. Michael L. Pollock, the chair of each of these writing groups, who initiated this Position Stand series, and whose pioneering research laid the foundation for the science of exercise prescription as it exists today. The authors thank Jay Cameron and Sarah Black for their valuable assistance in reference database development.

This pronouncement was reviewed by the American College of Sports Medicine Pronouncements Committee and by Kelly R. Evenson, Ph.D., FACSM; William L. Haskell, Ph.D., FACSM; Robert S. Staron, Ph.D.; and Walter R. Thompson, Ph.D., FACSM.

This Position Stand replaces the 1998 ACSM Position Stand "The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults," *Med Sci Sports Exerc*. 1998;30(6):975–91.

REFERENCES

1. Abe T, DeHoyos DV, Pollock ML, Garzarella L. Time course for strength and muscle thickness changes following upper and lower body resistance training in men and women. *Eur J Appl Physiol*. 2000;81(3):174–80.
2. Ackermann RT, Deyo RA, LoGerfo JP. Prompting primary providers to increase community exercise referrals for older adults: a randomized trial. *J Am Geriatr Soc*. 2005;53(2):283–9.
3. Adamson M, Macquaide N, Helgerud J, Hoff J, Kemi OJ. Unilateral arm strength training improves contralateral peak force and rate of force development. *Eur J Appl Physiol*. 2008;103(5):553–9.
4. Ainsworth BE, Haskell WL, Leon AS, et al. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc*. 1993;25(1):71–80.
5. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32(Suppl 9):S498–516.
6. Albright A, Franz M, Hornsby G, et al. American College of Sports Medicine. Position Stand: exercise and type 2 diabetes. *Med Sci Sports Exerc*. 2000;32(7):1345–60.
7. Almeida SA, Trone DW, Leone DM, Shaffer RA, Patheal SL, Long K. Gender differences in musculoskeletal injury rates: a function of symptom reporting? *Med Sci Sports Exerc*. 1999; 31(12):1807–12.
8. Almeida SA, Williams KM, Shaffer RA, Brodine SK. Epidemiological patterns of musculoskeletal injuries and physical training. *Med Sci Sports Exerc*. 1999;31(8):1176–82.
9. Amako M, Oda T, Masuoka K, Yokoi H, Campisi P. Effect of static stretching on prevention of injuries for military recruits. *Mil Med*. 2003;168(6):442–6.
10. American College of Sports Medicine. *Guidelines for Graded Exercise Testing and Exercise Prescription*. 1st ed. Philadelphia (PA): Lea and Febiger; 1975. p. 1–99.
11. American College of Sports Medicine. Position statement on the recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults. *Med Sci Sports Exerc*. 1978;10(3):vii–x.
12. American College of Sports Medicine. Position Stand: the recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med Sci Sports Exerc*. 1998;30(6):975–91.
13. American College of Sports Medicine. Position Stand: progression models in resistance training for healthy adults. *Med Sci Sports Exerc*. 2009;41(3):687–708.
14. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*. 8th ed. Philadelphia (PA): Lippincott Williams & Wilkins; 2010. p. 366.
15. American Geriatrics Society Panel on Exercise and Osteoarthritis. Exercise prescription for older adults with osteoarthritis pain: consensus practice recommendations. A supplement to the AGS Clinical Practice Guidelines on the management of chronic pain in older adults. *J Am Geriatr Soc*. 2001;49(6):808–23.
16. Annesi JJ. Effects of music, television, and a combination entertainment system on distraction, exercise adherence, and physical output in adults. *Can J Behav Sci*. 2001;33(3):193–202.
17. Anton SD, Perri MG, Riley J III, et al. Differential predictors of adherence in exercise programs with moderate versus higher levels of intensity and frequency. *J Sport Exerc Psychol*. 2005; 27:171–87.
18. Asikainen TM, Miilunpalo S, Oja P, et al. Randomised, controlled walking trials in postmenopausal women: the minimum dose to improve aerobic fitness? *Br J Sports Med*. 2002;36(3): 189–94.
19. Asikainen TM, Miilunpalo S, Kukkonen-Harjula K, et al. Walking trials in postmenopausal women: effect of low doses of exercise and exercise fractionization on coronary risk factors. *Scand J Med Sci Sports*. 2003;13(5):284–92.
20. Balady GJ, Arena R, Sietsema K, et al. Clinician's guide to cardiopulmonary exercise testing in adults: a scientific statement from the American Heart Association. *Circulation*. 2010;122(2): 191–225.
21. Bandy WD, Irion JM, Briggler M. The effect of time and frequency of static stretching on flexibility of the hamstring muscles. *Phys Ther*. 1997;77(10):1090–6.
22. Bandy WD, Irion JM, Briggler M. The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. *J Orthop Sports Phys Ther*. 1998;27(4):295–300.
23. Baranowski T, Anderson C, Carmack C. Mediating variable framework in physical activity interventions. How are we doing? How might we do better? [erratum appears in *Am J Prev Med* 1999;17(1):98]. *Am J Prev Med*. 1998;15(4):266–97.

24. Barlow CE, LaMonte MJ, Fitzgerald SJ, Kampert JB, Perrin JL, Blair SN. Cardiorespiratory fitness is an independent predictor of hypertension incidence among initially normotensive healthy women. *Am J Epidemiol*. 2006;163(2):142–50.
25. Bartholomew JB, Morrison D, Ciccolo JT. Effects of acute exercise on mood and well-being in patients with major depressive disorder. *Med Sci Sports Exerc*. 2005;37(12):2032–7.
26. Bassett DR Jr, Ainsworth BE, Swartz AM, Strath SJ, O'Brien WL, King GA. Validity of four motion sensors in measuring moderate intensity physical activity. *Med Sci Sports Exerc*. 2000; 32(Suppl 9):S471–80.
27. Bassett DR Jr, Wyatt HR, Thompson H, Peters JC, Hill JO. Pedometer-measured physical activity and health behaviors in U.S. adults. *Med Sci Sports Exerc*. 2010;42(10):1819–25.
28. Beauchamp MK, Nonoyama M, Goldstein RS, et al. Interval versus continuous training in individuals with chronic obstructive pulmonary disease—a systematic review. *Thorax*. 2010;65(2):157–64.
29. Beedle BB, Leydig SN, Carnucci JM. No difference in pre- and postexercise stretching on flexibility. *J Strength Cond Res*. 2007; 21(3):780–3.
30. Bell GJ, Harber V, Murray T, Courneya KS, Rodgers W. A comparison of fitness training to a pedometer-based walking program matched for total energy cost. *J Phys Act Health*. 2010; 7(2):203–13.
31. Bemben DA, Bemben MG. Dose–response effect of 40 weeks of resistance training on bone mineral density in older adults. *Osteoporos Int*. [Epub ahead of print]. 2010 [cited 2010 Feb 27]. Available from: http://www.springerlink.com/content/q3211614g6n205x1/.
32. Bennett GG, Wolin KY, Puleo EM, Masse LC, Atienza AA. Awareness of National Physical Activity Recommendations for Health Promotion among US adults. *Med Sci Sports Exerc*. 2009;41(10):1849–55.
33. Bergeron J, Couillard C, Despres JP, et al. Race differences in the response of postheparin plasma lipoprotein lipase and hepatic lipase activities to endurance exercise training in men: results from the HERITAGE Family Study. *Atherosclerosis*. 2001; 159(2):399–406.
34. Bhambhani YN, Eriksson P, Gomes PS. Transfer effects of endurance training with the arms and legs. *Med Sci Sports Exerc*. 1991;23(9):1035–41.
35. Bibeau WS, Moore JB, Mitchell NG, Vargas-Tonsing T, Bartholomew JB. Effects of acute resistance training of different intensities and rest periods on anxiety and affect. *J Strength Cond Res*. 2010;24(8):2184–91.
36. Bickel CS, Slade J, Mahoney E, Haddad F, Dudley GA, Adams GR. Time course of molecular responses of human skeletal muscle to acute bouts of resistance exercise. *J Appl Physiol*. 2005;98(2):482–8.
37. Bigaard J, Frederiksen K, Tjonneland A, et al. Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. *Int J Obes*. 2005;29(7):778–84.
38. Bird M, Hill KD, Ball M, Hetherington S, Williams AD. The long-term benefits of a multi-component exercise intervention to balance and mobility in healthy older adults. *Arch Gerontol Geriatr*. [Epub ahead of print]. 2010 [cited 2010 Apr 21]. Available from: http://dx.doi.org/10.1016/j.archger.2010.03.021.
39. Bischoff HA, Roos EM. Effectiveness and safety of strengthening, aerobic, and coordination exercises for patients with osteoarthritis. *Curr Opin Rheumatol*. 2003;15(2):141–4.
40. Blair SN, Connelly JC. How much physical activity should we do? The case for moderate amounts and intensities of physical activity. *Res Q Exerc Sport*. 1996;67(2):193–205.
41. Blair SN, Kohl HW 3rd, Barlow CE, Paffenbarger RS Jr, Gibbons LW, Macera CA. Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. *JAMA*. 1995;273(14):1093–8.
42. Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitness more important in defining health benefits? *Med Sci Sports Exerc*. 2001;33(Suppl 6):S379–99.
43. Blissmer B, McAuley E. Testing the requirements of stages of physical activity among adults: the comparative effectiveness of stage-matched, mismatched, standard care, and control interventions. *Ann Behav Med*. 2002;24(3):181–9.
44. Bocalini DS, Carvalho EV, de Sousa AF, Levy RF, Tucci PJ. Exercise training–induced enhancement in myocardial mechanics is lost after 2 weeks of detraining in rats. *Eur J Appl Physiol*. 2010;109(5):909–14.
45. Bonnar BP, Deivert RG, Gould TE. The relationship between isometric contraction durations during hold–relax stretching and improvement of hamstring flexibility. *J Sports Med Phys Fitness*. 2004;44(3):258–61.
46. Bonnefoy M, Jauffret M, Jusot JF. Muscle power of lower extremities in relation to functional ability and nutritional status in very elderly people. *J Nutr Health Aging*. 2007;11(3):223–8.
47. Booth FW, Gordon SE, Carlson CJ, Hamilton MT. Waging war on modern chronic diseases: primary prevention through exercise biology. *J Appl Physiol*. 2000;88(2):774–87.
48. Borg GA. Perceived exertion. *Exerc Sport Sci Rev*. 1974;2: 131–53.
49. Bouchard C, Rankinen T. Individual differences in response to regular physical activity. *Med Sci Sports Exerc*. 2001;33(Suppl 6): S446–51.
50. Boutelle K, Jeffery R, French S. Predictors of vigorous exercise adoption and maintenance over four years in a community sample. *Int J Behav Nutr Phys Act*. 2004;1(1):13.
51. Bravata DM, Smith-Spangler C, Sundaram V, et al. Using pedometers to increase physical activity and improve health: a systematic review. *JAMA*. 2007;298(19):2296–304.
52. Brawner CA, Keteyian SJ, Ehrman JK. The relationship of heart rate reserve to $\dot{V}O_2$ reserve in patients with heart disease. *Med Sci Sports Exerc*. 2002;34(3):418–22.
53. Brawner CA, Vanzant MA, Ehrman JK, et al. Guiding exercise using the talk test among patients with coronary artery disease. *J Cardiopulm Rehabil*. 2006;26(2):72–5.
54. Brill PA, Macera CA, Davis DR, Blair SN, Gordon N. Muscular strength and physical function. *Med Sci Sports Exerc*. 2000; 32(2):412–6.
55. Brooks N, Layne JE, Gordon PL, Roubenoff R, Nelson ME, Castaneda-Sceppa C. Strength training improves muscle quality and insulin sensitivity in Hispanic older adults with type 2 diabetes. *Int J Med Sci*. 2007;4(1):19–27.
56. Butcher LR, Thomas A, Backx K, Roberts A, Webb R, Morris K. Low-intensity exercise exerts beneficial effects on plasma lipids via PPARγ. *Med Sci Sports Exerc*. 2008;40(7):1263–70.
57. Byrne NM, Hills AP. Relationships between HR and $\dot{V}O_2$ in the obese. *Med Sci Sports Exerc*. 2002;34(9):1419–27.
58. Byrne NM, Hills AP, Hunter GR, Weinsier RL, Schutz Y. Metabolic equivalent: one size does not fit all. *J Appl Physiol*. 2005; 99(3):1112–9.
59. Campos GE, Luecke TJ, Wendeln HK, et al. Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. *Eur J Appl Physiol*. 2002;88(1–2):50–60.
60. Cardinal BJ, Esters J, Cardinal MK. Evaluation of the revised physical activity readiness questionnaire in older adults. *Med Sci Sports Exerc*. 1996;28(4):468–72.
61. Carroll JF, Pollock ML, Graves JE, Leggett SH, Spitler DL, Lowenthal DT. Incidence of injury during moderate- and high-intensity walking training in the elderly. *J Gerontol*. 1992;47(3): M61–6.
62. Carroll TJ, Herbert RD, Munn J, Lee M, Gandevia SC. Contralateral effects of unilateral strength training: evidence and possible mechanisms. *J Appl Physiol*. 2006;101(5):1514–22.

63. Carvalho MJ, Marques E, Mota J. Training and detraining effects on functional fitness after a multicomponent training in older women. *Gerontology*. 2009;55(1):41–8.
64. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep*. 1985;100(2):126–31.
65. Cassilhas RC, Antunes HK, Tufik S, de Mello MT. Mood, anxiety, and serum IGF-1 in elderly men given 24 weeks of high resistance exercise. *Percept Mot Skills*. 2010;110(1):265–76.
66. Castaneda C, Layne JE, Munoz-Orians L, et al. A randomized controlled trial of resistance exercise training to improve glycemic control in older adults with type 2 diabetes. *Diabetes Care*. 2002;25(12):2335–41.
67. Castaneda F, Layne JE, Castaneda C. Skeletal muscle sodium glucose co-transporters in older adults with type 2 diabetes undergoing resistance training. *Int J Med Sci*. 2006;3(3):84–91.
68. Castro CM, King AC, Brassington GS. Telephone versus mail interventions for maintenance of physical activity in older adults. *Health Psychol*. 2001;20(6):438–44.
69. Centers for Disease Control and Prevention. Prevalence of self-reported physically active adults—United States, 2007. *MMWR Morb Mortal Wkly Rep*. 2008;57(48):1297–300.
70. Centers for Disease Control and Prevention. Trends in leisure-time physical inactivity by age, sex, and race/ethnicity—United States, 1994–2004. *MMWR Morb Mortal Wkly Rep*. 2005;54(39): 991–4.
71. Chan BK, Marshall LM, Winters KM, Faulkner KA, Schwartz AV, Orwoll ES. Incident fall risk and physical activity and physical performance among older men: the Osteoporotic Fractures in Men Study. *Am J Epidemiol*. 2007;165(6):696–703.
72. Chen MJ, Fan X, Moe ST. Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *J Sports Sci*. 2002;20(11):873–99.
73. Chevan J. Demographic determinants of participation in strength training activities among U.S. adults. *J Strength Cond Res*. 2008; 22(2):553–8.
74. Chin APMJ, van Uffelen JG, Riphagen I, van Mechelen W. The functional effects of physical exercise training in frail older people: a systematic review. *Sports Med*. 2008;38(9): 781–93.
75. Church TS, LaMonte MJ, Barlow CE, Blair SN. Cardiorespiratory fitness and body mass index as predictors of cardiovascular disease mortality among men with diabetes. *Arch Intern Med*. 2005;165(18):2114–20.
76. Church TS, Earnest CP, Skinner JS, Blair SN. Effects of different doses of physical activity on cardiorespiratory fitness among sedentary, overweight or obese postmenopausal women with elevated blood pressure: a randomized controlled trial. *JAMA*. 2007; 297(19):2081–91.
77. Ciolac EG, Bocchi EA, Bortolotto LA, Carvalho VO, Greve JM, Guimaraes GV. Effects of high-intensity aerobic interval training vs. moderate exercise on hemodynamic, metabolic and neuro-humoral abnormalities of young normotensive women at high familial risk for hypertension. *Hypertens Res*. 2010;33(8): 836–43.
78. Clarkson PM. Exertional rhabdomyolysis and acute renal failure in marathon runners. *Sports Med*. 2007;37(4–5):361–3.
79. Colbert LH, Hootman JM, Macera CA. Physical activity–related injuries in walkers and runners in the aerobics center longitudinal study. *Clin J Sport Med*. 2000;10(4):259–63.
80. Collier S, Kanaley J, Carhart R Jr, et al. Cardiac autonomic function and baroreflex changes following 4 weeks of resistance versus aerobic training in individuals with pre hypertension. *Acta Physiol (Oxf)*. 2009;195(3):339–48.
81. Conn VS, Hafdahl AR, Brown LM. Meta-analysis of quality-of-life outcomes from physical activity interventions. *Nurs Res*. 2009;58(3):175–83.
82. Cononie CC, Graves JE, Pollock ML, Phillips MI, Sumners C, Hagberg JM. Effect of exercise training on blood pressure in 70- to 79-yr-old men and women. *Med Sci Sports Exerc*. 1991; 23(4):505–11.
83. Costa PB, Graves BS, Whitehurst M, Jacobs PL. The acute effects of different durations of static stretching on dynamic balance performance. *J Strength Cond Res*. 2009;23(1):141–7.
84. Courneya KS, Segal RJ, Reid RD, et al. Three independent factors predicted adherence in a randomized controlled trial of resistance exercise training among prostate cancer survivors. *J Clin Epidemiol*. 2004;57(6):571–9.
85. Covert CA, Alexander MP, Petronis JJ, Davis DS. Comparison of ballistic and static stretching on hamstring muscle length using an equal stretching dose. *J Strength Cond Res*. 2010;24(11): 3008–14.
86. Cox KL, Burke V, Gorely TJ, Beilin LJ, Puddey IB. Controlled comparison of retention and adherence in home- vs center-initiated exercise interventions in women ages 40–65 years: the S.W.E.A.T. study (Sedentary Women Exercise Adherence Trial). *Prev Med*. 2003;36(1):17–29.
87. Cox KL, Burke V, Beilin LJ, et al. Short and long-term adherence to swimming and walking programs in older women—the Sedentary Women Exercise Adherence Trial (SWEAT 2). *Prev Med*. 2008;46(6):511–7.
88. Coyle EF, Martin WH 3rd, Sinacore DR, Joyner MJ, Hagberg JM, Holloszy JO. Time course of loss of adaptations after stopping prolonged intense endurance training. *J Appl Physiol*. 1984; 57(6):1857–64.
89. Croft L, Bartlett JD, MacLaren DP, et al. High-intensity interval training attenuates the exercise-induced increase in plasma IL-6 in response to acute exercise. *Appl Physiol Nutr Metab*. 2009; 34(6):1098–107.
90. Cunha FA, Midgley AW, Monteiro WD, Farinatti PT. Influence of cardiopulmonary exercise testing protocol and resting $\dot{V}O(2)$ assessment on %HR(max), %HRR, %$\dot{V}O(2max)$ and %VO(2)R relationships. *Int J Sports Med*. 2010;31(5):319–26.
91. Cyarto EV, Brown WJ, Marshall AL. Retention, adherence and compliance: important considerations for home- and group-based resistance training programs for older adults. *J Sci Med Sport*. 2006;9(5):402–12.
92. de Koning L, Merchant AT, Pogue J, Anand SS. Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. *Eur Heart J*. 2007;28(7):850–6.
93. de Vos NJ, Singh NA, Ross DA, Stavrinos TM, Orr R, Fiatarone Singh MA. Optimal load for increasing muscle power during explosive resistance training in older adults. *J Gerontol A Biol Sci Med Sci*. 2005;60(5):638–47.
94. de Weijer VC, Gorniak GC, Shamus E. The effect of static stretch and warm-up exercise on hamstring length over the course of 24 hours. *J Orthop Sports Phys Ther*. 2003;33(12):727–33.
95. Decoster LC, Cleland J, Altieri C, Russell P. The effects of hamstring stretching on range of motion: a systematic literature review. *J Orthop Sports Phys Ther*. 2005;35(6):377–87.
96. Despres JP. Cardiovascular disease under the influence of excess visceral fat. *Crit Pathw Cardiol*. 2007;6(2):51–9.
97. DiPietro L, Dziura J, Yeckel CW, Neufer PD. Exercise and improved insulin sensitivity in older women: evidence of the enduring benefits of higher intensity training. *J Appl Physiol*. 2006; 100(1):142–9.
98. Dishman RK, ed. *Exercise Adherence: Its Impact on Public Health*. Champaign (IL): Human Kinetics; 1988. p. 406.
99. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, Smith BK. American College of Sports Medicine. Position Stand: appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc*. 2009;41(2):459–71.

from the American Heart Association. *Circulation*. 2001;104(14): 1694–740.

100. Duncan GE, Anton SD, Sydeman SJ, et al. Prescribing exercise at varied levels of intensity and frequency: a randomized trial. *Arch Int Med*. 2005;165(20):2362–9.
101. Dunn AL, Trivedi MH, Kampert JB, Clark CG, Chambliss HO. Exercise treatment for depression: efficacy and dose response. *Am J Prev Med*. 2005;28(1):1–8.
102. Durstine JL, Grandjean PW, Davis PG, Ferguson MA, Alderson NL, DuBose KD. Blood lipid and lipoprotein adaptations to exercise: a quantitative analysis. *Sports Med*. 2001;31(15):1033–62.
103. Durstine JL, Grandjean PW, Cox CA, Thompson PD. Lipids, lipoproteins, and exercise. *J Cardiopulm Rehabil*. 2002;22(6): 385–98.
104. Earnest CP, Blair SN, Church TS. Age attenuated response to aerobic conditioning in postmenopausal women. *Eur J Appl Physiol*. 2010;110(1):75–82.
105. Eden KB, Orleans T, Mulrow CD, Pender NJ, Teutsch SM. Clinician Counseling to Promote Physical Activity Systematic Evidence Reviews, No. 9. [Internet]. 2002. Rockville (MD): Agency for Healthcare Research and Quality (US). [Accessed 2011 Feb]. Available from: http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=es9.
106. Ekkekakis P, Hall EE, Petruzzello SJ. Practical markers of the transition from aerobic to anaerobic metabolism during exercise: rationale and a case for affect-based exercise prescription. *Prev Med*. 2004;38(2):149–59.
107. Ekkekakis P, Hall EE, Petruzzello SJ. Some like it vigorous: individual differences in the preference for and tolerance of exercise intensity. *J Sport Exerc Psychol*. 2005;27(3):350–74.
108. Ekkekakis P, Hall EE, Petruzzello SJ. The relationship between exercise intensity and affective responses demystified: to crack the 40-year-old nut, replace the 40-year-old nutcracker! *Ann Behav Med*. 2008;35(2):136–49.
109. Epstein LH, Roemmich JN. Reducing sedentary behavior: role in modifying physical activity. *Exerc Sport Sci Rev*. 2001;29(3): 103–8.
110. Evans WJ. Exercise training guidelines for the elderly. *Med Sci Sports Exerc*. 1999;31(1):12–7.
111. Farthing JP, Chilibeck PD, Binsted G. Cross-education of arm muscular strength is unidirectional in right-handed individuals. *Med Sci Sports Exerc*. 2005;37(9):1594–600.
112. Fatouros IG, Kambas A, Katrabasas I, et al. Strength training and detraining effects on muscular strength, anaerobic power, and mobility of inactive older men are intensity dependent. *Br J Sports Med*. 2005;39(10):776–80.
113. Fatouros IG, Kambas A, Katrabasas I, et al. Resistance training and detraining effects on flexibility performance in the elderly are intensity-dependent. *J Strength Cond Res*. 2006;20(3):634–42.
114. Feland JB, Marin HN. Effect of submaximal contraction intensity in contract–relax proprioceptive neuromuscular facilitation stretching. *Br J Sports Med*. 2004;38(4):E18.
115. Feland JB, Myrer JW, Schulthies SS, Fellingham GW, Measom GW. The effect of duration of stretching of the hamstring muscle group for increasing range of motion in people aged 65 years or older. *Phys Ther*. 2001;81(5):1110–7.
116. Fields KB, Sykes JC, Walker KM, Jackson JC. Prevention of running injuries. *Curr Sports Med Rep*. 2010;9(3):176–82.
117. FitzGerald SJBC, Kampert JB, Morrow JR Jr, Jackson AW, Blair SN. Muscular fitness and all-cause mortality: a prospective study. *J Phys Act Health*. 2004;1:7–18.
118. Fleg JL, Morrell CH, Bos AG, et al. Accelerated longitudinal decline of aerobic capacity in healthy older adults. *Circulation*. 2005;112(5):674–82.
119. Flegal KE, Kishiyama S, Zajdel D, Haas M, Oken BS. Adherence to yoga and exercise interventions in a 6-month clinical trial. *BMC Complement Altern Med* [Internet]. 2007 [cited 2001 Nov 9];7(37). Available from: http://www.biomedcentral.com/1472-6882/7/37.
120. Fletcher GF, Balady GJ, Amsterdam EA, et al. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation*. 2001;104(14): 1694–740.
121. Foster C, Porcari JP, Anderson J, et al. The talk test as a marker of exercise training intensity. *J Cardiopulm Rehabil Prev*. 2008; 28(1):24–30.
122. Fowler-Brown A, Pignone M, Pletcher M, Tice JA, Sutton SF, Lohr KN. Exercise tolerance testing to screen for coronary heart disease: a systematic review for the technical support for the U.S. Preventive Services Task Force. *Ann Intern Med*. 2004; 140(7):W9–24.
123. Fradkin AJ, Gabbe BJ, Cameron PA. Does warming up prevent injury in sport? The evidence from randomised controlled trials. *J Sci Med Sport*. 2006;9(3):214–20.
124. Fradkin AJ, Zazryn TR, Smoliga JM. Effects of warming-up on physical performance: a systematic review with meta-analysis. *J Strength Cond Res*. 2010;24(1):140–8.
125. Fried LP, Bandeen-Roche K, Kasper JD, Guralnik JM. Association of comorbidity with disability in older women: the Women's Health and Aging Study. *J Clin Epidemiol*. 1999;52(1):27–37.
126. Fried LP, Bandeen-Roche K, Chaves PH, Johnson BA. Preclinical mobility disability predicts incident mobility disability in older women. *J Gerontol A Biol Sci Med Sci*. 2000;55(1):M43–52.
127. Gajdosik RL, Allred JD, Gabbert HL, Sonsteng BA. A stretching program increases the dynamic passive length and passive resistive properties of the calf muscle–tendon unit of unconditioned younger women. *Eur J Appl Physiol*. 2007;99(4):449–54.
128. Gale CR, Martyn CN, Cooper C, Sayer AA. Grip strength, body composition, and mortality. *Int J Epidemiol*. 2007;36(1):228–35.
129. Gallagher KI, Jakicic JM, Napolitano MA, Marcus BH. Psychosocial factors related to physical activity and weight loss in overweight women. *Med Sci Sports Exerc*. 2006;38(5):971–80.
130. Garber CE, Greaney ML, Riebe D, Nigg CR, Burbank PA, Clark PG. Physical and mental health-related correlates of physical function in community dwelling older adults: a cross sectional study. *BMC Geriatr* [Internet]. 2010 [cited 2010 Feb 3]; 10:6. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2835714/?tool=pubmed.
131. Gary RA, Sueta CA, Dougherty M, et al. Home-based exercise improves functional performance and quality of life in women with diastolic heart failure. *Heart Lung*. 2004;33(4):210–8.
132. Gatts S. Neural mechanisms underlying balance control in tai chi. *Med Sport Sci*. 2008;52:87–103.
133. Gellish RL, Goslin BR, Olson RE, McDonald A, Russi GD, Moudgil VK. Longitudinal modeling of the relationship between age and maximal heart rate. *Med Sci Sports Exerc*. 2007;39(5): 822–9.
134. Giada F, Vigna GB, Vitale E, et al. Effect of age on the response of blood lipids, body composition, and aerobic power to physical conditioning and deconditioning. *Metabolism*. 1995;44(2): 161–5.
135. Giada F, Bertaglia E, De Piccoli B, et al. Cardiovascular adaptations to endurance training and detraining in young and older athletes. *Int J Cardiol*. 1998;65(2):149–55.
136. Gibbons RJ, Balady GJ, Bricker JT, et al. ACC/AHA 2002 guideline update for exercise testing: summary article: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (committee to update the 1997 Exercise Testing Guidelines). *Circulation*. 2002; 106(14):1883–92.
137. Gill TM, DiPietro L, Krumholz HM. Role of exercise stress testing and safety monitoring for older persons starting an exercise program. *JAMA*. 2000;284(3):342–9.
138. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev*. 2009;(2):CD007146.
139. Gillison FB, Skevington SM, Sato A, Standage M, Evangelidou S. The effects of exercise interventions on quality of life in clinical

and healthy populations; a meta-analysis. *Soc Sci Med*. 2009;68(9):1700–10.
140. Goldstein MG, Whitlock EP, DePue J. Multiple behavioral risk factor interventions in primary care. Summary of research evidence. *Am J Prev Med*. 2004;27(Suppl 2):61–79.
141. Gordon-Larsen P, Boone-Heinonen J, Sidney S, Sternfeld B, Jacobs DR Jr, Lewis CE. Active commuting and cardiovascular disease risk: the CARDIA study. *Arch Int Med*. 2009;169(13):1216–23.
142. Gormley SE, Swain DP, High R, et al. Effect of intensity of aerobic training on $\dot{V}O_{2max}$. *Med Sci Sports Exerc*. 2008;40(7):1336–43.
143. Gremion G. Is stretching for sports performance still useful? A review of the literature [in French]. *Rev Med Suisse*. 2005;1(28):1830–4.
144. Guimaraes GV, Ciolac EG, Carvalho VO, D'Avila VM, Bortolotto LA, Bocchi EA. Effects of continuous vs. interval exercise training on blood pressure and arterial stiffness in treated hypertension. *Hypertens Res*. 2010;33(6):627–32.
145. Guissard N, Duchateau J. Effect of static stretch training on neural and mechanical properties of the human plantar-flexor muscles. *Muscle Nerve*. 2004;29(2):248–55.
146. Guissard N, Duchateau J. Neural aspects of muscle stretching. *Exerc Sport Sci Rev*. 2006;34(4):154–8.
147. Gulati M, Shaw LJ, Thisted RA, Black HR, Merz CN, Arnsdorf MF. Heart rate response to exercise stress testing in asymptomatic women. The St. James Women Take Heart Project. *Circulation*. 2010;122(2):130–7.
148. Guthold R, Ono T, Strong KL, Chatterji S, Morabia A. Worldwide variability in physical inactivity a 51-country survey. *Am J Prev Med*. 2008;34(6):486–94.
149. Ham SA, Kruger J, Tudor-Locke C. Participation by US adults in sports, exercise, and recreational physical activities. *J Phys Act Health*. 2009;6(1):6–14.
150. Hamdy O, Porramatikul S, Al-Ozairi E. Metabolic obesity: the paradox between visceral and subcutaneous fat. *Curr Diabetes Rev*. 2006;2(4):367–73.
151. Hamer M, Chida Y. Active commuting and cardiovascular risk: a meta-analytic review. *Prev Med*. 2008;46(1):9–13.
152. Hardy CJ, Rejeski WJ. Not what, but how one feels: the measurement of affect during exercise. *J Sport Exerc Psychol*. 1989;11:304–17.
153. Harmer PA, Li F. Tai Chi and falls prevention in older people. *Med Sport Sci*. 2008;52:124–34.
154. Harris C, DeBeliso M, Adams KJ, Irmischer BS, Spitzer Gibson TA. Detraining in the older adult: effects of prior training intensity on strength retention. *J Strength Cond Res*. 2007;21(3):813–8.
155. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39(8):1423–34.
156. Hawkins S, Wiswell R. Rate and mechanism of maximal oxygen consumption decline with aging: implications for exercise training. *Sports Med*. 2003;33(12):877–88.
157. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661–6.
158. Healy GN, Dunstan DW, Salmon J, Shaw JE, Zimmet PZ, Owen N. Television time and continuous metabolic risk in physically active adults. *Med Sci Sports Exerc*. 2008;40(4):639–45.
159. Healy GN, Wijndaele K, Dunstan DW, et al. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care*. 2008;31(2):369–71.
160. Heitmann BL, Erikson H, Ellsinger BM, Mikkelsen KL, Larsson B. Mortality associated with body fat, fat-free mass and body mass index among 60-year-old Swedish men—a 22-year follow-up. The study of men born in 1913. *Int J Obes Relat Metab Disord*. 2000;24(1):33–7.
161. Helgerud J, Hoydal K, Wang E, et al. Aerobic high-intensity intervals improve $\dot{V}O_{2max}$ more than moderate training. *Med Sci Sports Exerc*. 2007;39(4):665–71.
162. Henwood TR, Taaffe DR. Detraining and retraining in older adults following long-term muscle power or muscle strength specific training. *J Gerontol A Biol Sci Med Sci*. 2008;63(7):751–8.
163. Herbert RD, de Noronha M. Stretching to prevent or reduce muscle soreness after exercise. *Cochrane Database Syst Rev*. 2007;(4):CD004577.
164. Herbert RD, Gabriel M. Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review. *BMJ*. 2002;325(7362):468.
165. Hewett TE, Myer GD, Ford KR. Reducing knee and anterior cruciate ligament injuries among female athletes: a systematic review of neuromuscular training interventions. *J Knee Surg*. 2005;18(1):82–8.
166. Hickson RC, Rosenkoetter MA. Reduced training frequencies and maintenance of increased aerobic power. *Med Sci Sports Exerc*. 1981;13(1):13–6.
167. Hickson RC, Kanakis C Jr, Davis JR, Moore AM, Rich S. Reduced training duration effects on aerobic power, endurance, and cardiac growth. *J Appl Physiol*. 1982;53(1):225–9.
168. Hickson RC, Foster C, Pollock ML, Galassi TM, Rich S. Reduced training intensities and loss of aerobic power, endurance, and cardiac growth. *J Appl Physiol*. 1985;58(2):492–9.
169. Hillsdon M, Foster C, Thorogood M. Interventions for promoting physical activity. *Cochrane Database Syst Rev*. 2005;(1):CD003180.
170. Holst AG, Winkel BG, Theilade J, et al. Incidence and etiology of sports-related sudden cardiac death in Denmark—implications for preparticipation screening. *Heart Rhythm*. 2010;7(10):1365–71.
171. Hootman JM, Macera CA, Ainsworth BE, Martin M, Addy CL, Blair SN. Association among physical activity level, cardiorespiratory fitness, and risk of musculoskeletal injury. *Am J Epidemiol*. 2001;154(3):251–8.
172. Hootman JM, Macera CA, Ainsworth BE, Addy CL, Martin M, Blair SN. Epidemiology of musculoskeletal injuries among sedentary and physically active adults. *Med Sci Sports Exerc*. 2002;34(5):838–44.
173. Howley ET. Type of activity: resistance, aerobic and leisure versus occupational physical activity. *Med Sci Sports Exerc*. 2001;33(Suppl 6):S364–9.
174. Hrysomallis C. Relationship between balance ability, training and sports injury risk. *Sports Med*. 2007;37(6):547–56.
175. Huang HJ, Ferris DP. Upper and lower limb muscle activation is bidirectionally and ipsilaterally coupled. *Med Sci Sports Exerc*. 2009;41(9):1778–89.
176. Huang Y, Macera CA, Blair SN, Brill PA, Kohl HW 3rd, Kronenfeld JJ. Physical fitness, physical activity, and functional limitation in adults aged 40 and older. *Med Sci Sports Exerc*. 1998;30(9):1430–5.
177. Hunter GR, McCarthy JP, Bamman MM. Effects of resistance training on older adults. *Sports Med*. 2004;34(5):329–48.
178. Hunter GR, Brock DW, Byrne NM, Chandler-Laney PC, Del Corral P, Gower BA. Exercise training prevents regain of visceral fat for 1 year following weight loss. *Obesity (Silver Spring)*. 2010;18(4):690–5.
179. Irving BA, Rutkowski J, Brock DW, et al. Comparison of Borg- and OMNI-RPE as markers of the blood lactate response to exercise. *Med Sci Sports Exerc*. 2006;38(7):1348–52.
180. Jacobson DM, Strohecker L, Compton MT, Katz DL. Physical activity counseling in the adult primary care setting: position statement of the American College of Preventive Medicine. *Am J Prev Med*. 2005;29(2):158–62.

181. Jahnke R, Larkey L, Rogers C, Etnier J, Lin F. A comprehensive review of health benefits of qigong and tai chi. *Am J Health Promot*. 2010;24(6):e1–25.
182. Jakicic JM, Winters C, Lang W, Wing RR. Effects of intermittent exercise and use of home exercise equipment on adherence, weight loss, and fitness in overweight women: a randomized trial. *JAMA*. 1999;282(16):1554–60.
183. Jette AM, Rooks D, Lachman M, et al. Home-based resistance training: predictors of participation and adherence. *Gerontologist*. 1998;38(4):412–21.
184. Johnson JL, Slentz CA, Houmard JA, et al. Exercise training amount and intensity effects on metabolic syndrome (from studies of a targeted risk reduction intervention through defined exercise). *Am J Cardiol*. 2007;100(12):1759–66.
185. Johnson PJ, Winter EM, Paterson DH, Koval JJ, Nevill AM, Cunningham DA. Modelling the influence of age, body size and sex on maximum oxygen uptake in older humans. *Exp Physiol*. 2000;85(2):219–25.
186. Jones BH, Cowan DN, Knapik JJ. Exercise, training and injuries. *Sports Med*. 1994;18(3):202–14.
187. Jordan AN, Jurca GM, Locke CT, Church TS, Blair SN. Pedometer indices for weekly physical activity recommendations in postmenopausal women. *Med Sci Sports Exerc*. 2005;37(9):1627–32.
188. Jurca R, LaMonte MJ, Church TS, et al. Associations of muscle strength and fitness with metabolic syndrome in men. *Med Sci Sports Exerc*. 2004;36(8):1301–7.
189. Jurca R, LaMonte MJ, Barlow CE, Kampert JB, Church TS, Blair SN. Association of muscular strength with incidence of metabolic syndrome in men. *Med Sci Sports Exerc*. 2005;37(11):1849–55.
190. Kahn EB, Ramsey LT, Brownson RC, et al. The effectiveness of interventions to increase physical activity. A systematic review. *Am J Prev Med*. 2002;22(Suppl 4):73–107.
191. Kalapotharakos V, Smilios I, Parlavatzas A, Tokmakidis SP. The effect of moderate resistance strength training and detraining on muscle strength and power in older men. *J Geriatr Phys Ther*. 2007;30(3):109–13.
192. Kallinen M, Markku A. Aging, physical activity and sports injuries. An overview of common sports injuries in the elderly. *Sports Med*. 1995;20(1):41–52.
193. Kang M, Marshall SJ, Barreira TV, Lee JO. Effect of pedometer-based physical activity interventions: a meta-analysis. *Res Q Exerc Sport*. 2009;80(3):648–55.
194. Karinkanta S, Heinonen A, Sievanen H, et al. A multi-component exercise regimen to prevent functional decline and bone fragility in home-dwelling elderly women: randomized, controlled trial. *Osteoporos Int*. 2007;18(4):453–62.
195. Kay SJ, Fiatarone Singh MA. The influence of physical activity on abdominal fat: a systematic review of the literature. *Obes Rev*. 2006;7(2):183–200.
196. Keller C, Trevino RP. Effects of two frequencies of walking on cardiovascular risk factor reduction in Mexican American women. *Res Nurs Health*. 2001;24(5):390–401.
197. King AC, Marcus B, Ahn D, et al. Identifying subgroups that succeed or fail with three levels of physical activity intervention: the Activity Counseling Trial. *Health Psychol*. 2006;25(3):336–47.
198. Kiviniemi MT, Voss-Humke AM, Seifert AL. How do I feel about the behavior? The interplay of affective associations with behaviors and cognitive beliefs as influences on physical activity behavior. *Health Psychol*. 2007;26(2):152–8.
199. Klimcakova E, Polak J, Moro C, et al. Dynamic strength training improves insulin sensitivity without altering plasma levels and gene expression of adipokines in subcutaneous adipose tissue in obese men. *J Clin Endocrinol Metab*. 2006;91(12):5107–12.
200. Kofotolis N, Kellis E. Effects of two 4-week proprioceptive neuromuscular facilitation programs on muscle endurance, flexibility, and functional performance in women with chronic low back pain. *Phys Ther*. 2006;86(7):1001–12.
201. Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR, American College of Sports Medicine. Position Stand: physical activity and bone health. *Med Sci Sports Exerc*. 2004;36(11):1985–96.
202. Kokkonen J, Nelson AG, Eldredge C, Winchester JB. Chronic static stretching improves exercise performance. *Med Sci Sports Exerc*. 2007;39(10):1825–31.
203. Kramer AF, Erickson KI. Capitalizing on cortical plasticity: influence of physical activity on cognition and brain function. *Trends Cogn Sci*. 2007;11(8):342–8.
204. Kumahara H, Tanaka H, Schutz Y. Are pedometers adequate instruments for assessing energy expenditure? *Eur J Clin Nutr*. 2009;63(12):1425–32.
205. Kuramoto AM. Therapeutic benefits of tai chi exercise: research review. *WMJ*. 2006;105(7):42–6.
206. Kwan BM, Bryan A. In-task and post-task affective response to exercise: translating exercise intentions into behaviour. *Br J Health Psychol*. 2010;15(Pt 1):115–31.
207. Laaksonen DE, Atalay M, Niskanen LK, et al. Aerobic exercise and the lipid profile in type 1 diabetic men: a randomized controlled trial. *Med Sci Sports Exerc*. 2000;32(9):1541–8.
208. Lagally KM, Robertson RJ. Construct validity of the OMNI resistance exercise scale. *J Strength Cond Res*. 2006;20(2):252–6.
209. LaRoche DP, Connolly DA. Effects of stretching on passive muscle tension and response to eccentric exercise. *Am J Sports Med*. 2006;34(6):1000–7.
210. Larson EB, Wang L, Bowen JD, et al. Exercise is associated with reduced risk for incident dementia among persons 65 years of age and older. *Ann Intern Med*. 2006;144(2):73–81.
211. Lauer M, Froelicher ES, Williams M, Kligfield P. Exercise testing in asymptomatic adults: a statement for professionals from the American Heart Association Council on Clinical Cardiology, Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention. *Circulation*. 2005;112(5):771–6.
212. Laursen PB, Jenkins DG. The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Med*. 2002;32(1):53–73.
213. Lee DC, Sui X, Ortega FB, et al. Comparisons of leisure-time physical activity and cardiorespiratory fitness as predictors of all-cause mortality in men and women. *Br J Sports Med*. [Epub ahead of print]. 2010 [cited 2010 Apr 23]. Available from: http://bjsm.bmj.com/content/early/2010/04/22/bjsm.2009.066209.abstract.
214. Lee IM, Skerrett PJ. Physical activity and all-cause mortality: what is the dose–response relation? *Med Sci Sports Exerc*. 2001;33(Suppl 6):S459–71; discussion S93–4.
215. Lee IM, Sesso HD, Paffenbarger RS Jr. Physical activity and coronary heart disease risk in men: does the duration of exercise episodes predict risk? *Circulation*. 2000;102(9):981–6.
216. Lee IM, Rexrode KM, Cook NR, Manson JE, Buring JE. Physical activity and coronary heart disease in women: is ''no pain, no gain'' passe? *JAMA*. 2001;285(11):1447–54.
217. Lee IM, Sesso HD, Oguma Y, Paffenbarger RS Jr. The ''weekend warrior'' and risk of mortality. *Am J Epidemiol*. 2004;160(7):636–41.
218. Lee M, Carroll TJ. Cross education: possible mechanisms for the contralateral effects of unilateral resistance training. *Sports Med*. 2007;37(1):1–14.
219. Lee M, Gandevia SC, Carroll TJ. Unilateral strength training increases voluntary activation of the opposite untrained limb. *Clin Neurophysiol*. 2009;120(4):802–8.
220. Leon AS, Togashi K, Rankinen T, et al. Association of apolipoprotein E polymorphism with blood lipids and maximal oxygen uptake in the sedentary state and after exercise training in the HERITAGE family study. *Metabolism*. 2004;53(1):108–16.

221. Leskinen T, Sipila S, Alen M, et al. Leisure-time physical activity and high-risk fat: a longitudinal population-based twin study. *Int J Obes*. 2009;33(11):1211–8.
222. Li JX, Xu DQ, Hong Y. Effects of 16-week tai chi intervention on postural stability and proprioception of knee and ankle in older people. *Age Ageing*. 2008;37(5):575–8.
223. Li JX, Xu DQ, Hong Y. Tai chi exercise and proprioception behavior in old people. *Med Sport Sci*. 2008;52:77–86.
224. Li Y, Devault CN, Van Oteghen S. Effects of extended tai chi intervention on balance and selected motor functions of the elderly. *Am J Chin Med*. 2007;35(3):383–91.
225. Lind E, Ekkekakis P, Vazou S. The affective impact of exercise intensity that slightly exceeds the preferred level: 'pain' for no additional 'gain'. *J Health Psychol*. 2008;13(4):464–8.
226. Liu-Ambrose T, Khan KM, Eng JJ, Lord SR, McKay HA. Balance confidence improves with resistance or agility training. Increase is not correlated with objective changes in fall risk and physical abilities. *Gerontology*. 2004;50(6):373–82.
227. Liu-Ambrose T, Khan KM, Eng JJ, Janssen PA, Lord SR, McKay HA. Resistance and agility training reduce fall risk in women aged 75 to 85 with low bone mass: a 6-month randomized, controlled trial. *J Am Geriatr Soc*. 2004;52(5):657–65.
228. Liu-Ambrose T, Donaldson MG, Ahamed Y, et al. Otago home-based strength and balance retraining improves executive functioning in older fallers: a randomized controlled trial. *J Am Geriatr Soc*. 2008;56(10):1821–30.
229. Lloyd-Jones D, Adams RJ, Brown TM, et al. Heart disease and stroke statistics—2010 update: a report from the American Heart Association. *Circulation*. 2010;121(7):e46–e215.
230. Logghe IH, Verhagen AP, Rademaker AC, et al. The effects of tai chi on fall prevention, fear of falling and balance in older people: a meta-analysis. *Prev Med*. 2010;51(3–4):222–7.
231. Lounana J, Campion F, Noakes TD, Medelli J. Relationship between $\%HR_{max}$, %HR reserve, $\%\dot{V}O_{2max}$, and $\%\dot{V}O_2$ reserve in elite cyclists. *Med Sci Sports Exerc*. 2007;39(2):350–7.
232. Mahieu NN, McNair P, De Muynck M, et al. Effect of static and ballistic stretching on the muscle–tendon tissue properties. *Med Sci Sports Exerc*. 2007;39(3):494–501.
233. Maimoun L, Sultan C. Effects of physical activity on bone remodeling. *Metabolism*. [Epub ahead of print]. 2010 [cited 2010 Mar 30]. Available from: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WN4-4YRGJMK-7&_user=10&_coverDate=03%2F31%2F2010&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=640ea80d585ccfbbbc90de3692d90ae0&searchtype=a.
234. Malik S, Wong ND, Franklin SS, et al. Impact of the metabolic syndrome on mortality from coronary heart disease, cardiovascular disease, and all causes in United States adults. *Circulation*. 2004;110(10):1245–50.
235. Manini TM, Everhart JE, Patel KV, et al. Daily activity energy expenditure and mortality among older adults. *JAMA*. 2006;296(2):171–9.
236. Mansfield A, Peters AL, Liu BA, Maki BE. A perturbation-based balance training program for older adults: study protocol for a randomised controlled trial. *BMC Geriatr*. [Internet]. 2007 [cited 2007 May 31];7:12. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1903355/?tool=pubmed.
237. Manson JE, Greenland P, LaCroix AZ, et al. Walking compared with vigorous exercise for the prevention of cardiovascular events in women. *N Engl J Med*. 2002;347:716–25.
238. Marcus BH, Dubbert PM, Forsyth LH, et al. Physical activity behavior change: issues in adoption and maintenance. *Health Psychol*. 2000;19(Suppl 1):32–41.
239. Marcus BH, Williams DM, Dubbert PM, et al. Physical activity intervention studies: what we know and what we need to know: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (subcommittee on Physical Activity); Council on Cardiovascular Disease in the Young; and the Interdisciplinary Working Group on Quality of Care and Outcomes Research. *Circulation*. 2006;114(24):2739–52.
240. Marles A, Legrand R, Blondel N, Mucci P, Betbeder D, Prieur F. Effect of high-intensity interval training and detraining on extra $\dot{V}O_2$ and on the $\dot{V}O_2$ slow component. *Eur J Appl Physiol*. 2007;99(6):633–40.
241. Maron BJ, Thompson PD, Ackerman MJ, et al. Recommendations and considerations related to preparticipation screening for cardiovascular abnormalities in competitive athletes: 2007 update: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism: endorsed by the American College of Cardiology Foundation. *Circulation*. 2007;115(12):1643–55.
242. Marshall SJ, Levy SS, Tudor-Locke CE, et al. Translating physical activity recommendations into a pedometer-based step goal: 3000 steps in 30 minutes. *Am J Prev Med*. 2009;36(5):410–5.
243. Marti B. Health effects of recreational running in women. Some epidemiological and preventive aspects. *Sports Med*. 1991;11(1):20–51.
244. Martinsen EW. Physical activity in the prevention and treatment of anxiety and depression. *Nord J Psych*. 2008;62(Suppl 47):25–9.
245. Masters KS, Ogles BM. Associative and dissociative cognitive strategies in exercise and running: 20 years later, what do we know. *Sport Psychol*. 1998;12:253–70.
246. McAuley E, Jerome GJ, Elavsky S, Marquez DX, Ramsey SN. Predicting long-term maintenance of physical activity in older adults. *Prev Med*. 2003;37(2):110–8.
247. McAuley P, Myers J, Emerson B, et al. Cardiorespiratory fitness and mortality in diabetic men with and without cardiovascular disease. *Diabetes Res Clin Pract*. 2009;85(3):e30–3.
248. McHugh MP, Cosgrave CH. To stretch or not to stretch: the role of stretching in injury prevention and performance. *Scand J Med Sci Sports*. 2010;20(2):169–81.
249. McMillian DJ, Moore JH, Hatler BS, Taylor DC. Dynamic vs. static-stretching warm up: the effect on power and agility performance. *J Strength Cond Res*. 2006;20(3):492–9.
250. Mead GE, Morley W, Campbell P, Greig CA, McMurdo M, Lawlor DA. Exercise for depression. *Cochrane Database Syst Rev*. 2009;(3):CD004366.
251. Merriam-Webster Online Medical Dictionary. [Internet]. Springfield, MA: Merriam-Webster. 2008 [cited 2008 Apr 23]. Available from: http://www.merriam-webster.com/medical/biomarker.
252. Messier SP. Obesity and osteoarthritis: disease genesis and nonpharmacologic weight management. *Med Clin North Am*. 2009;93(1):145–59, xi–xii.
253. Meyer T, Auracher M, Heeg K, Urhausen A, Kindermann W. Does cumulating endurance training at the weekends impair training effectiveness? *Eur J Cardiovasc Prev Rehabil*. 2006;13(4):578–84.
254. Midgley AW, McNaughton LR, Wilkinson M. Is there an optimal training intensity for enhancing the maximal oxygen uptake of distance runners?: empirical research findings, current opinions, physiological rationale and practical recommendations. *Sports Med*. 2006;36(2):117–32.
255. Midgley AW, McNaughton LR, Jones AM. Training to enhance the physiological determinants of long-distance running performance: can valid recommendations be given to runners and coaches based on current scientific knowledge? *Sports Med*. 2007;37(10):857–80.
256. Mujica V, Urzua A, Leiva E, et al. Intervention with education and exercise reverses the metabolic syndrome in adults. *J Am Soc Hypertens*. 2010;4(3):148–53.
257. Muller-Riemenschneider F, Reinhold T, Nocon M, Willich SN. Long-term effectiveness of interventions promoting physical activity: a systematic review. *Prev Med*. 2008;47(4):354–68.

258. Munn J, Herbert RD, Gandevia SC. Contralateral effects of unilateral resistance training: a meta-analysis. *J Appl Physiol*. 2004;96(5):1861–6.
259. Munn J, Herbert RD, Hancock MJ, Gandevia SC. Training with unilateral resistance exercise increases contralateral strength. *J Appl Physiol*. 2005;99(5):1880–4.
260. Murphy MH, Blair SN, Murtagh EM. Accumulated versus continuous exercise for health benefit: a review of empirical studies. *Sports Med*. 2009;39(1):29–43.
261. Musa DI, Adeniran SA, Dikko AU, Sayers SP. The effect of a high-intensity interval training program on high-density lipoprotein cholesterol in young men. *J Strength Cond Res*. 2009;23(2):587–92.
262. Myers J, Prakash M, Froelicher V, Do D, Partington S, Atwood JE. Exercise capacity and mortality among men referred for exercise testing. *N Engl J Med*. 2002;346(11):793–801.
263. National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. [Internet]. Rockville (MD): National Institutes of Health, National Heart, Lung, and Blood Institute. 1998. [cited 10/10/2010]. 228 p. Available from: http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf.
264. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39(8):1435–45.
265. Newman AB, Kupelian V, Visser M, et al. Strength, but not muscle mass, is associated with mortality in the health, aging and body composition study cohort. *J Gerontol A Biol Sci Med Sci*. 2006;61(1):72–7.
266. Nicklas BJ, Wang X, You T, et al. Effect of exercise intensity on abdominal fat loss during calorie restriction in overweight and obese postmenopausal women: a randomized, controlled trial. *Am J Clin Nutr*. 2009;89(4):1043–52.
267. Noble BJ, Borg GA, Jacobs I, Ceci R, Kaiser P. A category–ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. *Med Sci Sports Exerc*. 1983;15(6):523–8.
268. Nybo L, Sundstrup E, Jakobsen MD, et al. High-intensity training versus traditional exercise interventions for promoting health. *Med Sci Sports Exerc*. 2010;42(10):1951–8.
269. O'Donovan G, Kearney EM, Nevill AM, Woolf-May K, Bird SR. The effects of 24 weeks of moderate- or high-intensity exercise on insulin resistance. *Eur J Appl Physiol*. 2005;95(5–6):522–8.
270. O'Sullivan K, Murray E, Sainsbury D. The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. *BMC Musculoskelet Disord* [Internet]. 2009 [cited 2009 Apr 16];10:37. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2679703/?tool=pubmed.
271. Oeland AM, Laessoe U, Olesen AV, Munk-Jorgensen P. Impact of exercise on patients with depression and anxiety. *Nord J Psychiatry*. 2010;64(3):210–7.
272. Ogilvie D, Foster CE, Rothnie H, et al. Interventions to promote walking: systematic review. *BMJ*. 2007;334(7605):1204.
273. Oman RF, King AC. Predicting the adoption and maintenance of exercise participation using self-efficacy and previous exercise participation rates. *Am J Health Promot*. 1998;12(3):154–61.
274. Orr R, de Vos NJ, Singh NA, Ross DA, Stavrinos TM, Fiatarone-Singh MA. Power training improves balance in healthy older adults. *J Gerontol A Biol Sci Med Sci*. 2006;61(1):78–85.
275. Ory M, Resnick B, Jordan PJ, et al. Screening, safety, and adverse events in physical activity interventions: collaborative experiences from the behavior change consortium. *Ann Behav Med*. 2005;29(Suppl):20–8.
276. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behavior. *Exerc Sport Sci Rev*. 2010;38(3):105–13.
277. Panton LB, Graves JE, Pollock ML, et al. Relative heart rate, heart rate reserve, and $\dot{V}O_2$ during submaximal exercise in the elderly. *J Gerontol A Biol Sci Med Sci*. 1996;51(4):M165–71.
278. Parfitt G, Rose EA, Burgess WM. The psychological and physiological responses of sedentary individuals to prescribed and preferred intensity exercise. *Br J Health Psychol*. 2006;11(Pt 1):39–53.
279. Pate RR, Hughes RD, Chandler JV, Ratliffe JL. Effects of arm training on retention of training effects derived from leg training. *Med Sci Sports Exerc*. 1978;10:71–4.
280. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 1995;273(5):402–7.
281. Paterson DH, Warburton DE. Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *Int J Behav Nutr Phys Act*. 2010;7:38.
282. Penninx BW, Rejeski WJ, Pandya J, et al. Exercise and depressive symptoms: a comparison of aerobic and resistance exercise effects on emotional and physical function in older persons with high and low depressive symptomatology. *J Gerontol B Psychol Sci Soc Sci*. 2002;57(2):P124–32.
283. Persinger R, Foster C, Gibson M, Fater DC, Porcari JP. Consistency of the talk test for exercise prescription. *Med Sci Sports Exerc*. 2004;36(9):1632–6.
284. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA. American College of Sports Medicine. Position Stand: exercise and hypertension. *Med Sci Sports Exerc*. 2004;36(3):533–53.
285. Peterson MD, Rhea MR, Alvar BA. Applications of the dose–response for muscular strength development: a review of meta-analytic efficacy and reliability for designing training prescription. *J Strength Cond Res*. 2005;19(4):950–8.
286. Petrella RJ, Koval JJ, Cunningham DA, Paterson DH. Can primary care doctors prescribe exercise to improve fitness? The Step Test Exercise Prescription (STEP) project. *Am J Prev Med*. 2003;24(4):316–22.
287. Pettitt RW, Symons JD, Taylor JE, Eisenman PA, White AT. Adjustment for gas exchange threshold enhances precision of heart rate–derived $\dot{V}O_2$ estimates during heavy exercise. *Appl Physiol Nutr Metab*. 2008;33(1):68–74.
288. Pi-Sunyer X, Blackburn G, Brancati FL, et al. Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: one-year results of the look AHEAD trial. *Diabetes Care*. 2007;30(6):1374–83.
289. Pinet BM, Prud'homme D, Gallant CA, Boulay P. Exercise intensity prescription in obese individuals. *Obesity (Silver Spring)*. 2008;16(9):2088–95.
290. Pogliaghi S, Terziotti P, Cevese A, Balestreri F, Schena F. Adaptations to endurance training in the healthy elderly: arm cranking versus leg cycling. *Eur J Appl Physiol*. 2006;97(6):723–31.
291. Pollock ML, Carroll JF, Graves JE, et al. Injuries and adherence to walk/jog and resistance training programs in the elderly. *Med Sci Sports Exerc*. 1991;23(10):1194–200.
292. Pollock ML, Franklin BA, Balady GJ, et al. AHA Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription: An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; position paper endorsed by the American College of Sports Medicine. *Circulation*. 2000;101(7):828–33.
293. Porter D, Barrill E, Oneacre K, May BD. The effects of duration and frequency of Achilles tendon stretching on dorsiflexion and outcome in painful heel syndrome: a randomized, blinded, control study. *Foot Ankle Int*. 2002;23(7):619–24.

294. Puetz TW. Physical activity and feelings of energy and fatigue: epidemiological evidence. *Sports Med*. 2006;36(9):767–80.
295. Radford JA, Burns J, Buchbinder R, Landorf KB, Cook C. Does stretching increase ankle dorsiflexion range of motion? A systematic review. *Br J Sports Med*. 2006;40(10):870–5.
296. Rafferty AP, Reeves MJ, McGee HB, Pivarnik JM. Physical activity patterns among walkers and compliance with public health recommendations. *Med Sci Sports Exerc*. 2002;34(8):1255–61.
297. Rancour J, Holmes CF, Cipriani DJ. The effects of intermittent stretching following a 4-week static stretching protocol: a randomized trial. *J Strength Cond Res*. 2009;23(8):2217–22.
298. Rankinen T, Roth SM, Bray MS, et al. Advances in exercise, fitness, and performance genomics. *Med Sci Sports Exerc*. 2010; 42(5):835–46.
299. Rees SS, Murphy AJ, Watsford ML, McLachlan KA, Coutts AJ. Effects of proprioceptive neuromuscular facilitation stretching on stiffness and force-producing characteristics of the ankle in active women. *J Strength Cond Res*. 2007;21(2):572–7.
300. Reid DA, McNair PJ. Passive force, angle, and stiffness changes after stretching of hamstring muscles. *Med Sci Sports Exerc*. 2004;36(11):1944–8.
301. Reis JP, Macera CA, Araneta MR, Lindsay SP, Marshall SJ, Wingard DL. Comparison of overall obesity and body fat distribution in predicting risk of mortality. *Obesity (Silver Spring)*. 2009;17(6):1232–9.
302. Rejeski WJ, Mihalko SL. Physical activity and quality of life in older adults. *J Gerontol A Biol Sci Med Sci*. 2001;56 Spec No 2: 23–35.
303. Rejeski WJ, Brawley LR, Ambrosius WT, et al. Older adults with chronic disease: benefits of group-mediated counseling in the promotion of physically active lifestyles. *Health Psychol*. 2003; 22(4):414–23.
304. Rejeski WJ, Katula J, Rejeski A, Rowley J, Sipe M. Strength training in older adults: does desire determine confidence? *J Gerontol B Psychol Sci Soc Sci*. 2005;60(6):P335–7.
305. Rethorst CD, Wipfli BM, Landers DM. The antidepressive effects of exercise: a meta-analysis of randomized trials. *Sports Med*. 2009;39(6):491–511.
306. Rhea MR, Alvar BA, Burkett LN, Ball SD. A meta-analysis to determine the dose response for strength development. *Med Sci Sports Exerc*. 2003;35(3):456–64.
307. Rhodes RE, Warburton DE, Murray H. Characteristics of physical activity guidelines and their effect on adherence: a review of randomized trials. *Sports Med*. 2009;39(5):355–75.
308. Richardson CR, Newton TL, Abraham JJ, Sen A, Jimbo M, Swartz AM. A meta-analysis of pedometer-based walking interventions and weight loss. *Ann Fam Med*. 2008;6(1):69–77.
309. Rietjens GJ, Keizer HA, Kuipers H, Saris WH. A reduction in training volume and intensity for 21 days does not impair performance in cyclists. *Br J Sports Med*. 2001;35(6):431–4.
310. Ring-Dimitriou S, von Duvillard SP, Paulweber B, et al. Nine months aerobic fitness induced changes on blood lipids and lipoproteins in untrained subjects versus controls. *Eur J Appl Physiol*. 2007;99(3):291–9.
311. Robertson RJ, Goss FL, Rutkowski J, et al. Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Med Sci Sports Exerc*. 2003;35(2):333–41.
312. Robertson RJ, Goss FL, Dube J, et al. Validation of the adult OMNI scale of perceived exertion for cycle ergometer exercise. *Med Sci Sports Exerc*. 2004;36(1):102–8.
313. Rognmo O, Hetland E, Helgerud J, Hoff J, Slordahl SA. High intensity aerobic interval exercise is superior to moderate intensity exercise for increasing aerobic capacity in patients with coronary artery disease. *Eur J Cardiovasc Prev Rehabil*. 2004;11(3): 216–22.
314. Rose EA, Parfitt G. Can the feeling scale be used to regulate exercise intensity? *Med Sci Sports Exerc*. 2008;40(10):1852–60.
315. Rotstein A, Meckel Y. Estimation of $\%\dot{V}O_2$ reserve from heart rate during arm exercise and running. *Eur J Appl Physiol*. 2000; 83(6):545–50.
316. Rotstein A, Meckel Y, Inbar O. Perceived speech difficulty during exercise and its relation to exercise intensity and physiological responses. *Eur J Appl Physiol*. 2004;92(4–5):431–6.
317. Roux L, Pratt M, Tengs TO, et al. Cost effectiveness of community-based physical activity interventions. *Am J Prev Med*. 2008;35(6):578–88.
318. Ruscheweyh R, Willemer C, Kruger K, et al. Physical activity and memory functions: an interventional study. *Neurobiol Aging* [Epub ahead of print]. 2009 [cited 2009 Aug 27]. Available from: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T09-4X3VKV3-1&_user=10&_coverDate=08%2F29%2F2009&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=121444dbf93259d0d170fb899a7df2da&searchtype=a.
319. Seguin RA, Economos CD, Palombo R, Hyatt R, Kuder J, Nelson ME. Strength training and older women: a cross-sectional study examining factors related to exercise adherence. *J Aging Phys Act*. 2010;18(2):201–18.
320. Sesso HD, Paffenbarger RS Jr, Lee IM. Physical activity and coronary heart disease in men: the Harvard Alumni Health Study. *Circulation*. 2000;102(9):975–80.
321. Sevick MA, Napolitano MA, Papandonatos GD, Gordon AJ, Reiser LM, Marcus BH. Cost-effectiveness of alternative approaches for motivating activity in sedentary adults: results of Project STRIDE. *Prev Med*. 2007;45(1):54–61.
322. Sharman MJ, Cresswell AG, Riek S. Proprioceptive neuromuscular facilitation stretching: mechanisms and clinical implications. *Sports Med*. 2006;36(11):929–39.
323. Shephard RJ. Absolute versus relative intensity of physical activity in a dose–response context. *Med Sci Sports Exerc*. 2001; 33(Suppl 6):S400–18; discussion S19–20.
324. Shephard RJ. Is active commuting the answer to population health? *Sports Med*. 2008;38(9):751–8.
325. Shephard RJ. PAR-Q, Canadian Home Fitness Test and exercise screening alternatives. *Sports Med*. 1988;5(3):185–95.
326. Shrier I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clin J Sport Med*. 1999;9(4):221–7.
327. Sigal RJ, Kenny GP, Boule NG, et al. Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: a randomized trial. *Ann Intern Med*. 2007;147(6):357–69.
328. Sillanpaa E, Laaksonen DE, Hakkinen A, et al. Body composition, fitness, and metabolic health during strength and endurance training and their combination in middle-aged and older women. *Eur J Appl Physiol*. 2009;106(2):285–96.
329. Simpson ME, Serdula M, Galuska DA, et al. Walking trends among U.S. adults: the Behavioral Risk Factor Surveillance System, 1987–2000. *Am J Prev Med*. 2003;25(2):95–100.
330. Sisson SB, Katzmarzyk PT, Earnest CP, Bouchard C, Blair SN, Church TS. Volume of exercise and fitness nonresponse in sedentary, postmenopausal women. *Med Sci Sports Exerc*. 2009;41(3): 539–45.
331. Slemenda C, Heilman DK, Brandt KD, et al. Reduced quadriceps strength relative to body weight: a risk factor for knee osteoarthritis in women? *Arthritis Rheum*. 1998;41(11):1951–9.
332. Slentz CA, Houmard JA, Johnson JL, et al. Inactivity, exercise training and detraining, and plasma lipoproteins. STRRIDE: a randomized, controlled study of exercise intensity and amount. *J Appl Physiol*. 2007;103(2):432–42.
333. Smith PJ, Blumenthal JA, Hoffman BM, et al. Aerobic exercise and neurocognitive performance: a meta-analytic review of randomized controlled trials. *Psychosom Med*. 2010;72(3): 239–52.

334. Solberg EE, Gjertsen F, Haugstad E, Kolsrud L. Sudden death in sports among young adults in Norway. *Eur J Cardiovasc Prev Rehabil*. 2010;17(3):337–41.
335. Stofan JR, DiPietro L, Davis D, Kohl HW 3rd, Blair SN. Physical activity patterns associated with cardiorespiratory fitness and reduced mortality: the Aerobics Center Longitudinal Study. *Am J Pub Health*. 1998;88(12):1807–13.
336. Strath SJ, Swartz AM, Bassett DR Jr, O'Brien WL, King GA, Ainsworth BE. Evaluation of heart rate as a method for assessing moderate intensity physical activity. *Med Sci Sports Exerc*. 2000; 32(Suppl 9):S465–70.
337. Strohle A. Physical activity, exercise, depression and anxiety disorders. *J Neural Transm*. 2009;116(6):777–84.
338. Sui X, LaMonte MJ, Blair SN. Cardiorespiratory fitness and risk of nonfatal cardiovascular disease in women and men with hypertension. *Am J Hypertens*. 2007;20(6):608–15.
339. Sui X, LaMonte MJ, Blair SN. Cardiorespiratory fitness as a predictor of nonfatal cardiovascular events in asymptomatic women and men. *Am J Epidemiol*. 2007;165(12):1413–23.
340. Sui X, LaMonte MJ, Laditka JN, et al. Cardiorespiratory fitness and adiposity as mortality predictors in older adults. *JAMA*. 2007; 298(21):2507–16.
341. Suominen H. Muscle training for bone strength. *Aging Clin Exp Res*. 2006;18(2):85–93.
342. Swain DP. Energy cost calculations for exercise prescription: an update. *Sports Med*. 2000;30(1):17–22.
343. Swain DP. Moderate or vigorous intensity exercise: which is better for improving aerobic fitness? *Prev Cardiol*. 2005;8(1):55–8.
344. Swain DP, Franklin BA. Comparative cardioprotective benefits of vigorous vs. moderate intensity aerobic exercise. *Am J Cardiol*. 2006:97(1):141–7.
345. Swain DP, Franklin BA. $\dot{V}O_2$ reserve and the minimal intensity for improving cardiorespiratory fitness. *Med Sci Sports Exerc*. 2002;34(1):152–7.
346. Swain DP, Leutholtz BC. Heart rate reserve is equivalent to $\%\dot{V}O_2$ reserve, not to $\%\dot{V}O_{2max}$. *Med Sci Sports Exerc*. 1997; 29(3):410–4.
347. Swain DP, Leutholtz BC, King ME, Haas LA, Branch JD. Relationship between % heart rate reserve and $\%\dot{V}O_2$ reserve in treadmill exercise. *Med Sci Sports Exerc*. 1998;30(2):318–21.
348. Swensen TC, Howley ET. Effect of one- and two-leg training on arm and two-leg maximum aerobic power. *Eur J Appl Physiol Occup Physiol*. 1993;66(3):285–8.
349. Taaffe DR, Henwood TR, Nalls MA, Walker DG, Lang TF, Harris TB. Alterations in muscle attenuation following detraining and retraining in resistance-trained older adults. *Gerontology*. 2009;55(2):217–23.
350. Takeshima N, Rogers NL, Rogers ME, Islam MM, Koizumi D, Lee S. Functional fitness gain varies in older adults depending on exercise mode. *Med Sci Sports Exerc*. 2007;39(11):2036–43.
351. Talanian JL, Holloway GP, Snook LA, Heigenhauser GJ, Bonen A, Spriet LL. Exercise training increases sarcolemmal and mitochondrial fatty acid transport proteins in human skeletal muscle. *Am J Physiol Endocrinol Metab*. 2010;299(2):E180–8.
352. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*. 2001;37(1):153–6.
353. Tanasescu M, Leitzmann MF, Rimm EB, Willett WC, Stampfer MJ, Hu FB. Exercise type and intensity in relation to coronary heart disease in men. *JAMA*. 2002;288(16):1994–2000.
354. Teychenne M, Ball K, Salmon J. Sedentary behavior and depression among adults: a review. *Int J Behav Med*. 2010;17(4):246–54.
355. Thacker SB, Gilchrist J, Stroup DF, Kimsey CD Jr. The impact of stretching on sports injury risk: a systematic review of the literature. *Med Sci Sports Exerc*. 2004;36(3):371–8.
356. Thomas S, Reading J, Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Can J Sport Sci*. 1992;17(4):338–45.
357. Thomas TR, Warner SO, Dellsperger KC, et al. Exercise and the metabolic syndrome with weight regain. *J Appl Physiol*. 2010; 109(1):3–10.
358. Thompson D, Markovitch D, Betts JA, Mazzatti D, Turner J, Tyrrell RM. Time course of changes in inflammatory markers during a 6-mo exercise intervention in sedentary middle-aged men: a randomized-controlled trial. *J Appl Physiol*. 2010;108(4):769–79.
359. Thompson PD. The cardiovascular complications of vigorous physical activity. *Arch Int Med*. 1996;156(20):2297–302.
360. Thompson PD, Crouse SF, Goodpaster B, Kelley D, Moyna N, Pescatello L. The acute versus the chronic response to exercise. *Med Sci Sports Exerc*. 2001;33(Suppl 6):S438–45.
361. Thompson PD, Buchner D, Pina IL, et al. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation*. 2003;107(24):3109–16.
362. Thompson PD, Franklin BA, Balady GJ, et al. Exercise and acute cardiovascular events placing the risks into perspective: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism and the Council on Clinical Cardiology. *Circulation*. 2007;115(17):2358–68.
363. Thornton EW, Sykes KS, Tang WK. Health benefits of tai chi exercise: improved balance and blood pressure in middle-aged women. *Health Promot Int*. 2004;19(1):33–8.
364. Thorp AA, Healy GN, Owen N, et al. Deleterious associations of sitting time and television viewing time with cardiometabolic risk biomarkers: Australian Diabetes, Obesity and Lifestyle (AusDiab) study 2004–2005. *Diabetes Care*. 2010;33(2):327–34.
365. Trappe S, Williamson D, Godard M. Maintenance of whole muscle strength and size following resistance training in older men. *J Gerontol A Biol Sci Med Sci*. 2002;57(4):B138–43.
366. Tudor-Locke C, Lutes L. Why do pedometers work?: a reflection upon the factors related to successfully increasing physical activity. *Sports Med*. 2009;39(12):981–93.
367. Tudor-Locke C, Bassett DR Jr, Rutherford WJ, et al. BMI-referenced cut points for pedometer-determined steps per day in adults. *J Phys Act Health*. 2008;5(Suppl 1):S126–39.
368. Tudor-Locke C, Hatano Y, Pangrazi RP, Kang M. Revisiting "how many steps are enough?" *Med Sci Sports Exerc*. 2008; 40(Suppl 7):S537–43.
369. Tuzun S, Aktas I, Akarirmak U, Sipahi S, Tuzun F. Yoga might be an alternative training for the quality of life and balance in postmenopausal osteoporosis. *Eur J Phys Rehabil Med*. 2010; 46(1):69–72.
370. US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans* [Internet]. Washington (DC): ODPHP Publication No. U0036. 2008 [cited 2010 Oct 10]. 61 p. Available from: http://www.health.gov/paguidelines/pdf/paguide.pdf.
371. US Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General* [Internet]. Atlanta (GA): US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion. 1999 [cited 2010 Oct 10]. 278 p. Available from: http://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf.
372. US Department of Health and Human Services. *Physical Activity Guidelines Advisory Committee Report*, 2008 [Internet]. Washington (DC): ODPHP Publication No. U0049. 2008 [cited 2010 Sep 24]. 683 p. Available from: http://www.health.gov/paguidelines/Report/pdf/CommitteeReport.pdf.
373. Utter AC, Robertson RJ, Green JM, Suminski RR, McAnulty SR, Nieman DC. Validation of the Adult OMNI Scale of perceived exertion for walking/running exercise. *Med Sci Sports Exerc*. 2004;36(10):1776–80.

374. van den Berg MH, Schoones JW, Vliet Vlieland TP. Internet-based physical activity interventions: a systematic review of the literature. *J Med Internet Res* [Internet]. 2007 [cited 2007 Sep 30];9(3):e26. Available from: http://www.jmir.org/2007/3/e26/.
375. Verhagen AP, Immink M, van der Meulen A, Bierma-Zeinstra SM. The efficacy of tai chi Chuan in older adults: a systematic review. *Fam Pract*. 2004;21(1):107–13.
376. Volaklis KA, Spassis AT, Tokmakidis SP. Land versus water exercise in patients with coronary artery disease: effects on body composition, blood lipids, and physical fitness. *Am Heart J*. 2007;154(3):560.e1–6.
377. Vukovich MD, Arciero PJ, Kohrt WM, Racette SB, Hansen PA, Holloszy JO. Changes in insulin action and GLUT-4 with 6 days of inactivity in endurance runners. *J Appl Physiol*. 1996;80(1):240–4.
378. Wang C, Bannuru R, Ramel J, Kupelnick B, Scott T, Schmid CH. Tai chi on psychological well-being: systematic review and meta-analysis. *BMC Complement Altern Med* [Internet]. 2010 [cited 2010 May 21];10:23. Available from: http://www.biomedcentral.com/1472-6882/10/23.
379. Wang JS. Effects of exercise training and detraining on cutaneous microvascular function in man: the regulatory role of endothelium-dependent dilation in skin vasculature. *Eur J Appl Physiol*. 2005;93(4):429–34.
380. Wang JS, Chow SE. Effects of exercise training and detraining on oxidized low-density lipoprotein-potentiated platelet function in men. *Arch Phys Med Rehabil*. 2004;85(9):1531–7.
381. Wang PT, Chiang IT, Lin CY, et al. Effect of a two-month detraining on glucose tolerance and insulin sensitivity in athletes—link to adrenal steroid hormones. *Chin J Physiol*. 2006;49(5):251–7.
382. Wankel LM. The importance of enjoyment to adherence and psychological benefits from physical activity. *Int J Sport Psychol*. 1993;24(2):151–69.
383. Warburton DE, McKenzie DC, Haykowsky MJ, et al. Effectiveness of high-intensity interval training for the rehabilitation of patients with coronary artery disease. *Am J Cardiol*. 2005;95(9):1080–4.
384. Warren TY, Barry V, Hooker SP, Sui X, Church TS, Blair SN. Sedentary behaviors increase risk of cardiovascular disease mortality in men. *Med Sci Sports Exerc*. 2010;42(5):879–85.
385. Weiss EP, Holloszy JO. Improvements in body composition, glucose tolerance, and insulin action induced by increasing energy expenditure or decreasing energy intake. *J Nutr*. 2007;137(4):1087–90.
386. Wernbom M, Augustsson J, Thomee R. The influence of frequency, intensity, volume and mode of strength training on whole muscle cross-sectional area in humans. *Sports Med*. 2007;37(3):225–64.
387. Weuve J, Kang JH, Manson JE, Breteler MM, Ware JH, Grodstein F. Physical activity, including walking, and cognitive function in older women. *JAMA*. 2004;292(12):1454–61.
388. Whyte JJ, Laughlin MH. The effects of acute and chronic exercise on the vasculature. *Acta Physiol (Oxf)*. 2010;199(4):441–50.
389. Whyte LJ, Gill JM, Cathcart AJ. Effect of 2 weeks of sprint interval training on health-related outcomes in sedentary overweight/obese men. *Metabolism*. 2010;59(10):1421–8.
390. Wijndaele K, Healy GN, Dunstan DW, et al. Increased cardio-metabolic risk is associated with increased TV viewing time. *Med Sci Sports Exerc*. 2010;42(8):1511–8.
391. Williams DM. Exercise, affect, and adherence: an integrated model and a case for self-paced exercise. *J Sport Exerc Psychol*. 2008;30(5):471–96.
392. Williams MA, Haskell WL, Ades PA, et al. Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation*. 2007;116(5):572–84.
393. Williams PT, Thompson PD. Dose-dependent effects of training and detraining on weight in 6406 runners during 7.4 years. *Obesity (Silver Spring)*. 2006;14(11):1975–84.
394. Willy RW, Kyle BA, Moore SA, Chleboun GS. Effect of cessation and resumption of static hamstring muscle stretching on joint range of motion. *J Orthop Sports Phys Ther*. 2001;31(3):138–44.
395. Wilmore JH. Dose–response: variation with age, sex, and health status. *Med Sci Sports Exerc*. 2001;33(Suppl 6):S622–34.
396. Winchester JB, Nelson AG, Kokkonen J. A single 30-s stretch is sufficient to inhibit maximal voluntary strength. *Res Q Exerc Sport*. 2009;80(2):257–61.
397. Winters MV, Blake CG, Trost JS, et al. Passive versus active stretching of hip flexor muscles in subjects with limited hip extension: a randomized clinical trial. *Phys Ther*. 2004;84(9):800–7.
398. Wipfli B, Landers D, Nagoshi C, Ringenbach S. An examination of serotonin and psychological variables in the relationship between exercise and mental health. *Scand J Med Sci Sports* [Epub ahead of print]. 2009 [cited 2009 Dec 18]. Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0838.2009.01049.x/abstract.
399. Wisloff U, Stoylen A, Loennechen JP, et al. Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: a randomized study. *Circulation*. 2007;115(24):3086–94.
400. Witvrouw E, Mahieu N, Roosen P, McNair P. The role of stretching in tendon injuries. *Br J Sports Med*. 2007;41(4):224–6.
401. Woods K, Bishop P, Jones E. Warm-up and stretching in the prevention of muscular injury. *Sports Med*. 2007;37(12):1089–99.
402. Woolstenhulme MT, Griffiths CM, Woolstenhulme EM, Parcell AC. Ballistic stretching increases flexibility and acute vertical jump height when combined with basketball activity. *J Strength Cond Res*. 2006;20(4):799–803.
403. Writing Group for the Activity Counseling Trial Research G. Effects of physical activity counseling in primary care: the Activity Counseling Trial: a randomized controlled trial. *JAMA*. 2001;286(6):677–87.
404. Wu G. Evaluation of the effectiveness of tai chi for improving balance and preventing falls in the older population—a review. *J Am Geriatr Soc*. 2002;50(4):746–54.
405. Yaffe K, Fiocco AJ, Lindquist K, et al. Predictors of maintaining cognitive function in older adults: the Health ABC study. *Neurology*. 2009;72(23):2029–35.
406. Yau MK. Tai chi exercise and the improvement of health and well-being in older adults. *Med Sport Sci*. 2008;52:155–65.
407. Zhu N, Suarez-Lopez JR, Sidney S, et al. Longitudinal examination of age-predicted symptom-limited exercise maximum HR. *Med Sci Sports Exerc*. 2010;42(8):1519–27.