ACSM's

Guidelines for Exercise Testing and Prescription

TENTH EDITION

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AMERICAN COLLEGE of SPORTS MEDICINE
www.acsm.org

ACSM's Guidelines for Exercise Testing and Prescription

TENTH EDITION

Wolters Kluwer

Philadelphia • Baltimore • New York • London
Buenos Aires • Hong Kong • Sydney • Tokyo

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Tenth Edition

9 8 7 6 5 4 3 2 1

Printed in China

Library of Congress Cataloging-in-Publication Data

Names: American College of Sports Medicine, author, issuing body. | Riebe, Deborah, editor. | Ehrman, Jonathan K., 1962- editor. | Liguori, Gary, 1965- editor. | Magal, Meir, editor.
Title: ACSM's guidelines for exercise testing and prescription / senior editor, Deborah Riebe ; associate editors, Jonathan K. Ehrman, Gary Liguori, Meir Magal.
Other titles: American College of Sports Medicine's guidelines for exercise testing and prescription | Guidelines for exercise testing and prescription
Description: Tenth edition. | Philadelphia, PA : Wolters Kluwer Health, [2018] | Includes bibliographical references and index.
Identifiers: LCCN 2016042823 | ISBN 9781496339065
Subjects: | MESH: Motor Activity | Exercise Test—standards | Exercise Therapy—standards | Physical Exertion | Guideline
Classification: LCC RC684.E9 | NLM WE 103 | DDC 615.8/2—dc23 LC record available at
https://lccn.loc.gov/2016042823

This book is dedicated to the hundreds of volunteer professionals who have, since 1975, contributed thousands of hours developing these internationally adopted Guidelines. *Now in its 10th edition, it is the most widely circulated set of guidelines established for exercise professionals. This edition is dedicated to the editors, the writing teams, and the reviewers of this and previous editions who have not only provided their collective expertise but also sacrificed precious time with their colleagues, friends, and families to make sure that these* Guidelines *meet the highest standards in both science and practice.*

The American College of Sports Medicine (ACSM) *Guidelines* origins are within the ACSM Committee on Certification and Registry Boards (CCRB, formerly known as the Certification and Education Committee and the Preventive and Rehabilitative Exercise Committee). Today, the *Guidelines* remain under the auspices of the CCRB and have become the primary resource for anyone conducting exercise testing or exercise programs. The *Guidelines* provide the foundation of content for its supporting companion texts produced by ACSM, which include the fifth edition of *ACSM's Certification Review*, fifth edition of *ACSM's Resources for the Personal Trainer*, second edition of *ACSM's Resources for the Exercise Physiologist*, fifth edition of *ACSM's Health-Related Physical Fitness Assessment Manual*, and several other key ACSM titles.

The first edition of the *Guidelines* was published in 1975, with updated editions published approximately every 4 to 6 years. The outstanding scientists and clinicians who have served in leadership positions as chairs and editors of the *Guidelines* since 1975 are:

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Preface

The 10th edition of *ACSM's Guidelines for Exercise Testing and Prescription* will continue the efforts of the editors and contributing authors of the eighth and ninth editions to make it a true *guidelines* book rather than a sole and inclusive *resource*. It was the original intent of the *Guidelines* to be user-friendly, easily accessible, and a current primary resource for exercise and other health professionals who conduct exercise testing and exercise programs. To this effect, in this edition, text descriptions have been minimized; more tables, boxes, and figures have been included; and key Web sites conclude each chapter.

The reader of this edition of *ACSM's Guidelines for Exercise Testing and Prescription* will notice several innovations. The 10th edition of the *Guidelines* presents ACSM's new recommendations for the preparticipation health screening process, which represents a significant change from previous versions. Recommendations for the Frequency, Intensity, Time, and Type (FITT) principle of exercise prescription are presented using a new succinct format for quick reference. Some of the book content has been reorganized to make it easier to locate information quickly. Finally, there was a substantial increase in the number of external reviewers. In lieu of chapter reviewers, the 10th edition used content expert reviewers for specific sections within chapters. This included the development of an expert panel which met several times to develop the new preparticipation health screening process. We have integrated the most recent guidelines and recommendations available from ACSM position stands and other relevant professional organizations' scientific statements so that the *Guidelines* are the most current, primary resource for exercise testing and prescription. It is important for the readership to know that new themes and innovations included in the 10th edition were developed with input from the ACSM membership prior to the initiation of this project via an electronic survey and focus groups conducted at the 2014 ACSM Annual Meeting that asked respondents and participants, respectively, for their suggestions regarding the content.

Any updates made in this edition of the *Guidelines* after their publication and prior to the publication of the next edition of the *Guidelines* can be accessed from the ACSM Certification link (http://certification.acsm.org/updates). Furthermore, the reader is referred to the ACSM Get Certified link for a listing of ACSM Certifications at www.acsmcertification.org/get-certified) and to http://certification.acsm.org/outlines for detailed exam content outlines..

ACKNOWLEDGMENTS

It is in this preface that the editors of the 10th edition have the opportunity to thank the many people who helped to see this project to completion. First and foremost, we thank our families and friends for their understanding of the extensive time commitment we made to this project that encompassed over three years.

We are in great debt to the contributing authors of the 10th edition of the *Guidelines* for volunteering their expertise and valuable time to ensure the *Guidelines* meet the highest standards in exercise science and practice. The 10th edition contributing authors are listed in the following section.

The *Guidelines* review process was extensive, undergoing many layers of expert scrutiny to ensure the highest quality of content. We thank the external and ACSM Committee on Certification and Registry Boards (CCRB) reviewers of the 10th edition for their careful reviews. These reviewers are listed later in this front matter.

This book could not have been completed without the patience, expertise, and guidance of Katie Feltman, ACSM Director of Publishing. We thank Richard T. Cotton, ACSM National Director of Certification; Traci Sue Rush, ACSM Assistant Director of Certification Programs; Kela Webster, ACSM Certification Coordinator; Robin Ashman and Dru Romanini, ACSM Certification Department Assistants; Angela Chastain, ACSM Editorial Services Office; Jeffrey Potteiger, ACSM Publications Committee Chair; and the extraordinarily hardworking Publications Committee.

We thank our publisher, and in particular Michael Nobel, Executive Editor; Amy Millholen, Senior Product Development Editor; and Shauna Kelley, Marketing Manager.

We thank the ACSM CCRB for their valuable insights into the content of this edition of the *Guidelines* and council on administrative issues related to seeing this project to completion. The ACSM CCRB tirelessly reviewed manuscript drafts to ensure the content of this edition of the *Guidelines* meets the highest standards in exercise science and practice.

On a more personal note, I thank my three associate editors — Dr. Jonathan Ehrman, Dr. Gary Liguori, and Dr. Meir Magal — who selflessly devoted their valuable time and expertise to the 10th edition of the *Guidelines*. Their strong sense of commitment to the *Guidelines* emanated from an underlying belief held by the editorial team of the profound importance the *Guidelines* have in informing and directing the work we do in exercise science and practice. Words cannot express the extent of my gratitude to the three of you for your tireless efforts to see this project to completion.

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ADDITIONAL RESOURCES

ACSM's Guidelines for Exercise Testing and Prescription, *Tenth Edition*, includes additional resources for instructors that are available on the book's companion Web site at http://thepoint.lww.com/.

Instructors

Approved adopting instructors will be given access to the following additional resources:

- Brownstone test generator
- PowerPoint presentations
- Image bank
- Angel/Blackboard/Moodle ready cartridges

Nota Bene

The views and information contained in the 10th edition of *ACSM's Guidelines for Exercise Testing and Prescription* are provided as guidelines — as opposed to *standards of practice*. This distinction is an important one because specific legal connotations may be attached to standards of practice that are not attached to guidelines. This distinction is critical inasmuch as it gives the professional in exercise testing and programmatic settings the freedom to deviate from these guidelines when necessary and appropriate in the course of using independent and prudent judgment. *ACSM's Guidelines for Exercise Testing and Prescription* presents a framework whereby the professional may certainly — and in some cases has the obligation to — tailor to individual client or patient needs while balancing institutional or legal requirements.

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Abbreviations

AACVPR	American Association of Cardiovascular and Pulmonary Rehabilitation
ABI	ankle/brachial pressure index
ACC	American College of Cardiology
ACE-I	angiotensin-converting enzyme inhibitors
ACLS	advanced cardiac life support
ACS	Acute coronary syndrome
ACSM	American College of Sports Medicine
ADL	activities of daily living
ADT	androgen deprivation therapy
AEDs	automated external defibrillators
AHA	American Heart Association
AHFS	American Hospital Formulary Service
AIDS	acquired immunodeficiency syndrome
ALT	alanine transaminase
AMI	acute myocardial infarction
AMS	acute mountain sickness
ARBs	angiotensin II receptor blockers
ART	antiretroviral therapy
AS	ankylosing spondylitis
ASH	American Society of Hypertension
AST	aspartate aminotransferase
ATP III	Adult Treatment Panel III
ATS	American Thoracic Society
AV	atrioventricular
AVD	atherosclerotic vascular disease
BIA	bioelectrical impedance analysis
BLS	basic life support
BMD	bone mineral density
BMI	body mass index
BMT	bone marrow transplantation
BP	blood pressure
BUN	blood urea nitrogen
CAAHEP	Commission on Accreditation of Allied Health Education Programs
CABG(S)	coronary artery bypass graft (surgery)
CAC	coronary artery calcium
CAD	coronary artery disease
CCB	calcium channel blockers
CDC	Centers for Disease Control and Prevention
CEP	ACSM Certified Clinical Exercise Physiologist®
CHF	congestive heart failure
CKD	chronic kidney disease
CM	cardiomyopathy
CNS	central nervous system
CoAES	Committee on Accreditation for the Exercise Sciences
COPD	chronic obstructive pulmonary disease
CP	cerebral palsy
CPET	cardiopulmonary exercise test
CPISRA	Cerebral Palsy International Sport and Recreation Association
CPR	cardiopulmonary resuscitation
CPT	ACSM Certified Personal Trainer℠

CR	cardiac rehabilitation
CRF	cardiorespiratory fitness
CVD	cardiovascular disease
CWR	constant work rate
DASH	Dietary Approaches to Stop Hypertension
Db	body density
DBP	diastolic blood pressure
DBS	deep brain stimulation
DEXA	dual-energy X-ray absorptiometry
DM	diabetes mellitus
DMARD	disease-modifying antirheumatic drug
DOMS	delayed onset muscle soreness
DRI	direct renin inhibitor
DS	Down syndrome
DVR	dynamic variable resistance
EAS	European Atherosclerosis Society
ECG	electrocardiogram (electrocardiographic)
EDSS	Kurtzke Expanded Disability Status Scale
EE	energy expenditure
EI	energy intake
EIB	exercise-induced bronchoconstriction
EIM	Exercise is Medicine
EMS	emergency medical service
EP-C	ACSM Certified Exercise Physiologist[SM]
ERS	European Respiratory Society
ESC	European Society of Cardiology
ESRD	end-stage renal disease
ETT	exercise tolerance testing
Ex R_x	exercise prescription
FES-LCE	functional electrical stimulation-leg cycle ergometry
$FEV_{1.0}$	forced expiratory volume in one second
FFBd	fat-free body density
FFM	fat-free mass
FITT-VP	Frequency, Intensity, Time, Type, Volume, and Progression
FM	fat mass
FN	false negative
FP	false positive
FPG	fasting plasma glucose
FRAX	Fracture Risk Algorithm
FRIEND	Fitness Registry and the Importance of Exercise National Database
FVC	forced vital capacity
GEI	ACSM Certified Group Exercise Instructor[SM]
GFR	glomerular filtration rate
GLP-1	glucagon-like peptide 1
GOLD	Global Initiative for Chronic Obstructive Lung Disease
GXT	graded exercise test
HACE	high-altitude cerebral edema
HAPE	high-altitude pulmonary edema
HbA1C	glycolated hemoglobin
HBM	health belief model
HCTZ	hydrochlorothiazide
HDL-C	high-density lipoprotein cholesterol
HFpEF	heart failure with preserved ejection fraction
HFrEF	heart failure with reduced ejection fraction
HIIT	high intensity interval training
HIPAA	Health Insurance Portability and Accountability Act
HIV	human immunodeficiency virus
HMG-CoA	hydroxymethylglutaryl-CoA
HR	heart rate
HR_{max}	maximal heart rate
HR_{peak}	peak heart rate
HRR	heart rate reserve

HR_{rest}	resting heart rate
hs-CRP	high-sensitivity C-reactive protein
HSCT	hematopoietic stem cell transplantation
HTN	hypertension
ICD	implantable cardioverter defibrillator
ID	intellectual disability
IDF	International Diabetes Federation
IDL	intermediate-density lipoprotein
IFG	impaired fasting glucose
IGT	impaired glucose tolerance
IHD	ischemic heart disease
IMT	inspiratory muscle training
ISH	International Society of Hypertension
IVC	inspiration vital capacity
IVCD	intraventricular conduction delay
JTA	job task analysis
KSs	knowledge and skills
LABS	Longitudinal Assessment of Bariatric Surgery
LBP	low back pain
LDL-C	low-density lipoprotein cholesterol
L-G-L	Lown-Ganong-Levine
LLN	lower limit of normal
LVAD	left ventricular assist device
LVEF	left ventricular ejection fraction
LVH	left ventricular hypertrophy
MAP	mean arterial pressure
MET	metabolic equivalent
Metsyn	metabolic syndrome
MI	myocardial infarction
MR	mitral regurgitation
MS	multiple sclerosis
MSI	musculoskeletal injury
MVC	maximal voluntary contraction
MVV	maximal voluntary ventilation
6MWT	6-min walk test
NCCA	National Commission for Certifying Agencies
NCEP	National Cholesterol Education Program
NFCI	nonfreezing cold injuries
NHANES	National Health and Nutrition Examination Survey
NHLBI	National Heart, Lung, and Blood Institute
NOTF	National Obesity Task Force
NSAIDs	nonsteroidal anti-inflammatory drugs
NSTE	non–ST-segment elevation
NSTEMI	non–ST-segment elevation myocardial infarction
NYHA	New York Heart Association
OA	osteoarthritis
OGTT	oral glucose tolerance test
OSHA	Occupational Safety and Health Administration
OUES	oxygen uptake efficiency slope
PA	physical activity
PAD	peripheral artery disease
$PaCO_2$	partial pressure of carbon dioxide
PAH	pulmonary arterial hypertension
P_aO_2	partial pressure of arterial oxygen
PAR-Q+	Physical Activity Readiness Questionnaire+
PCI	percutaneous coronary intervention
PD	Parkinson disease
PEF	peak expiratory flow
PG	plasma glucose
PKU	phenylketonuria
PNF	proprioceptive neuromuscular facilitation

PPMS	primary progressive multiple sclerosis
PR	pulmonary rehabilitation
PRMS	progressive relapsing multiple sclerosis
PTCA	percutaneous transluminal coronary angioplasty
PVC	premature ventricular contraction
$\dot{Q}$	cardiac output
QTc	QT corrected for heart rate
RA	rheumatoid arthritis
RCEP	ACSM Registered Clinical Exercise Physiologist®
RER	respiratory exchange ratio
RHR	resting heart rate
1-RM	one repetition maximum
ROM	range of motion
RPE	rating of perceived exertion
RRMS	relapsing-remitting multiple sclerosis
RVH	right ventricular hypertrophy
SaO_2	percent saturation of arterial oxygen
SBP	systolic blood pressure
SCA	sudden cardiac arrest
SCD	sudden cardiac death
SCI	spinal cord injury
SCT	social cognitive theory
SD	standard deviation
SDT	self-determination theory
SEE	standard error of the estimate
SET	social ecological theory
SIT	sprint interval training
SpO_2	percent saturation of arterial oxygen
SPPB	Short Physical Performance Battery
SRT	shuttle run test
T1DM	Type 1 diabetes mellitus
T2DM	Type 2 diabetes mellitus
TAVR	transcatheter aortic valve replacement
TG	triglycerides
THR	target heart rate
TLC	total lung capacity
TN	true negative
TOBEC	total body electrical conductivity
TP	true positive
TPB	theory of planned behavior
TTM	transtheoretical model
VAT	ventilatory-derived anaerobic threshold
VC	vital capacity
$\dot{V}CO_2$	volume of carbon dioxide per minute
$\dot{V}E$	expired ventilation per minute
VF	ventricular fibrillation
VHD	valvular heart disease
VLDL	very low-density lipoprotein
$\dot{V}O_2$	volume of oxygen consumed per minute
$\dot{V}O_{2max}$	maximal volume of oxygen consumed per minute (maximal oxygen uptake, maximal oxygen consumption)
$\dot{V}O_{2peak}$	peak oxygen uptake
$\dot{V}O_2R$	oxygen uptake reserve
$\%\dot{V}O_2R$	percentage of oxygen uptake reserve
VT	ventilatory threshold
WBGT	wet-bulb globe temperature
WCT	Wind Chill Temperature Index
WHR	waist-to-hip ratio
W-P-W	Wolff-Parkinson-White

CHAPTER 1

Benefits and Risks Associated with Physical Activity

INTRODUCTION

The purpose of this chapter is to provide current information on the benefits and risks of physical activity (PA) and/or exercise. For clarification purposes, key terms used throughout the *Guidelines* related to PA and fitness are defined in this chapter. Additional information specific to a disease, disability, or health condition are explained within the context of the chapter in which they are discussed in the *Guidelines*. PA continues to take on an increasingly important role in the prevention and treatment of multiple chronic diseases, health conditions, and their associated risk factors. Therefore, *Chapter 1* focuses on the public health perspective that forms the basis for the current PA recommendations (5,26,34,70,93). *Chapter 1* concludes with recommendations for reducing the incidence and severity of exercise-related complications for primary and secondary prevention programs.

PHYSICAL ACTIVITY AND FITNESS TERMINOLOGY

PA and exercise are often used interchangeably, but these terms are not synonymous. *PA* is defined as any bodily movement produced by the contraction of skeletal muscles that results in a substantial increase in caloric requirements over resting energy expenditure (14,78). *Exercise* is a type of PA consisting of planned, structured, and repetitive bodily movement done to improve and/or maintain one or more components of physical fitness (14). *Physical fitness* has been defined in several ways, but the generally accepted definition is the ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and meet unforeseen emergencies (76). Physical fitness is composed of various elements that can be further grouped into health-related and skill-related components which are defined in *Box 1.1*.

In addition to defining PA, exercise, and physical fitness, it is important to clearly define the wide range of intensities associated with PA (see *Table 6.1*). Methods for quantifying the relative intensity of PA include specifying a percentage

Box 1.1 Health-Related and Skill-Related Components of Physical Fitness

Health-Related Physical Fitness Components

- Cardiorespiratory endurance: the ability of the circulatory and respiratory system to supply oxygen during sustained physical activity
- Body composition: the relative amounts of muscle, fat, bone, and other vital parts of the body
- Muscular strength: the ability of muscle to exert force
- Muscular endurance: the ability of muscle to continue to perform without fatigue
- Flexibility: the range of motion available at a joint

Skill-Related Physical Fitness Components

- Agility: the ability to change the position of the body in space with speed and accuracy
- Coordination: the ability to use the senses, such as sight and hearing, together with body parts in performing tasks smoothly and accurately
- Balance: the maintenance of equilibrium while stationary or moving
- Power: the ability or rate at which one can perform work
- Reaction time: the time elapsed between stimulation and the beginning of the reaction to it
- Speed: the ability to perform a movement within a short period of time

Adapted from (96). Available from http://www.fitness.gov/digest_mar2000.htm

of oxygen uptake reserve ($\dot{V}O_2R$), heart rate reserve (HRR), oxygen consumption ($\dot{V}O_2$), heart rate (HR), or metabolic equivalents (METs) (see *Box 6.2*). Each of these methods for describing the intensity of PA has strengths and limitations. Although determining the most appropriate method is left to the exercise professional, *Chapter 6* provides the methodology and guidelines for selecting a suitable method.

METs are a useful, convenient, and standardized way to describe the absolute intensity of a variety of physical activities. Light intensity PA is defined as requiring 2.0–2.9 METs, moderate as 3.0–5.9 METs, and vigorous as ≥6.0 METs (26). *Table 1.1* gives specific examples of activities in METs for each of the intensity ranges. A complete list of physical activities and their associated estimates of energy expenditure can be found elsewhere (2).

Maximal aerobic capacity usually declines with age (26). For this reason, when older and younger individuals work at the same MET level, the relative exercise intensity (*e.g.*, %$\dot{V}O_{2max}$) will usually be different (see *Chapter 6*). In other words, the older individual will be working at a greater relative percentage of maximal oxygen consumption ($\dot{V}O_{2max}$) than their younger counterparts. Nonetheless, physically active older adults may have aerobic capacities comparable to or greater than those of physically inactive younger adults.

TABLE 1.1

Metabolic Equivalents (METs) Values of Common Physical Activities Classified as Light, Moderate, or Vigorous Intensity

Very Light/Light (<3.0 METs)	Moderate (3.0–5.9 METs)	Vigorous (≥6.0 METs)
Walking	**Walking**	**Walking, jogging, and running**
Walking slowly around home, store, or office = 2.0[a]	Walking 3.0 mi · h^{-1} = 3.0[a]	Walking at very, very brisk pace (4.5 mi · h^{-1}) = 6.3[a]
	Walking at very brisk pace (4 mi · h^{-1}) = 5.0[a]	Walking/hiking at moderate pace and grade with no or light pack (<10 lb) = 7.0
		Hiking at steep grades and pack 10–42 lb = 7.5–9.0
		Jogging at 5 mi · h^{-1} = 8.0[a]
		Jogging at 6 mi · h^{-1} = 10.0[a]
		Running at 7 mi · h^{-1} = 11.5[a]
Household and occupation	**Household and occupation**	**Household and occupation**
Standing performing light work, such as making bed, washing dishes, ironing, preparing food, or store clerk = 2.0–2.5	Cleaning, heavy — washing windows, car, clean garage = 3.0	Shoveling sand, coal, etc. = 7.0
	Sweeping floors or carpet, vacuuming, mopping = 3.0–3.5	Carrying heavy loads, such as bricks = 7.5
	Carpentry — general = 3.6	Heavy farming, such as bailing hay = 8.0
	Carrying and stacking wood = 5.5	Shoveling, digging ditches = 8.5
	Mowing lawn — walk power mower = 5.5	
Leisure time and sports	**Leisure time and sports**	**Leisure time and sports**
Arts and crafts, playing cards = 1.5	Badminton — recreational = 4.5	Bicycling on flat — light effort (10–12 mi · h^{-1}) = 6.0
Billiards = 2.5	Basketball — shooting around = 4.5	Basketball game = 8.0
Boating — power = 2.5	Dancing — ballroom slow = 3.0; ballroom fast = 4.5	Bicycling on flat — moderate effort (12–14 mi · h^{-1}) = 8.0; fast (14–16 mi · h^{-1}) = 10.0
Croquet = 2.5	Fishing from riverbank and walking = 4.0	Skiing cross-country — slow (2.5 mi · h^{-1}) = 7.0; fast (5.0–7.9 mi · h^{-1}) = 9.0
Darts = 2.5	Golf — walking, pulling clubs = 4.3	Soccer — casual = 7.0; competitive = 10.0
Fishing — sitting = 2.5	Sailing boat, wind surfing = 3.0	Swimming leisurely = 6.0[b]; swimming — moderate/hard = 8.0–11.0[b]
Playing most musical instruments = 2.0–2.5	Table tennis = 4.0	Tennis singles = 8.0
	Tennis doubles = 5.0	Volleyball — competitive at gym or beach = 8.0
	Volleyball — noncompetitive = 3.0–4.0	

[a]On flat, hard surface.
[b]MET values can vary substantially from individual to individual during swimming as a result of different strokes and skill levels.

Adapted from (2).

PUBLIC HEALTH PERSPECTIVE FOR CURRENT RECOMMENDATIONS

Over 20 yr ago, the American College of Sports Medicine (ACSM) in conjunction with the Centers for Disease Control and Prevention (CDC) (73), the U.S. Surgeon General (93), and the National Institutes of Health (75) issued landmark publications on PA and health. An important goal of these reports was to clarify for exercise professionals and the public the amount and intensity of PA needed to improve health, lower susceptibility to disease (morbidity), and decrease premature mortality (73,75,93). In addition, these reports documented the dose-response relationship between PA and health (*i.e.*, some activity is better than none, and more activity, up to a point, is better than less).

In 1995, the CDC and ACSM recommended that "every U.S. adult should accumulate 30 min or more of moderate PA on most, preferably all, days of the week" (73). The intent of this statement was to increase public awareness of the importance of the health-related benefits of moderate intensity PA. As a result of an increasing awareness of the adverse health effects of physical inactivity and because of some confusion and misinterpretation of the original PA recommendations, the ACSM and American Heart Association (AHA) issued updated recommendations for PA and health in 2007 (*Box 1.2*) (34).

More recently, the federal government convened an expert panel, the 2008 Physical Activity Guidelines Advisory Committee, to review the scientific evidence on PA and health published since the 1996 U.S. Surgeon General's Report (76). This committee found compelling evidence regarding the benefits of PA for health as well as the presence of a dose-response relationship for many diseases and health conditions. Two important conclusions from the *Physical Activity*

Box 1.2 The ACSM-AHA Primary Physical Activity (PA) Recommendations (33)

- All healthy adults aged 18–65 yr should participate in moderate intensity aerobic PA for a minimum of 30 min on 5 $d \cdot wk^{-1}$ or vigorous intensity aerobic activity for a minimum of 20 min on 3 $d \cdot wk^{-1}$.
- Combinations of moderate and vigorous intensity exercise can be performed to meet this recommendation.
- Moderate intensity aerobic activity can be accumulated to total the 30 min minimum by performing bouts each lasting ≥10 min.
- Every adult should perform activities that maintain or increase muscular strength and endurance for a minimum of 2 $d \cdot wk^{-1}$.
- Because of the dose-response relationship between PA and health, individuals who wish to further improve their fitness, reduce their risk for chronic diseases and disabilities, and/or prevent unhealthy weight gain may benefit by exceeding the minimum recommended amounts of PA.

ACSM, American College of Sports Medicine; AHA, American Heart Association.

Guidelines Advisory Committee Report that influenced the development of the PA recommendations are the following:

- Important health benefits can be obtained by performing a moderate amount of PA on most, if not all, days of the week.
- Additional health benefits result from greater amounts of PA. Individuals who maintain a regular program of PA that is longer in duration, of greater intensity, or both are likely to derive greater benefit than those who engage in lesser amounts.

Similar recommendations have been made in the 2008 federal PA guidelines (http://www.health.gov/PAguidelines) (93) based on the *2008 Physical Activity Guidelines Advisory Committee Report* (76) (*Box 1.3*).

Since the release of the *U.S. Surgeon General's Report* in 1996 (93), several reports have advocated PA levels above the minimum CDC-ACSM PA recommendations (22,26,80,92). These guidelines and recommendations primarily refer to the volume of PA required to prevent weight gain and/or obesity and should not be viewed as contradictory. In other words, PA that is sufficient to reduce the risk of developing chronic diseases and delaying mortality may be insufficient to prevent or reverse weight gain and/or obesity given the typical American lifestyle. PA beyond the minimum recommendations combined with proper nutrition is likely needed in many individuals to manage and/or prevent weight gain and obesity (22,42).

Several large-scale epidemiology studies have been performed that document the dose-response relationship between PA and cardiovascular disease (CVD) and premature mortality (52,57,72,79,88,107). Williams (104) performed a meta-analysis of 23 sex-specific cohorts reporting varying levels of PA or cardiorespiratory fitness (CRF) representing 1,325,004 individual-years of follow-up and showed a dose-response relationship between PA or CRF and the risks of coronary artery disease (CAD) and CVD (*Figure 1.1*). It is clear that greater amounts of PA or increased CRF levels provide additional health benefits. *Table 1.2* provides the

Box 1.3 The Primary Physical Activity Recommendations from the *2008 Physical Activity Guidelines Advisory Committee Report* (93)

- All Americans should participate in an amount of energy expenditure equivalent to 150 min · wk^{-1} of moderate intensity aerobic activity, 75 min · wk^{-1} of vigorous intensity aerobic activity, or a combination of both that generates energy equivalency to either regimen for substantial health benefits.
- These guidelines further specify a dose-response relationship, indicating additional health benefits are obtained with 300 min · wk^{-1} or more of moderate intensity aerobic activity, 150 min · wk^{-1} or more of vigorous intensity aerobic activity, or an equivalent combination of moderate and vigorous intensity aerobic activity.
- Adults should do muscle strengthening activities that are moderate or high intensity and involve all major muscle groups in ≥2 d · wk^{-1} because these activities provide additional health benefits.

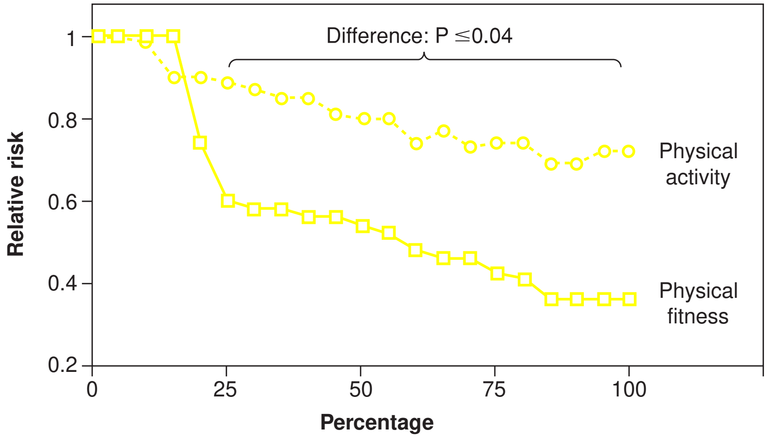

Figure 1.1 Estimated dose-response curve for the relative risk of atherosclerotic cardiovascular disease by sample percentages of fitness and physical activity. Studies weighted by individual-years of experience. Used with permission from (104).

strength of evidence for the dose-response relationships among PA and numerous health outcomes.

The ACSM and AHA have also released two publications examining the relationship between PA and public health in older adults (5,70). In general, these publications offered some recommendations that are similar to the updated guidelines for adults (26,34), but the recommended intensity of aerobic activity reflected in these guidelines is related to the older adult's CRF level. In addition, age-specific recommendations are made concerning the importance of flexibility, neuromotor, and muscle strengthening activities. The *2008 Physical Activity Guidelines for Americans* made age-specific recommendations targeted at adults (18–64 yr) and older adults (≥65 yr) as well as children and adolescents (6–17 yr) (http://www.health.gov/PAguidelines) (93) that are similar to recommendations by the ACSM and AHA.

Despite the well-known health benefits, physical inactivity is a global pandemic that has been identified as one of the four leading contributors to premature mortality (30,50). Globally, 31.1% of adults are physically inactive (30). In the United States, 51.6% of adults meet aerobic activity guidelines, 29.3% meet muscle strengthening guidelines, and 20.6% meet both the aerobic and muscle strengthening guidelines (15).

SEDENTARY BEHAVIOR AND HEALTH

Prolonged periods of sitting or sedentary behavior are associated with deleterious health consequences (see *Chapter 6*) (35,36,44,47) independent of PA levels (8,51, 63,82). This is concerning from a public health perspective because population-based studies have demonstrated that more than 50% of an average person's waking day involves activities associated with prolonged sitting such as television viewing and computer use (62). A recent meta-analysis demonstrated that after statistical adjustment

TABLE 1.2

Evidence for Dose-Response Relationship between Physical Activity and Health Outcome

Variable	Evidence for a Dose-Response Relationship	Strength of Evidence[a]
All-cause mortality	Yes	Strong
Cardiorespiratory health	Yes	Strong
Metabolic health	Yes	Moderate
Energy balance:		
Weight maintenance	Insufficient data	Weak
Weight loss	Yes	Strong
Weight maintenance following weight loss	Yes	Moderate
Abdominal obesity	Yes	Moderate
Musculoskeletal health:		
Bone	Yes	Moderate
Joint	Yes	Strong
Muscular	Yes	Strong
Functional health	Yes	Moderate
Colon and breast cancers	Yes	Moderate
Mental health:		
Depression and distress	Yes	Moderate
Well-being:		
Anxiety, cognitive health, and sleep	Insufficient data	Weak

[a]Strength of the evidence was classified as follows:
"Strong" — Strong, consistent across studies and populations
"Moderate" — Moderate or reasonable, reasonably consistent
"Weak" — Weak or limited, inconsistent across studies and populations

Adapted from (76).

for PA, sedentary time was independently associated with a greater risk for all-cause mortality, CVD incidence or mortality, cancer incidence or mortality (breast, colon, colorectal, endometrial, and epithelial ovarian), and Type 2 diabetes mellitus (T2DM) in adults (8). However, sedentary time was associated with a 30% lower relative risk for all-cause mortality among those with high levels of PA as compared with those with low levels of PA, suggesting that the adverse outcomes associated with sedentary time decrease in magnitude among persons who are more physically active (8).

HEALTH BENEFITS OF REGULAR PHYSICAL ACTIVITY AND EXERCISE

Evidence to support the inverse relationship between regular PA and/or exercise and premature mortality, CVD/CAD, hypertension, stroke, osteoporosis, T2DM, metabolic syndrome (Metsyn), obesity, 13 cancers (breast, bladder, rectal, head and neck, colon, myeloma, myeloid leukemia, endometrial, gastric cardia, kidney, lung, liver, esophageal adenocarcinoma), depression, functional health, falls, and cognitive function continues to accumulate (26,67,76). For many of these diseases and health conditions, there is also strong evidence of a dose-response relationship with PA (see *Table 1.2*). This evidence has resulted from clinical intervention studies as well as large-scale, population-based, observational studies (26,34,37,45,54,69,94,100,103).

Several large-scale epidemiology studies have clearly documented a dose-response relationship between PA and risk of CVD and premature mortality in men and women and in ethnically diverse participants (52,57,69,71,76,88,107). It is also important to note that aerobic capacity (*i.e.*, CRF) has an inverse relationship with risk of premature death from all causes and specifically from CVD, and higher levels of CRF are associated with higher levels of habitual PA, which in turn are associated with many health benefits (10,11,26,49,84,99,103). *Box 1.4* summarizes the benefits of regular PA and/or exercise.

HEALTH BENEFITS OF IMPROVING MUSCULAR FITNESS

The health benefits of enhancing muscular fitness (*i.e.*, the functional parameters of muscle strength, endurance, and power) are well established (26,93,102). Higher levels of muscular strength are associated with a significantly better cardiometabolic risk factor profile, lower risk of all-cause mortality, fewer CVD events, lower risk of developing physical function limitations, and lower risk for nonfatal disease (26). 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, blood glucose levels, insulin sensitivity, and blood pressure in individuals with mild or moderate hypertension (17,26,74). Recent evidence suggests that resistance training is as effective as aerobic training in the management and treatment of T2DM (106) and in improving the blood lipid profiles of individuals who are overweight/obese (83). Resistance training positively affects walking distance and velocity in those with peripheral artery disease (PAD) (6,106). Further health benefits attributed to resistance training were confirmed by a recent meta-analysis of published reports which revealed that regimens featuring mild-to-moderate intensity isometric muscle actions were more effective in reducing blood pressure in both normotensive and hypertensive people than aerobic training or dynamic resistance training (13). Accordingly, resistance training may be effective for preventing and treating the dangerous constellation of conditions referred to as Metsyn (26) (see *Chapter 10*).

Exercise that enhances muscle strength and mass also increases bone mass (*i.e.*, bone mineral density and content) and bone strength of the specific bones stressed and may serve as a valuable measure to prevent, slow, or reverse the loss of bone mass in individuals with osteoporosis (5,26,93) (see *Chapter 11*). Resistance training can reduce pain and disability in individuals with osteoarthritis (26,65) and has been shown to be effective in the treatment of chronic back pain (57,97).

Box 1.4 Benefits of Regular Physical Activity and/or Exercise

Improvement in Cardiovascular and Respiratory Function

- Increased maximal oxygen uptake resulting from both central and peripheral adaptations
- Decreased minute ventilation at a given absolute submaximal intensity
- Decreased myocardial oxygen cost for a given absolute submaximal intensity
- Decreased heart rate and blood pressure at a given submaximal intensity
- Increased capillary density in skeletal muscle
- Increased exercise threshold for the accumulation of lactate in the blood
- Increased exercise threshold for the onset of disease signs or symptoms (*e.g.*, angina pectoris, ischemic ST-segment depression, claudication)

Reduction in Cardiovascular Disease Risk Factors

- Reduced resting systolic/diastolic pressure
- Increased serum high-density lipoprotein cholesterol and decreased serum triglycerides
- Reduced total body fat, reduced intra-abdominal fat
- Reduced insulin needs, improved glucose tolerance
- Reduced blood platelet adhesiveness and aggregation
- Reduced inflammation

Decreased Morbidity and Mortality

- Primary prevention (*i.e.*, interventions to prevent the initial occurrence)
  - Higher activity and/or fitness levels are associated with lower death rates from CAD
  - Higher activity and/or fitness levels are associated with lower incidence rates for CVD, CAD, stroke, Type 2 diabetes mellitus, metabolic syndrome, osteoporotic fractures, cancer of the colon and breast, and gallbladder disease
- Secondary prevention (*i.e.*, interventions after a cardiac event to prevent another)
  - Based on meta-analyses (*i.e.*, pooled data across studies), cardiovascular and all-cause mortality are reduced in patients with post-myocardial infarction (MI) who participate in cardiac rehabilitation exercise training, especially as a component of multifactorial risk factor reduction (Note: randomized controlled trials of cardiac rehabilitation exercise training involving patients with post-MI do not support a reduction in the rate of nonfatal reinfarction).

Other Benefits

- Decreased anxiety and depression
- Improved cognitive function
- Enhanced physical function and independent living in older individuals
- Enhanced feelings of well-being
- Enhanced performance of work, recreational, and sport activities
- Reduced risk of falls and injuries from falls in older individuals
- Prevention or mitigation of functional limitations in older adults
- Effective therapy for many chronic diseases in older adults

CAD, coronary artery disease; CVD, cardiovascular disease.

Adapted from (45,70,94).

Preliminary work suggests that resistance exercise may prevent and improve depression and anxiety, increase vigor, and reduce fatigue (26,86).

RISKS ASSOCIATED WITH PHYSICAL ACTIVITY AND EXERCISE

Although the benefits of regular PA are well established, participation in exercise is associated with an increased risk for musculoskeletal injury (MSI) and cardiovascular complications (26). MSI is the most common exercise-related complication and is often associated with exercise intensity, the nature of the activity, preexisting conditions, and musculoskeletal anomalies. Adverse cardiovascular events such as sudden cardiac death (SCD) and acute myocardial infarction (AMI) are usually associated with vigorous intensity exercise (3,66,93). SCD and AMI are much less common than MSI but may lead to long-term morbidity and mortality (4).

Exercise-Related Musculoskeletal Injury

Participation in exercise and PA increases the risk of MSI (68,76). The intensity and type of exercise may be the most important factors related to the incidence of injury (26). Walking and moderate intensity physical activities are associated with a very low risk of MSI, whereas jogging, running, and competitive sports are associated with an increased risk of injury (26,39,40). The risk of MSI is higher in activities where there is direct contact between participants or with the ground (*e.g.*, football, wrestling) versus activities where the contact between participants or with the ground is minimal or nonexistent (*i.e.*, baseball, running, walking) (38,76). In 2012, over 6 million Americans received medical attention for sport-related injuries, with the highest rates found in children between the ages of 12 and 17 yr (91.34 injury episodes per 1,000 population) and children younger than the age of 12 yr (20.03 injury episodes per 1,000 population) (1). The most common anatomical sites for MSI are the lower extremities with higher rates in the knees followed by the foot and ankle (39,40).

The literature on injury consequences of PA participation often focuses on men from nonrepresentative populations (*e.g.*, military personnel, athletes) (43). A prospective study of community-dwelling women found that meeting the national guidelines of $\geq$150 min · wk^{-1} of moderate-to-vigorous intensity PA resulted in a modest increase in PA-related MSI compared to women not meeting the PA guidelines (68). However, the risk for developing MSI is inversely related to physical fitness level (76). For any given dose of PA, individuals who are physically inactive are more likely to experience MSI when compared to their more active counterparts (76).

Commonly used methods to reduce MSI (*e.g.*, stretching, warm-up, cool-down, and gradual progression of exercise intensity and volume) may be helpful in some situations; however, there is a lack of controlled studies confirming the effectiveness of these methods (26). A comprehensive list of strategies that may prevent MSI can be found elsewhere (12,28).

SUDDEN CARDIAC DEATH AMONG YOUNG INDIVIDUALS

The cardiovascular causes of exercise-related sudden death in young athletes are shown in *Table 1.3* (4). It is clear from these data that the most common causes of SCD in young individuals are congenital and hereditary abnormalities including

TABLE 1.3

Cardiovascular Causes of Exercise-Related Sudden Death in Young Athletes[a]

	Van Camp et al. (*n* = 100)[b] (95)	Maron et al. (*n* = 134) (60)	Corrado et al. (*n* = 55)[c] (18)
Hypertrophic CM	51	36	1
Probable hypertrophic CM	5	10	0
Coronary anomalies	18	23	9
Valvular and subvalvular aortic stenosis	8	4	0
Possible myocarditis	7	3	5
Dilated and nonspecific CM	7	3	1
Atherosclerotic CVD	3	2	10
Aortic dissection/rupture	2	5	1
Arrhythmogenic right ventricular CM	1	3	11
Myocardial scarring	0	3	0
Mitral valve prolapse	1	2	6
Other congenital abnormalities	0	1.5	0
Long QT syndrome	0	0.5	0
Wolff-Parkinson-White syndrome	1	0	1
Cardiac conduction disease	0	0	3
Cardiac sarcoidosis	0	0.5	0
Coronary artery aneurysm	1	0	0
Normal heart at necropsy	7	2	1
Pulmonary thromboembolism	0	0	1

[a]Ages ranged from 13 to 24 yr (95), 12 to 40 yr (60), and 12 to 35 yr (18). References (95) and (60) used the same database and include many of the same athletes. All (95), 90% (60), and 89% (18) had symptom onset during or within an hour of training or competition.
[b]Total exceeds 100% because several athletes had multiple abnormalities.
[c]Includes some athletes whose deaths were not associated with recent exertion. Includes aberrant artery origin and course, tunneled arteries, and other abnormalities.
CM, cardiomyopathy; CVD, cardiovascular disease.

Used with permission from (4).

hypertrophic cardiomyopathy, coronary artery abnormalities, and aortic stenosis. The absolute annual risk of exercise-related death among high school and college athletes is 1 per 133,000 men and 769,000 women (95). It should be noted that these rates, although low, include all sports-related nontraumatic deaths. Of the 136 total identifiable causes of death, 100 were caused by CVD. A more recent estimate places the annual incidence of cardiovascular deaths among young competitive athletes in the United States as 1 death per 185,000 men and 1.5 million women. (58). Some experts, however, believe the incidence of exercise-related sudden death in young sports participants is higher, ranging between 1 per 40,000 and 1 per 80,000 athletes per year (32). Furthermore, death rates seem to be higher in African American male athletes and basketball players (32,59). Experts debate on why estimates of the incidence of exercise-related sudden deaths vary among studies. These variances are likely due to differences in (a) the populations studied, (b) estimation of the number of sport participants, and (c) subject and/or incident case assignment. In an effort to reduce the risk of SCD incidence in young individuals, well-recognized organizations such as the International Olympic Committee and AHA have endorsed the practice of preparticipation cardiovascular screening (19,53,61). The recent position stand by the American Medical Society for Sports Medicine presents the latest evidence based research on cardiovascular preparticipation screening in athletes (23).

EXERCISE-RELATED CARDIAC EVENTS IN ADULTS

In general, exercise does not provoke cardiovascular events in healthy individuals with normal cardiovascular systems. The risk of SCD and AMI is very low in apparently healthy individuals performing moderate intensity PA (76,101). There is an acute and transient increase in the risk of SCD and AMI in individuals performing vigorous intensity exercise, particularly in sedentary men and women with diagnosed or occult CVD (3,4,29,66,85,90,105). However, this risk decreases with increasing volumes of regular exercise (89). *Chapter 2* includes an exercise preparticipation health screening algorithm to help identify individuals who may be at risk for exercise-related cardiovascular events.

It is well established that the transient risks of SCD and AMI are substantially higher during acute vigorous physical exertion as compared with rest (29,66,85,91,105). A recent meta-analysis reported a fivefold increased risk of SCD and 3.5-fold increased risk of AMI during or shortly after vigorous intensity PA (20). The risk of SCD or AMI is higher in middle-aged and older adults than in younger individuals due to the higher prevalence of CVD in the older population. The rates of SCD and AMI are disproportionately higher in the most sedentary individuals when they perform unaccustomed or infrequent exercise (4). For example, the Onset Study (65) showed that the risk of AMI during or immediately following vigorous intensity exercise was 50 times higher for the habitually sedentary compared to individuals who exercised vigorously for 1-h sessions $\geq$5 d · wk^{-1} (*Figure 1.2*).

Although the *relative* risks of SCD and AMI are higher during sudden vigorous physical exertion versus rest, the *absolute* risk of these events is very low.

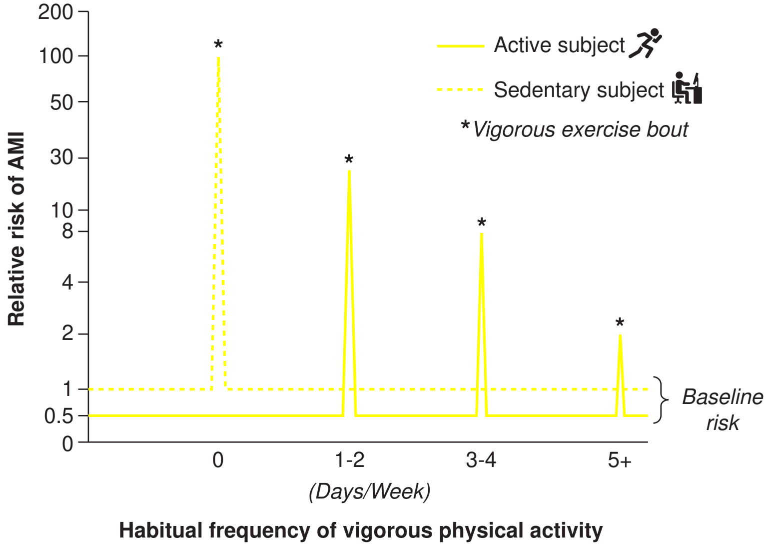

Figure 1.2 The relationship between habitual frequency of vigorous physical activity and the relative risk of acute myocardial infarction (AMI). Used with permission from (24).

Prospective evidence from the Physicians' Health Study and Nurses' Health Study suggests that SCD occurs every 1.5 million episodes of vigorous physical exertion in men (3) and every 36.5 million h of moderate-to-vigorous exertion in women (101). Retrospective analyses also support the rarity of these events. Thompson et al. (90) reported 1 death per 396,000 h of jogging. An analysis of exercise-related cardiovascular events among participants at YMCA sports centers found 1 death per 2,897,057 person-hours, although exercise intensity was not documented (55). Kim et al. (46) studied over 10 million marathon and half-marathon runners and identified an overall cardiac arrest incidence rate of 1 per 184,000 runners and an SCD incidence rate of 1 per 256,000 runners, which translates to 0.20 cardiac arrests and 0.14 SCDs per 100,000 estimated runner-hours.

Although the risk is extremely low, vigorous intensity exercise has a small but measurable acute risk of CVD complications; therefore, mitigating this risk in susceptible individuals is important (see *Chapter 2*). The exact mechanism of SCD during vigorous intensity exercise with asymptomatic adults is not completely understood. However, evidence exists that the increased frequency of cardiac contraction and excursion of the coronary arteries produces bending and flexing of the coronary arteries may be the underlying cause. This response may cause cracking of the atherosclerotic plaque with resulting platelet aggregation and possible acute thrombosis and has been documented angiographically in individuals with exercise-induced cardiac events (9,16,31).

EXERCISE TESTING AND THE RISK OF CARDIAC EVENTS

As with vigorous intensity exercise, the risk of cardiac events during exercise testing varies directly with the prevalence of diagnosed or occult CVD in the study population. Several studies have documented these risks during exercise testing (7,27,41,48,64,78,87). *Table 1.4* summarizes the risks of various cardiac events including AMI, ventricular fibrillation, hospitalization, and death. These data indicate in a mixed population the risk of exercise testing is low with approximately six cardiac events per 10,000 tests. One of these studies includes data for which the exercise testing was supervised by nonphysicians (48). In addition, the majority of these studies used symptom-limited maximal exercise tests. Therefore, it would be expected that the risk of submaximal testing in a similar population would be lower.

TABLE 1.4

Cardiac Complications during Exercise Testing[a]

Reference	Year	Site	No. of Tests	MI	VF	Death	Hospitalization	Comment
Rochmis and Blackburn (78)	1971	73 U.S. centers	170,000	NA	NA	1	3	34% of tests were symptom limited; 50% of deaths in 8 h; 50% over the next 4 d
Irving et al. (41)	1977	15 Seattle facilities	10,700	NA	4.67	0	NR	
McHenry (64)	1977	Hospital	12,000	0	0	0	0	
Atterhög et al. (7)	1979	20 Swedish centers	50,000	0.8	0.8	0.4	5.2	
Stuart and Ellestad (87)	1980	1,375 U.S. centers	518,448	3.58	4.78	0.5	NR	VF includes other dysrhythmias requiring treatment.
Gibbons et al. (27)	1989	Cooper Clinic	71,914	0.56	0.29	0	NR	Only 4% of men and 2% of women had CVD.
Knight et al. (48)	1995	Geisinger Cardiology Service	28,133	1.42	1.77	0	NR	25% were inpatient tests supervised by non-MDs.

[a]Events are per 10,000 tests.

CVD, cardiovascular disease; MD, medical doctor; MI, myocardial infarction; NA, not applicable; NR, not reported; VF, ventricular fibrillation.

TABLE 1.5

Summary of Contemporary Exercise-Based Cardiac Rehabilitation Program Complication Rates

Investigator	Year	Patient Exercise Hours	Cardiac Arrest	Myocardial Infarction	Fatal Events	Major Complications[a]
Van Camp and Peterson (96)	1980–1984	2,351,916	1/111,996[b]	1/293,990	1/783,972	1/81,101
Digenio et al. (21)	1982–1988	480,000	1/120,000[c]		1/160,000	1/120,000
Vongvanich et al. (98)	1986–1995	268,503	1/89,501[d]	1/268,503[d]	0/268,503	1/67,126
Franklin et al. (25)	1982–1998	292,254	1/146,127[d]	1/97,418[d]	0/292,254	1/58,451
Average			1/116,906	1/219,970	1/752,365	1/81,670

[a]Myocardial infarction and cardiac arrest.
[b]Fatal 14%.
[c]Fatal 75%.
[d]Fatal 0%.

Used with permission from (4).

RISKS OF CARDIAC EVENTS DURING CARDIAC REHABILITATION

The highest risk of cardiovascular events occurs in those individuals with diagnosed CAD. In one survey, there was one nonfatal complication per 34,673 h and one fatal cardiovascular complication per 116,402 h of cardiac rehabilitation (33). Other studies have found a lower rate: one cardiac arrest per 116,906 patient-hours, one AMI per 219,970 patient-hours, one fatality per 752,365 patient-hours, and one major complication per 81,670 patient-hours (21,25,96,98). These studies are presented in *Table 1.5* (4). A more recent study demonstrated an even lower rate of cardiovascular complications during cardiac rehabilitation with one cardiac arrest per 169,344 patient-hours, no AMI per 338,638 patient-hours, and one fatality per 338,638 patient-hours (81). Although these complication rates are low, it should be noted that patients were screened and exercised in medically supervised settings equipped to handle cardiac emergencies. The mortality rate appears to be six times higher when patients exercised in facilities without the ability to successfully manage cardiac arrest (4,21,25,96,98). Interestingly, however, a review of home-based cardiac rehabilitation programs found no increase in cardiovascular complications versus formal center-based exercise programs (100).

PREVENTION OF EXERCISE-RELATED CARDIAC EVENTS

Because of the low incidence of cardiac events related to vigorous intensity exercise, it is very difficult to test the effectiveness of strategies to reduce the occurrence of these events. According to a recent statement by the ACSM and AHA (4), "Physicians should not overestimate the risks of exercise because the benefits of habitual physical activity substantially outweigh the risks." This report also recommends several strategies to reduce these cardiac events during vigorous intensity exercise (4):

- Health care professionals should know the pathologic conditions associated with exercise-related events so that physically active children and adults can be appropriately evaluated.
- Physically active individuals should know the nature of cardiac prodromal symptoms (*e.g.*, excessive, unusual fatigue and pain in the chest and/or upper back) and seek prompt medical care if such symptoms develop (see *Table 2.1*).
- High school and college athletes should undergo preparticipation screening by qualified professionals.
- Athletes with known cardiac conditions or a family history should be evaluated prior to competition using established guidelines.
- Health care facilities should ensure their staff is trained in managing cardiac emergencies and have a specified plan and appropriate resuscitation equipment (see *Appendix B*).
- Physically active individuals should modify their exercise program in response to variations in their exercise capacity, habitual activity level, and the environment (see *Chapters 6* and *8*).

Although strategies for reducing the number of cardiovascular events during vigorous intensity exercise have not been systematically studied, it is incumbent on the exercise professional to take reasonable precautions when working with individuals who wish to become more physically active/fit and/or increase their PA/fitness levels. These precautions are particularly true when the exercise program will be of vigorous intensity. Although many sedentary individuals can safely begin a light-to-moderate intensity exercise program, all individuals should participate in the exercise preparticipation screening process to determine the need for medical clearance (see *Chapter 2*).

Exercise professionals who supervise exercise and fitness programs should have current training in basic and/or advanced cardiac life support and emergency procedures. These emergency procedures should be reviewed and practiced at regular intervals (see *Appendix B*). Finally, individuals should be educated on the signs and symptoms of CVD and should be referred to a physician for further evaluation should these symptoms occur.

ONLINE RESOURCES

American College of Sports Medicine Position Stand on the Quantity and Quality of Exercise:
http://www.acsm.org

2008 Physical Activity Guidelines for Americans:
http://www.health.gov/PAguidelines

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CHAPTER 2

Exercise Preparticipation Health Screening

INTRODUCTION

Historically, the exercise preparticipation health screening process centered on the risk classification (*i.e.*, low, moderate, high) of all individuals which was based on (a) the number of cardiovascular disease (CVD) risk factors and (b) the presence of signs or symptoms and/or known cardiovascular (CV), metabolic, and/or pulmonary disease. Recommendations for a preparticipation medical examination and exercise testing were then based on the risk classification and proposed exercise intensity. These recommendations were designed to avoid exposing habitually inactive individuals with known or occult CVD to the transiently heightened risks of unaccustomed vigorous intensity exercise, including sudden cardiac death (SCD) and acute myocardial infarction (AMI) as discussed in *Chapter 1*.

Although the overarching goal of exercise preparticipation health screening remains the same as in the previous editions of the *Guidelines*, the updated version of *Chapter 2*:

- Bases the exercise preparticipation health screening process on (a) the individual's current level of physical activity (PA); (b) the presence of signs or symptoms and/or known CV, metabolic, or renal disease; and (c) the desired exercise intensity because these three factors have been identified as important risk modulators of exercise-related CV events.
- No longer includes the CVD risk factor profile as part of the decision making for referral to a health care provider prior to the initiating a moderate-to-vigorous intensity exercise program.
- No longer recommends a low, moderate, or high risk classification scheme.
- Makes general recommendations for *medical clearance* versus specific recommendations for *medical exams* or *exercise tests*, leaving the manner of clearance to the discretion of the health care provider.
- Does not automatically refer individuals with pulmonary disease for medical clearance prior to the initiation of an exercise program.

This edition of the *Guidelines* not only continues to encourage preparticipation health screening for persons interested in initiating or progressing exercise or other PA programs but also seeks to further simplify the preparticipation health screening process that was updated in the ninth edition in order to remove unnecessary barriers to adopting a physically active lifestyle (23). This edition of the *Guidelines* also continues to recommend that exercise professionals consult with their medical colleagues when there are questions about patients with known disease or signs and symptoms suggestive of disease or any other concern about an individual's ability to safely participate in an exercise program. The new exercise preparticipation health screening recommendations are not a replacement for sound clinical judgment, and decisions about referral to a health care provider for medical clearance prior to the initiation of an exercise program should continue to be made on an individual basis.

This updated preparticipation process is based on the outcomes of a scientific roundtable sponsored by the American College of Sports Medicine (ACSM) in 2014 (25). The expert panel unanimously agreed that the relative risk of a CV event is transiently increased during vigorous intensity exercise as compared with rest but that the absolute risk of an exercise-related acute cardiac event is low in healthy asymptomatic individuals (see *Figure 1.2*) (1,15,19,20,28–30,35). Accordingly, preparticipation screening was deemed necessary, but screening recommendations needed refinement to better reflect the state of the science and reduce potential barriers to the adoption of PA. The new evidence-informed model for exercise preparticipation health screening is based on a screening algorithm with recommendations for medical clearance based on an individual's current PA level, presence of signs or symptoms and/or known CV, metabolic, or renal disease, and the anticipated or desired exercise intensity (25). These factors are included because among adults, the risk for activity-associated SCD and AMI is known to be highest among those with underlying CVD who perform unaccustomed vigorous PA (7,20,29). The relative risk of SCD and AMI during vigorous-to-near maximal intensity exercise is directly related to the presence of CVD and/or exertional symptoms (29) and is inversely related to the habitual level of PA (1,2,5,8,20,23,24). The relative and absolute risks of an adverse CV event during exercise are extremely low even during vigorous intensity exercise in asymptomatic individuals (26,28,30).

Insufficient evidence is available to suggest that the presence of CVD risk factors *without* underlying disease confers substantial risk of adverse exercise-related CV events. The high prevalence of CVD risk factors among adults (36), combined with the rarity of exercise-related SCD and AMI (28,29), suggests that the ability to predict these rare events by assessing risk factors is low, especially among otherwise healthy adults (29,31). Furthermore, recent evidence suggests that conventional CVD risk factor–based exercise preparticipation health screening may be overly conservative due to the high prevalence of risk factors and may generate excessive physician referrals, particularly in older adults (36). Although removed from preparticipation screening, this edition of the *Guidelines* affirms the importance of identifying and controlling CVD risk factors as an important objective of overall CV and metabolic disease prevention and management. Exercise professionals are encouraged to complete a CVD risk factor assessment with their patients/clients as part of the preexercise evaluation (see *Chapter 3*). Regardless of the number of risk factors, the exercise professional should use clinical judgment and make decisions about referral to a health care provider for medical clearance on an individual basis.

The decision to recommend general *medical clearance* rather than *medical examination* or *exercise testing* builds on changes introduced in the ninth edition of the *Guidelines* and is intended to better align with recent relevant evidence that exercise testing is not a uniformly recommended screening procedure. As noted in the ninth edition of the *Guidelines*, exercise testing is a poor predictor of acute cardiac events in asymptomatic individuals. Although exercise testing may detect flow-limiting coronary lesions via the provocation of ischemic ST-segment depression, angina pectoris, or both, SCD and AMI are usually triggered by the rapid progression of a previously nonobstructive lesion (29). Furthermore, lack of consensus exists regarding the extent of the medical evaluation (*i.e.*, physical exam; peak or symptom-limited exercise testing) needed as part of the preparticipation health screening process prior to initiating an exercise program, even when the program will be of vigorous intensity. The American College of Cardiology (ACC)/American Heart Association (AHA) recommend exercise testing prior to moderate or vigorous intensity exercise programs when the risk of CVD is increased but acknowledge that these recommendations are based on conflicting evidence and divergent opinions (9). The U.S. Preventive Services Task Force recommends against the use of routine diagnostic testing or exercise electrocardiography as a screening tool in asymptomatic individuals who are at low risk for CVD events and concluded that there is insufficient evidence to evaluate the benefits and harm of exercise testing before initiating a PA program. Furthermore, the U.S. Preventive Services Task Force did not make specific recommendations regarding the need for exercise testing for individuals at intermediate and high risk for CVD events (22). Similarly, others have emphasized that randomized trial data on the clinical value of exercise testing for screening purposes are absent; in other words, it is presently not known if exercise testing in asymptomatic adults reduces the risk of premature mortality or major cardiac morbidity (17). The 2008 Physical Activity Guidelines Advisory Committee Report to the Secretary of Health and Human Services (23) states that "symptomatic persons or those with cardiovascular disease, diabetes, or other active chronic conditions who want to begin engaging in *vigorous* PA and who have not already developed a PA plan with their health care provider may wish to do so" but does not mandate medical clearance. There also is evidence from decision analysis modeling that routine screening using exercise testing prior to initiating an exercise program is not warranted regardless of baseline individual risk (16). These considerations and other recent reports (10,23) further shaped the present ACSM recommendation that the inclusion of exercise testing or any other type of exam, as part of medical clearance, should be left to the clinical judgment of qualified health care providers.

In the new exercise preparticipation health screening procedures, individuals with pulmonary disease are no longer automatically referred for medical clearance because pulmonary disease does not increase the risks of nonfatal or fatal CV complications during or immediately after exercise; in fact, it is the associated inactive and sedentary lifestyle of many patients with pulmonary disease that may increase the risk of these events (13). However, chronic obstructive pulmonary disease

(COPD) and CVD are often comorbid due to the common risk factor of smoking, and the presence of COPD in current or former smokers is an independent predictor of overall CV events (6). Thus, careful attention to the presence of signs and symptoms of CV and metabolic disease is warranted in individuals with COPD during the exercise preparticipation health screening process. Nevertheless, despite this change, the presence of pulmonary or other diseases remains an important consideration for determining the safest and most effective exercise prescription (Ex R_x) (25).

The goals of the new ACSM exercise preparticipation health screening process are to identify individuals (a) who should receive medical clearance before initiating an exercise program or increasing the frequency, intensity, and/or volume of their current program; (b) with clinically significant disease(s) who may benefit from participating in a medically supervised exercise program; and (c) with medical conditions that may require exclusion from exercise programs until those conditions are abated or better controlled. This chapter provides guidance for using the new exercise preparticipation health screening algorithm with respect to:

- Determining current PA levels
- Identifying signs and symptoms of underlying CV, metabolic, and renal disease (*Table 2.1*)
- Identifying individuals with diagnosed CV and metabolic disease
- Using signs and symptoms, disease history, current exercise participation, and desired exercise intensity to guide recommendations for preparticipation medical clearance

By following a preparticipation screening algorithm taking into account the preceding points, exercise professionals are better able to identify participants who are at risk for exercise- or PA-related CV complications. The algorithm is designed to identify individuals who should receive medical clearance before initiating an exercise program or increasing the frequency, intensity, and/or volume of their current program and may also help to identify those with clinically significant disease(s) who may benefit from participating in a medically supervised exercise program and those with medical conditions that may require exclusion from exercise programs until those conditions are abated or better controlled (18,25).

PREPARTICIPATION HEALTH SCREENING

The following section provides guidance for preparticipation screening for exercise professionals working with the general, nonclinical population. Recommendations for those individuals who are working in a clinical or cardiac rehabilitation setting are presented separately, later in the chapter.

Preparticipation health screening before initiating PA or an exercise program is a two-stage process:

1. The need for medical clearance before initiating or progressing exercise programming is determined using the updated and revised ACSM screening algorithm (see *Figure 2.2*) and the help of a qualified exercise or health