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AHA Scientific Statement

Guide to the Assessment of Physical Activity: Clinical and Research Applications

A Scientific Statement From the American Heart Association

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Approximately 60 years ago, the foundational works of Jeremy Morris and colleagues showed that the incidence of coronary heart disease in bus conductors who climbed up and down stairs of double-deck buses collecting tickets and in postal carriers who delivered the mail on foot was lower than that of the relatively inactive bus drivers or postal office workers who spent most of their occupational time sitting.[1,2] Since then, numerous other investigators have confirmed the strong link between physical activity and health in a variety of populations.[3] The accumulation of evidence connecting physical activity to health led the American Heart Association to include physical inactivity as a major risk factor for coronary artery disease in 1992.[4] A recent report characterized the impact of physical inactivity as similar to that of smoking in relation to the burden of noncommunicable diseases worldwide.[5] The deleterious effects of physical inactivity are associated with many of the most common chronic diseases and conditions, including heart disease, type 2 diabetes mellitus, hypertension, obesity, osteoporosis, depression, and breast and colorectal cancers.[5,6] In the United States, chronic diseases cause 7 in 10 deaths and account for ≈75% of all healthcare spending.[7] Chenoweth and Leutzinger[8] used data from direct medical expenditures, workers' compensation, and productivity loss to calculate that in 2003, the financial impact of physical inactivity for all US adults was ≈$251 billion.

A physically active lifestyle is 1 of the top 10 health indicators for Americans in the Healthy People 2020 objectives[9] and is 1 of the 7 goals listed for ideal cardiovascular health in the 2020 American Heart Association Impact Goals.[10] In September 2012, the Global Cardiovascular Disease Taskforce, which comprises an international panel of experts in cardiovascular and noncommunicable disease communities, released a joint communication that set a goal of a 10% relative reduction in the prevalence of insufficient physical activity, which is 1 of the top 4 evidenced-based global targets to reduce noncommunicable disease.[11]

The first public health recommendations for physical activity in the United States were released in 1995,[12] and these were followed by additional and updated recommendations in 1996[3] and 2007.[13,14] In 2008, the body of evidence culminated in the first-ever federal guidelines for physical activity.[6] These guidelines simplified the message for the general public concerning health-enhancing levels of physical activity and included the following recommendations: (1) Adults should avoid inactivity (ie, some physical activity is better than none); (2) substantial health benefits are obtained from accumulating, in bouts of ≥10 minutes, 150 minutes per week of moderate-intensity or 75 minutes per week of vigorous-intensity aerobic activity, or an equivalent combination of both; (3) additional and more extensive health benefits are obtained by increasing aerobic physical activity to 300 minutes per

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week at moderate intensity or 150 minutes per week at vigorous intensity or an equivalent combination of both; and (4) muscle-strengthening activities of moderate to high intensity should be performed ≥2 days per week.

Despite the well-established individual benefit of leading a physically active lifestyle and the broader public health impact of reducing chronic disease risk and premature mortality, too many US adults are insufficiently physically active. Estimates of adult physical activity levels and prevalence vary. For example, data from the 2005 National Health Interview Survey reported 31% of US adults obtained regular physical activity (defined as ≥30 minutes of moderate-intensity physical activity on 5 days of the week or ≥20 minutes of vigorous-intensity physical activity on 3 days of the week)[15]; however, the 2007 Behavioral Risk Factor Surveillance System telephone survey suggested 49% of US adults were obtaining the same recommended amount of physical activity.[16] These survey-derived findings differ from the 2003–2004 National Health and Nutritional Examination Survey's accelerometer-based assessment that reported <5% of adults were regularly active (defined as having accumulated ≥30 minutes of moderate or greater intensity activity in ≥8–10-minute bouts during a day on ≥5 days of 1 week).[17] These discrepancies highlight the need for routine and consistent assessment of physical activity in research and clinical settings to improve risk factor identification, minimize physical inactivity, and further advance our understanding of the health-related impact. Understandably, research versus clinical setting differences present unique challenges to the routine assessment of physical activity, but there are numerous tools (subjective and objective) available to both settings that may make such assessment feasible and sustainable.

Recently, subjective (eg, self-report)[18] and objective (eg, accelerometer) measurement[19] methods for assessing physical activity were reviewed. Although these reports provide evidenced-based appraisals and application information for the methods reviewed, they do not provide clear recommendations for use. At present, there is little information available to guide the selection of a physical activity assessment method that is appropriate for the wide variety of potential applications. Consider an example in which a clinician desires to assess physical activity as a health indicator, similar to the standard assessments made for all other cardiovascular disease risk factors. The assessment of physical activity is needed to allow the clinician to provide specific recommendations for patients identified as insufficiently active. In selecting the appropriate physical activity assessment method, several questions must be considered, such as the physical activity dimensions and domains that are desired, the number of patients who will be assessed, the costs, the personnel requirements, and how quickly the results are needed. In different settings, the same underlying questions could be used to guide the selection of the best measurement tool that is feasible, practical, sensitive enough to detect change, and sustainable in those settings.

With the documented health benefits of a physically active lifestyle as its guiding principle, this scientific statement recommends that physical activity be assessed regularly, as are the other major risk factors. The primary objectives of this statement are to (1) provide the rationale for the importance of assessing physical activity, (2) explain key concepts involved in the assessment of physical activity, and (3) provide an overview of options for assessment of physical activity available to clinicians and researchers. A decision matrix is presented as a tool to guide the selection of the best physical activity assessment method based on specific needs of clinicians and researchers.

Key Concepts for Understanding Physical Activity Assessment

Physical Activity

Before one considers units of measure in physical activity assessment, assessment options/tools, their inherent strengths and weaknesses, and other practical considerations that inform best-practice recommendations, it is necessary to define key concepts, starting with the definition of physical activity. The most popular and widely cited definition of physical activity was published by Caspersen and colleagues in 1985.[20] *Physical activity* was defined as "any bodily movements produced by skeletal muscles that result in energy expenditure." This term is commonly used as an abbreviation for health-enhancing physical activity. Other iterations of this definition have been proposed and used; however, most are a derivation of the definition by Caspersen et al.[20]

Physical activity can either be classified as structured or incidental. Structured physical activity or *exercise* is planned, purposeful activity undertaken to promote health and fitness benefits.[20] Incidental physical activity is not planned and usually is the result of daily activities at work, at home, or during transport.

Dimensions and Domains of Physical Activity

The 4 dimensions of physical activity include (1) mode or type of activity, (2) frequency of performing activity, (3) duration of performing activity, and (4) intensity of performing activity. Table 1 identifies, defines, and contextualizes the 4 dimensions.

In addition to the dimensions of physical activity, the domains in which physical activity occurs are central to understanding the assessment of physical activity. This is particularly important when behavior change is the intended goal. Four common domains of physical activity are occupational, domestic, transportation, and leisure time. Table 2 presents this 4-category classification schema with contextual definitions and examples.

Historically, approaches to promoting physical activity focused on leisure time physical activity, and assessment instruments were developed and validated accordingly; however, because health-enhancing physical activity may occur in any and all of these domains, assessment of total physical activity should capture each of the 4 domains. This is evident because a substitution effect can materialize; for instance, an increase in physical activity in one domain (eg, occupation) may be compensated by a decreased activity in another domain (eg, leisure time). Therefore, it becomes paramount that all domains be captured; otherwise the assessment of total physical activity will be incomplete.

Table 1. Physical Activity Dimensions: Mode, Frequency, Duration, and Intensity

Dimension	Definition and Context
Mode	Specific activity performed (eg, walking, gardening, cycling). Mode can also be defined in the context of physiological and biomechanical demands/types (eg, aerobic versus anaerobic activity, resistance or strength training, balance and stability training).
Frequency	Number of sessions per day or per week. In the context of health-promoting physical activity, frequency is often qualified as number of sessions (bouts) ≥10 min in duration/length.
Duration	Time (minutes or hours) of the activity bout during a specified time frame (eg, day, week, year, past month).
Intensity	Rate of energy expenditure. Intensity is an indicator of the metabolic demand of an activity. It can be objectively quantified with physiological measures (eg, oxygen consumption, heart rate, respiratory exchange ratio), subjectively assessed by perceptual characteristics (eg, rating of perceived exertion, walk-and-talk test), or quantified by body movement (eg, stepping rate, 3-dimensional body accelerations).

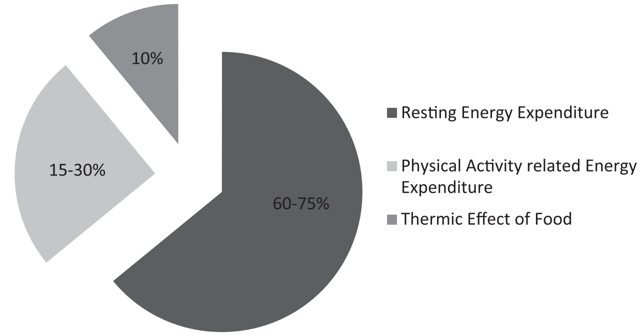


Figure 1. Components of typical total daily energy expenditure. Resting energy expenditure indicates the energy needed to maintain vital life functions during basal and sleeping conditions; physical activity–related energy expenditure, the energy needed to maintain movement demand above that of resting conditions; and thermic effect of food, the energy required for purposes of digestion and the breakdown of food stuff. Modified from McArdle et al.[21]

Quantifying Units of Measure Indicative of Physical Activity Level

Physical activity results in an increase in energy expenditure above resting levels, and the rate of energy expenditure is directly linked to the intensity of the physical activity. The energy expended during physical activity is just 1 of the 3 components of total daily energy expenditure, as shown in Figure 1. Physical activity–related energy expenditure (PAEE) is the most variable portion of total daily energy expenditure.

Physical activities are commonly quantified by determining the energy expenditure in kilocalories or by using the metabolic equivalent (MET) of the activity. Another common method is to compute how much time a person spends in different physical activity intensity categories on a given day or over a given week.

Kilocalories

One liter of oxygen consumption is approximately equal to 5 kcal of energy.[21] Consider the example of a 70-kg individual walking for 30 minutes at 4 mph, which results in an oxygen consumption of 1 L/min. For this 30-minute walk, the individual would consume 30 L of oxygen. In this example, the gross (including resting) energy expenditure would be ≈150 kcal (30 L×5 kcal/L). The net or PAEE would be ≈112.5 kcal (30 L×[5−1.25 (resting kilocalories expenditure)] kcal/L). Daily PAEE would be the sum of all the different physical activities performed on a given day. Energy expenditure during ambulatory physical activity increases directly with the mass of the body being moved. For this reason, energy expenditure is sometimes expressed relative to body mass as kilocalories per kilogram of body mass per minute ($kcal \cdot kg^{-1} \cdot min^{-1}$).

Metabolic Equivalent

The MET is a common unit used to express exercise intensity. One MET represents the resting energy expenditure during quiet sitting and is commonly defined as 3.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ or ≈250 mL/min of oxygen consumed, which represents the average value for a standard 70-kg person. METs can be converted to kilocalories (1 MET=1 $kcal \cdot kg^{-1} \cdot h^{-1}$). These values represent approximations, because factors of sex, age, and body composition will affect measures of resting energy expenditure, and thus, actual MET values may vary.[21]

Oxygen consumption increases with the intensity of physical activity. Thus, a simple approach to quantifying the intensity of physical activity is to use multiples of resting energy expenditure. For example, performing an activity that requires an oxygen consumption of 10.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ is equal to 3 METs (ie, 3 times the resting level). Physical activity volume, or total physical activity level, can therefore be estimated by multiplying the dimensions of intensity, duration, and frequency over a given time period, typically 1 day or 1 week. For example, the total daily volume associated with the transportation domain for an individual who walked to and from work, each bout lasting 30 minutes and performed at an intensity of 3 METs, would be calculated as follows:

$$\begin{gathered}3\ \text{METs}\ (\text{intensity}) \times 30\ \text{min}\ (\text{duration}) \\ \times 2\ \text{times per day}\ (\text{frequency})\end{gathered} = \begin{gathered}180\ \text{MET}\cdot\text{min}^{-1}\cdot\text{d}^{-1} \\ \text{or } 3\ \text{MET}\cdot\text{h}^{-1}\cdot\text{d}^{-1}\end{gathered}$$

Table 2. Physical Activity Domains

Domain	Contextual Definition or Examples
Occupational	Work-related: involving manual labor tasks, walking, carrying or lifting objects
Domestic	Housework, yard work, child care, chores, self-care, shopping, incidental
Transportation/utilitarian	Purpose of going somewhere: walking, bicycling, climbing/descending stairs to public transportation, standing while riding transportation
Leisure time	Discretionary or recreational activities: sports, hobbies, exercise, volunteer work

Moderate- and Vigorous-Intensity Physical Activity

Perhaps one of the most common measures of interest from a physical activity assessment is simply the amount of time an individual spends in a specified physical activity intensity threshold range. For example, assessments frequently seek to determine whether an individual is meeting the 2008 physical activity guidelines for Americans[6] of a cumulative 150 minutes per week of moderate-intensity physical activity or 75 minutes per week of vigorous-intensity physical activity. Moderate-intensity and vigorous-intensity physical activity can be defined in both absolute and relative terms. Absolute intensity is determined by the external work performed, whereas relative intensity is determined relative to an individual's level of cardiorespiratory fitness ($\dot{V}O_2max$). Standard definitions for both relative and absolute intensity are shown in Table 3. Walking, for instance, is often described as a moderate-intensity physical activity; however, the actual intensity for an individual may vary. In absolute terms, walking at a speed of ≈3 mph is equivalent to 3 METs, which meets the criteria for moderate intensity. However, a difference can be noted when one compares individuals of different fitness levels (person A with a $\dot{V}O_2max$ of 17.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ [5 METs] versus person B with a $\dot{V}O_2max$ of 42 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ [12 METs]) walking together at a speed of 3 mph. From an absolute standpoint, both person A and person B are performing at the same absolute level of physical activity intensity (3 METs). From a relative standpoint, though, person A is performing at a hard-intensity level (walking at 60% of $\dot{V}O_2max$), whereas person B is performing a light-intensity activity (walking at 25% of $\dot{V}O_2max$).

Available Methods of Assessing Physical Activity

There are 2 broad categories of methods available to assess physical activity: subjective methods and objective methods. Subjective methodologies rely on the individual either to record activities as they occur or to recall previous activities. Objective methodologies include all wearable monitors that directly measure 1 or more biosignals, such as acceleration, heart rate, or some other indicator of physical activity or energy expenditure, as they occur.

Table 3. Classification of Physical Activity Intensity

	Relative Intensity			Absolute Intensity	
Intensity	$\dot{V}O_2max$ (%) Heart Rate Reserve, %*	Maximal Heart Rate, %	RPE	Intensity	METs
Very light	<25	<30	<9	Sedentary	1–1.5
Light	25–44	30–49	9–10	Light	1.6–2.9
Moderate	45–59	50–69	11–12	Moderate	3.0–5.9
Hard	60–84	70–89	13–16	Vigorous	≥6.0
Very hard	≥85	≥90	>16		
Maximal	100	100	20		

METs indicates metabolic equivalents; RPE, rating of perceived exertion; and $\dot{V}O_2max$, maximal aerobic capacity.

*% Heart rate reserve (HRR) formula=Maximal heart rate (HR)−resting HR=HRR; calculate HRR target by (HRR×%value)+resting HR.

Modified from *Physical Activity and Health: A Report of the Surgeon General*.[3(p33)]

Subjective Methods of Assessing Physical Activity

Two types of subjective methods are used to assess physical activity: questionnaires and diaries/logs.

Physical Activity Questionnaires

Physical activity questionnaires are used to identify the dimensions and domains of physical activity behaviors from either self-reported responses or interviews. Questionnaires vary in their detail, ranging from a few items that give a global overview of activity to a long, detailed quantitative history of activity over the past year or even a lifetime. Physical activity questionnaires are classified into 3 categories: global, recall, and quantitative history. Overall, validation studies of questionnaires show strong correlations and agreement with other construct criteria measures for vigorous-intensity physical activity, but they are generally less accurate for light- to moderate-intensity activities.[22–24] Discriminant validation studies have shown that questionnaires are able to classify individuals in rank order according to activity level,[25] so in other words, within a sample, they are able to discern who is less or more physically active. Table 4 provides an overview of some of the most commonly used global, recall, and quantitative history questionnaires, along with questionnaire characteristics and key references that provide validity information to help inform choice when considering a questionnaire as a physical activity assessment tool.

Global Physical Activity Questionnaires

Global questionnaires provide a quick overview of a person's physical activity level. Global questionnaires are typically short (2 to 4 items) and are used to identify whether an individual meets a physical activity standard (eg, 150 min/wk of moderate to vigorous physical activity) or to provide a classification (eg, active versus inactive). As a self-administered tool, global questionnaires are preferred in many clinical settings, epidemiological studies, and surveillance settings for their ease of administration, brevity, and ability to determine a physical activity score.

One example of a commonly used global questionnaire is the Exercise Vital Sign. This 2-item global questionnaire is used in electronic medical records to assess the minutes per week patients spent in moderate- or vigorous-intensity activity. Administration to nearly 2 million patients in a healthcare setting showed the questionnaire had good discriminant validity when the proportions of patients classified as inactive, insufficiently active, or sufficiently active were compared with national physical activity surveillance data.[26]

Short Recall Physical Activity Questionnaires

Short recall physical activity questionnaires provide a quick assessment of the total volume of physical activity classified by dimension of intensity level or by domain. Short recalls often are used to determine the proportion of adults meeting national physical activity guidelines in surveillance and descriptive epidemiology settings[45,71,72] and to identify physical activity behavior change in intervention studies.[73] Types of activities surveyed include moderate- and vigorous-intensity categories or selected activities and behaviors such as walking, stair climbing, and sitting. Short recall physical activity questionnaires generally have from 7 to 12 items and can be

Table 4. Available Sample of Subjective Physical Activity Assessment Methods

Instrument	Number of Items	Administration Mode	Summary Score Unit	Dimensions Assessed*	Domains Assessed†	Setting	Population	Key References
Global								
Exercise Vital Sign	2	Self	min/wk	5	2	Clinic	Adults	26
EPIC PAQ	4	Self	min/wk, MET·h⁻¹·wk⁻¹	1, 3, 4	2, 3, 4	Community	Adults	27, 28
Godin Leisure Time Exercise	4	Self	Total leisure activity score	1, 2, 3	3	Worksite, community	Adults, men, women, white, black, Asian, Latino, MS patients	23, 29–33
Lipid Research Clinics	4	Self, interviewer	Activity score	5	3, 4	Community	Adults, older adults, men, women, white	23, 34–37
Minnesota Heart Health	4	Self	5- Point score	4	3	Community	Adults, men, women, white	23, 37, 38
Physical Activity Vital Sign	2	Self, interviewer	min/wk	5	2	Clinic	Adults	39
Rapid Assessment of Physical Activity	7 (9)	Self, telephone	Active score	5	2	Clinic, community	Older adults	40, 41
Stanford Usual PAQ	11	Interviewer	Activity score	2	3	Community	Adults, older adults, men, women, white	23, 34, 42
Short recall								
ARIC-Baecke	16	Self	Work index, nonsport leisure, total score	2, 3	3, 4	Community	Adults, men, women, white	35, 37, 43
Aerobic Center Longitudinal Study	15	Self	PA index from total energy expenditure in kcal/wk	1, 2, 3, 4	3, 6	Community	Men, adults, older adults, white	44
BRFSS, 2001	Varies	Telephone interviewer	Continuous or categorical score; min/wk	1, 2, 3, 5	1, 3, 5, 6	Community	Men, women, adults, white, black, Hispanic	45–48
CARDIA	60	Self	Weighted frequency	2, 3	3, 4	Community	Adults, men, women, white	23, 37, 38
CHAMPS	33	Self	Activity scores, MET·min⁻¹·wk⁻¹, kcal/wk	1, 2, 3, 4	3	Community	Older adults, white, men, women	49, 50
Global PAQ	16	Interviewer	Continuous or categorical score; MET·min⁻¹·wk⁻¹	2, 3, 4, 5	1, 2, 3, 4, 5	Community	Adults	51
International PAQ short	4	Telephone interviewer, self	Continuous or categorical score; MET·min⁻¹·wk⁻¹	1, 2, 3, 6	3, 4, 5, 6	Community	Adults, men, women, older adults, white, Chinese, Japanese, Latino, Hispanic, black	52, 53
International PAQ long	27	Telephone interviewer, self	Continuous or categorical score; MET·min⁻¹·wk⁻¹	1, 2, 3, 6	3, 4, 5, 6	Community	Adults, adolescents, men, women, white, Chinese, Japanese, Latino, Hispanic, black	52

(*Continued*)

Table 4. Continued

Instrument	Number of Items	Administration Mode	Summary Score Unit	Dimensions Assessed*	Domains Assessed†	Setting	Population	Key References
Kaiser PAQ (KPAS)	75	Interviewer, self	Activity index (1–5), total activity index	2, 3, 4	2, 3, 4, 6	Community	Adults, women, pregnant women, white	54, 55
LOPAR		Interviewer	$MET{\cdot}h^{-1}{\cdot}wk^{-1}$	1, 2, 3	3, 4, 6	Clinic	Adults	56
Pregnancy PAQ	32	Self	$MET{\cdot}h^{-1}{\cdot}wk^{-1}$	2, 3	3, 4, 5, 6	Community	Pregnant women, white, black, Hispanic	57
Seven-day PA Recall	4–8	Interviewer	$MET{\cdot}min^{-1}{\cdot}wk^{-1}$, $MET{\cdot}h^{-1}{\cdot}wk^{-1}$	1, 2, 3	3, 4	Community, clinic	Adults, older adults, children, adolescents, men, women, black, Asian, Hispanic	23, 34, 37
Yale PAQ (YPAS)	25	Interviewer	Activity index (kcal/wk), total time index (h/wk), summary index	1, 2, 3, 6	1, 3, 6	Clinic	Older adults, adults, men, women, white	34, 58, 59
Quantitative history								
Friedenrich Lifetime Leisure	Varies	Interviewer	$MET{\cdot}h^{-1}{\cdot}wk^{-1}$, day, month, year	1, 2, 3	3, 4, 6	Recovery group	Adults, older adults, women, white, Asian	60
Minnesota LTPA	63	Interviewer	Total metabolic activity index	4	3, 6	Community, military	Older adults, adults, men, women, white, Spanish, black	34, 35, 43, 58, 61–65
Modifiable Activity Questionnaire	Varies	Interviewer, self	h/wk, $MET{\cdot}h^{-1}{\cdot}wk^{-1}$	2, 3, 4	3, 4	Community	Adults, men, women, Native American, white, Iranian	66–70
Tecumseh Self-Administered Occupational PAQ	29	Self	Work activity units, transportation activity units, walking, bicycling, stair activity units	6	4	Community	Adults, men, women, white, black	23, 37, 43, 61

Physical activity questionnaires represent a listing of commonly used measures; this does not represent an exhaustive list.

ARIC indicates Atherosclerosis Risk in Communities; BRFSS, Behavioral Risk Factor Surveillance Survey; CARDIA, Cardiovascular Risk Development in Young Adults; CHAMPS, Community Healthy Activities Model Program for Seniors; EPIC, European Prospective Investigation Into Cancer and Nutrition; KPAS, Kaiser Physical Activity Survey; LOPAR, Low-level physical activity recall; LTPA, leisure-time physical activity; MET, metabolic equivalent; MS, multiple sclerosis; PA, physical activity; PAQ, physical activity questionnaire; and YPAS, Yale Physical Activity Survey.

*Dimensions assessed: 1=intensity, 2=frequency, 3=duration, 4=total physical activity, 5=meeting physical activity guidelines, and 6=energy expenditure.

†Domains assessed: 1=walking, 2=lifestyle, 3=leisure time, 4=occupational, 5=transportation, and 6=household.

self-administered or interviewer administered. A physical activity score can be a simple ordinal number, with higher numbers reflecting greater levels of activity, or a volume score computed by multiplying the frequency in sessions per week (or month), minutes per session, and intensity of the activity recalled. The intensity often is expressed as METs. The "Compendium of Physical Activities: Classification of Energy Costs of Human Physical Activities"[74] was published in 1993, with updates in 2000 and 2011.[75,76] This publication provides a comprehensive list of physical activity MET values for use in scoring physical activity questionnaires. Once a MET value is obtained for a physical activity performed, an activity score can be computed. An example of a short recall physical activity questionnaire is the International Physical Activity Questionnaire.[52]

Quantitative History Physical Activity Questionnaires

Quantitative history physical activity questionnaires are detailed surveys often performed over the past month or year or over a lifetime. The questionnaires may contain 20 to 60 detailed questions and are usually interviewer administered. Quantitative history questionnaires generally are used in epidemiological studies to understand what types and intensities of physical activity contribute to mortality, as well as to examine various types of morbidities and health-enhancing behaviors.[77–79] The value of using the quantitative history approach is its ability to obtain an estimate of one's physical activity volume during periods in the past that may be relevant to one's current health status. One example commonly used is the Bone Loading History Questionnaire,[80] which is a recall of physical activities performed at various ages from childhood to the past year for determination of hip and spine weight-bearing and bone-loading activities.

Physical Activity Diaries/Logs

Diaries are often used to obtain a detailed hour-by-hour or activity-by-activity record of one's physical activity and sedentary behaviors. Researchers use diaries to evaluate the psychometric properties of physical activity questionnaires and as an adjunct to objective monitoring. Diaries are completed by the user and can be in the form of a paper-and-pencil booklet[81] or a cell phone programmed to remind the user to enter information about current activities or activities performed in the past 1 to 4 hours.[82] The type of information recorded varies but generally includes the time an activity started and stopped, a rating of intensity, and the mode/type of activity. The diaries can be scored by use of the "Compendium of Physical Activities."[75] Physical activity diaries can also be used as part of an ecological momentary assessment[83,84] to better understand social and physical contextual information. Such data are able to record significant features of the immediate situation and to examine how that situation affects physical activity behavior in that particular setting and moment in time.[85]

The Bouchard Physical Activity Record is a well-known physical activity log that has users identify 1 of 9 types of movement behaviors performed every 15 minutes.[86] The activities are rated on a 1 to 9 scale that corresponds to a range of 1.0 to 7.8 METs. To score the log, the numbers are summed and multiplied by the assigned MET values, and estimations of energy expenditure per day (kcal/kg of body weight) can be derived. An example of another log is that of Ainsworth and colleagues,[87] who developed and implemented a 7-page log (1 page for each day) that contained 48 items (7 resting/light intensity [<3.0 METs], 25 moderate intensity [3–6 METs], and 16 vigorous intensity [>6 METs]), organized by different physical activity domains.

Objective Methods of Assessing Physical Activity

There are numerous methods available to objectively assess physical activity. For the purpose of this scientific statement, objective methods will be separated into the following categories: measures of energy expenditure, physiological measures, motion sensors, and assessment methods that combine more than one type of sensor.

Measures of Energy Expenditure

Indirect Calorimetry

Measuring energy expenditure by indirect calorimetry entails measurement of the ventilatory volume and the amounts of oxygen consumed and carbon dioxide produced. It is considered the reference, or criterion, method for measuring energy expenditure under controlled conditions (ie, in a laboratory).

The most commonly used form of indirect calorimetry employs an open-circuit system in which a person breathes either room air or a mixture of gases of known concentration and the expired amounts of oxygen and carbon dioxide are analyzed. Different types of open systems are available, including whole-body room calorimeters and computerized metabolic cart systems. Detailed reviews of the theory and assumptions underlying these methods are available elsewhere.[88–90]

The Doubly Labeled Water Method

The doubly labeled water (DLW) method measures total energy expenditure in free-living individuals over a period of 1 to 3 weeks. The method was first used in humans in the early 1980s[91–93] and has contributed significantly to our understanding of human energy expenditure. When combined with measurements of resting energy expenditure and the thermic effect of food, the DLW method can be used to calculate PAEE.

The basic principle of the DLW method relies on the difference in elimination rates between 2 stable isotopes, oxygen-18 (^{18}O) and deuterium (^{2}H). Known quantities of these stable (nonradioactive) and completely safe isotopes are ingested as water. The isotopes are distributed in the body water pool, and labeled deuterium is eliminated from the body as water, whereas the labeled oxygen isotope (^{18}O) is eliminated as both water and carbon dioxide. Thus, the difference in elimination rate between these isotopes represents the carbon dioxide production over the measurement time. From the isotope disappearance curves, 4 parameters are deduced: the 2 pool sizes of ^{2}H and ^{18}O and the fractional rate constants of elimination for each of these isotopes. These variables are thereafter used to estimate carbon dioxide production over the measurement time. Detailed reviews of this method are available elsewhere.[91–97]

Direct Observation

Direct observation entails a trained observer watching or video recording an individual who is partaking in physical activities to monitor and record them.[98] This method of assessment can be used to generate important contextual information, and it thus permits an evaluation of the mode/type of physical activity, as well as when, where, and with whom it occurs. As a method of assessing physical activity, direct observation is more commonly used with children than with adults.[99] Detailed overviews of the instrumentation available for direct observation can be found elsewhere.[98,100] Common to most observational approaches is the use of small time intervals and a coded score of movement intensity, activity type or domain, and the location in which the activity occurred.

Physiological Measures

Heart Rate Monitoring

The practicality and feasibility of this objective method for assessing physical activity have increased significantly with the development of small wrist-worn heart rate monitor receivers that are able to accept signals wirelessly from electrodes secured to a chest strap and to store data at high resolution for days. The principle underlying the use of heart rate as a measure of physical activity derives from the physiological connection that makes alterations in heart rate indicative of cardiorespiratory stress during movement of any sort, and thus during physical activity and exercise. Assessment of physical activity by use of heart rate is problematic at low-intensity levels of activity, because heart rate is also influenced by factors that cause sympathetic reactivity (eg, caffeine consumption, emotional state, temperature). Heart rate does, however, increase linearly and proportionately with the intensity of movement during moderate- to vigorous-intensity aerobic activity.[101] However, one confounder is that activities that involve the use of upper-extremity musculature result in a higher heart rate response per given rate of total energy expenditure than activities performed primarily with the legs. Additionally, the heart rate response to changes in physical activity is not immediately reflective of the energy demands. With both the onset of activity and the cessation of activity, there is a lag period. Therefore, heart rate may miss sporadic activity or overestimate the time spent in different intensities of activity during recovery. Measures of physical activity derived from heart rate monitoring are typically time spent in physical activities at different intensity levels (eg, moderate and vigorous intensity) and PAEE. The accuracy of estimating outcomes indicative of physical activity from heart rate monitoring is improved by calibrating an individual's heart rate and energy expenditure response (via oxygen consumption measurement) to different levels of activity, thus accounting for variation across individual heart rate response.[101–104] To overcome the necessity for individual calibration to estimate energy expenditure from heart rate monitoring, generalized approaches have been developed. One such approach is the use of estimates of energy expenditure from heart rate by use of multivariate predictive equations derived from group data in adults.[101,105–107] Group-level analysis has been found to be satisfactory for some population groups.[108]

Motion Sensors

Wearable devices that measure body motion can be used to assess physical activity and estimate energy expenditure. The most commonly used sensors for these purposes are accelerometers, which measure acceleration and movement, and pedometers, which measure steps and can estimate distance walked. Both devices are popular tools for objective assessment of specific aspects of physical activity behavior. Tables 5 through 7 provide an overview of commonly used accelerometers, pedometers, and multiunit sensing devices, coupled with characteristics of each unit (eg, cost, memory, and recording time) and key references that provide validity information to help inform choice when considering motion sensors as a physical activity assessment tool.

Accelerometers

Accelerometer sensors used to estimate physical activity provide a measure of accelerations of the body during movement and have the advantage of capturing frequency, duration, and intensity of physical movement in a time-stamped manner. Acceleration is measured in either 1 plane (usually vertical), 2 planes (vertical and mediolateral or vertical and anterior-posterior), or 3 planes (vertical, mediolateral, and anterior-posterior).[209] The device is enclosed in a case and then attached to the body (either at the hip, ankle, wrist, or lower back), typically by a strap. Recent advances in microelectromechanical technology have reduced the cost and size of accelerometers significantly. Many accelerometers are now able to record high-resolution data, as well as store data for several weeks.

The use of accelerometers has increased dramatically in recent years, and this will likely continue with new

Table 5. Available Objective Methods to Assess Physical Activity: Accelerometers

	Actical	ActiGraph	ActivPAL	GENEActiv	Lifecorder Plus	RT3
Size	29×37×11 mm	4.6×3.3×1.5 cm	53×35×7 mm	43×40×13 mm	7.25×4.2×1.8 cm	7.1×5.3×2.8 cm
Weight, g	16	19	15	14	48	65
Battery	CR2025 lithium	Rechargeable lithium	Rechargeable lithium	Rechargeable lithium	CR2032 lithium	AAA battery
Memory	32 MB	512 MB	16 MB	500 MB	128 kB	N/A
Recording time	Raw: 12 d; 1 s Steps: 194 d	Raw: 40 d at 30 Hz	8 d	45 d at 10 Hz, 7 d at 100 Hz	7-d LCD display; 60-d internal memory	3 h to 21 d
Modes for sampling	Raw + steps; 1, 2, 5, 15, 30, 60 s (counts) epochs	Raw acceleration	Raw acceleration	Raw acceleration	Steps, intensity 1 (low) to 9 (high), proprietary algorithm from raw acceleration	Counts
Interface	USB	USB	USB	USB	USB	USB with docking unit
Number of axes	Omnidirectional	Triaxial	Uniaxial	Triaxial	Uniaxial	Triaxial
Placement	Hip, wrist, ankle	Hip, wrist, ankle	Thigh	Wrist, ankle, hip, thigh,	Hip	Hip
Outcome measures	Physical activity energy expenditure, steps	Energy expenditure, steps, physical activity intensity, body position	Sitting/lying, standing time, steps, step rate, number of posture changes, MET hours, physical activity level	Physical activity, activity type, posture	Steps, moderate to vigorous physical activity, total energy expenditure	Energy expenditure, METs, activity counts
Software for data processing	Respironics Actiware 5	Actilife 6	activPAL 5.8	GENEActivPC Software	Physical activity analysis software	RT3 Assist Software
Web site	http://www.philips.com/actical	http://www.theactigraph.com	http://www.paltechnologies.com	http://www.geneactiv.co.uk/	http://www.suzuken-kenz.com	http://www.stayhealthy.com
Cost	Monitor $450; $950 for monitor device, reader, and software	Monitor $249; $1249 for monitor device, belt, and software	Monitor $616; $1386 for monitor device, software, and docking station	$270	$129.95	$300 (Monitor currently being upgraded)
Key references	109–118	19, 110, 119–146	147–158	159–162	163–172	110, 173–183

Accelerometers listed represent commonly used devices; this does not represent an exhaustive list.
LCD indicates liquid crystal display; MET, metabolic equivalent; N/A, information not readily available; and USB, universal serial bus.

Table 6. Available Objective Methods to Assess Physical Activity: Pedometers

	StepWatch	Omron (HJ-720ITC)*	New Lifestyles (NL-2000i)*	Yamax (CW 700)*
Size	75×50×20 mm	53×15×74 mm	5.7×1.9×4.4 cm	5.1×1.9×3.8 cm
Weight, g	38	32	14	36
Battery	Lithium	CR2032	CR-20	CR-2032
Recording time	2 mo	41 d	7–14 d	7–14 d
Sensor	Accelerometer	Accelerometer	Accelerometer	Spring/lever
Placement	Ankle	Hip, pocket, chest	Hip	Hip
Outcome measures	Steps, gait parameters	Steps, aerobic steps, energy expenditure, distance	Steps, distance, energy expenditure	Steps, activity time, distance, energy expenditure
Connectivity	PC	PC/USB	None	None
Web site	http://www.orthocareinnovations.com/	http://www.omronhealthcare.com	http://www.new-lifestyles.com	http://www.yamaxx.com
Cost	$2000	$59	$70	$24
Key references	158, 184–188	163–165, 189–194	163–165, 194, 195	163–165, 183, 193–196

Pedometers listed represent commonly used devices; this does not represent an exhaustive list. Before selecting any pedometer for use, it is recommended to test the model. Walk at a slow, moderate, and fast pace and count steps over a 100- to 200-m course and compare pedometer steps to counted steps.

PC indicates personal computer; and USB, universal serial bus.

*There are numerous models available per manufacturer. Check the specifications for each model and select a model that provides the type of data needed. The price increases with more options.

applications such as the insertion of accelerometers into smart phones and other commonly used devices. Some of the most frequently used models that are available commercially are described in Tables 5 through 7. There are differences between and sometimes within accelerometer models, which have been reported elsewhere.[109,119,173,210,211] The detailed technical specifications of accelerometers have also been described by Chen and Bassett.[209]

Accelerometer Data Transformation. The main data outcome from accelerometers is a recording of body acceleration and deceleration. This measurement, which is often referred to as raw accelerometer data, is typically recorded in units of acceleration due to gravity (g) and expressed as acceleration in meters per second squared. This is then further transformed into other units. The most common unit of measure for accelerometers is the count, which can be

Table 7. Available Objective Methods to Assess Physical Activity: Multisensing Tools

	SenseWear	IDEEA	Actiheart
Size	88×56×24 mm	Recorder: 7×5.4×1.7 cm Sensors: 1.8×1.5×3 mm	32×6 mm
Weight, g	82.2	Recorder: 59 Sensor: 2	10
Battery	Lithium polymer	AA battery	Rechargeable lithium
Memory		200 MB	512 kB
Recording time, d	28	8	21
Modes for sampling	Raw signals	Raw acceleration	Raw acceleration
Interface	USB	USB	USB
Number of axes	Triaxial	Biaxial	Uniaxial
Sensors	Triaxial accelerometer, galvanic skin temperature and response, heat flux sensing	5 Biaxial accelerometers, hip-worn receiver	Uniaxial accelerometer and heart rate sensing
Placement	Upper arm	Chest, thigh, and feet simultaneously	Chest
Outcome measures	Energy expenditure; moderate- to vigorous-intensity time, steps, METs	Activity type, energy expenditure	Physical activity energy expenditure, moderate- to vigorous-intensity time
Software for data processing	Online activity manager	Commercial software available from manufacturer	Commercial software available from manufacturer
Web site	http://sensewear.bodymedia.com	http://www.minisun.com/	http://www.camntech.com/products/actiheart/actiheart-overview
Cost	$149 or $198 with display	$4000	$1600
Key references	142, 197–202	203–205	206–208

Multisensing monitors listed represent commonly used devices; this does not represent an exhaustive list.

IDEEA indicates Intelligent Device for Energy Expenditure and Activity; MET, metabolic equivalent; and USB, universal serial bus.

expressed in different ways: counts per second, counts per minute, or summed as total counts per day. An accelerometer count is a derived unit or score that is largely dependent on the individual accelerometer, because the onboard functions of different accelerometers process the raw accelerometer data differently.

Accelerometer Data Converted to Meaningful Physical Activity Outcomes. For assessment of physical activity, accelerometers must be calibrated to translate monitor signals into energy expenditure units (ie, kilocalories or METs) or activity intensity categories. This operation results in either prediction equations or count thresholds that delineate a particular intensity of activity. The advantage of this approach is the ability to convert accelerometer values into physical activity outcomes such as kilocalories per week, METs per hour, or METS per minute, or how much time an individual spends in moderate- or vigorous-intensity physical activity. This latter outcome can be used to determine what percentage of a given population is meeting recommended physical activity guidelines. The different approaches to developing prediction equations or intensity count cut points from accelerometers have varied greatly within the literature,[120–124] and these prediction equations are also sensor placement–site specific. Furthermore, equations derived from selected activities tend to be good at estimating those same activities. A detailed summary and analysis of many reported accelerometer prediction equations was reported by Lyden et al.[110] It is paramount to understand that there is substantial variability in the prediction equations that have been developed (for instance, moderate-intensity activity ranges begin at points that range from ≈200 to >2000 counts/min, depending on the reference source). An end user must critically examine how a prediction equation was derived, including the individuals and specific activities involved, and must understand the limitations of its use. For further discussion on this topic, see Matthew[123] and Welk.[212]

The accelerometer signal is typically collected continuously over time, and with older processing techniques (eg, simple regression using counts), a substantial amount of accelerometer signal feature information is not used.[125–127,213] Several groups[128–130,159,214,215] have investigated how to extract and use more of the accelerometer signal using machine-learning algorithms to process data. These analyses provide detailed information about overall physical activity behavior, including time spent in different intensities of physical activity and activity type.

Pedometers

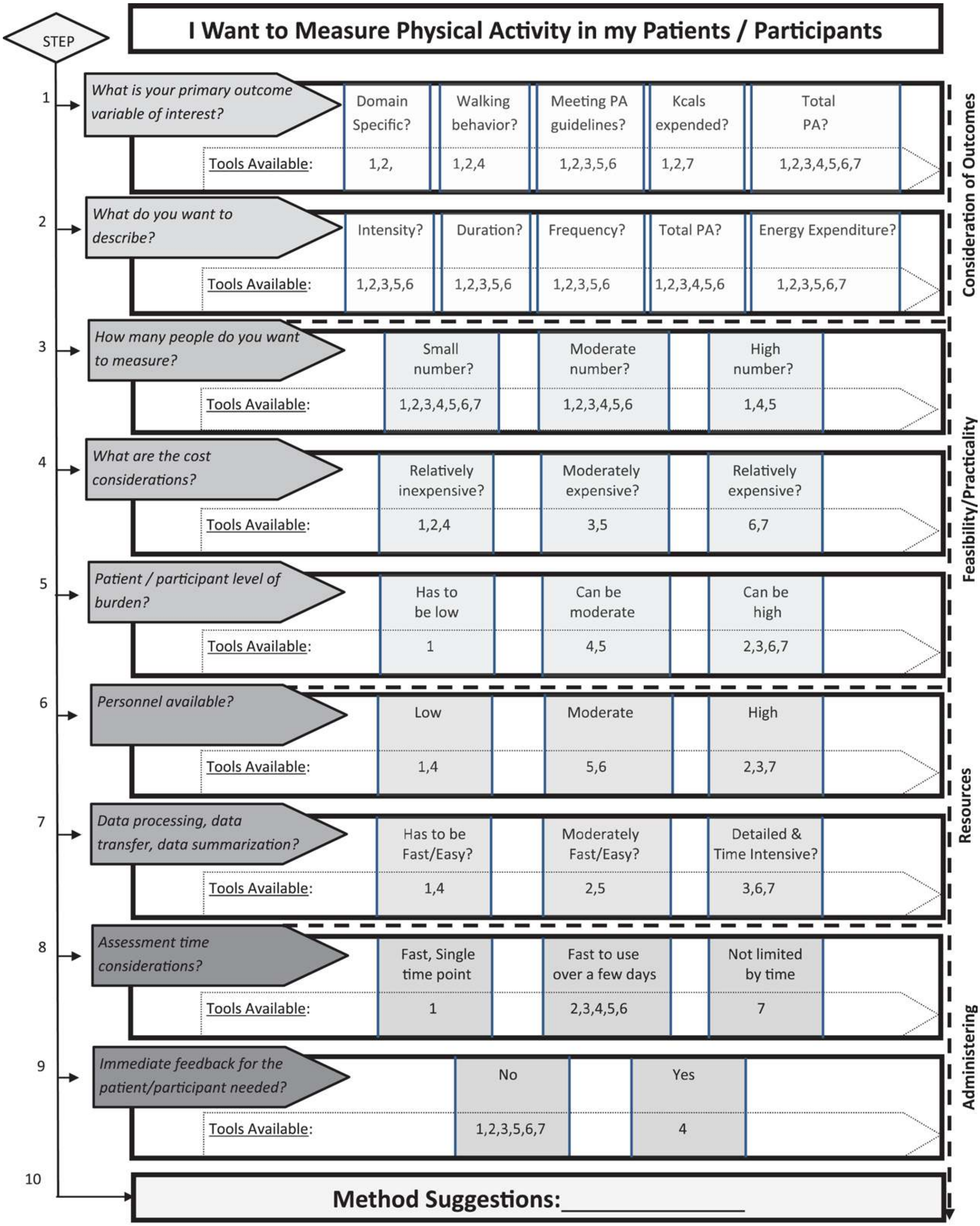
The pedometer is typically a belt- or waistband-worn motion sensor that records movement during regular gait cycles.[216] The outcome measure of movement is steps taken, so the pedometer is a device that is designed to measure walking behavior.

There are many commercially available pedometer models, and these are able to be categorized by features available. For instance, simple pedometers are largely able to quantify steps and estimate distance, whereas newer enhanced pedometers have a built-in time clock, memory function, and features to estimate time spent in different intensity classifications, and some are able to upload data directly to a computer (Tables 5–7). The models available differ substantially in cost and accuracy and also vary by internal mechanism. Pedometers tend to have 1 of 3 commonly used internal mechanisms, either a spring-suspended lever arm, a horizontal beam, or a piezoelectric crystal.[216] Several excellent studies exist that have performed comprehensive evaluations and comparisons of commercially available pedometers.[163,164,196] In one study, Crouter et al[163] examined the accuracy and precision of 10 pedometers in estimating steps, distance, and energy expenditure. Adult subjects walked on a treadmill at 5 different walking speeds while steps were observed and energy expenditure was measured via indirect calorimetry. These criterion data were compared with data displayed on the 10 pedometers. At the slowest walking speed (54 m/min), most pedometers underestimated steps. Above 80 m/min, observed steps and pedometer-measured steps were virtually identical for 6 models. Distance estimates were less accurate, and energy expenditure tended to be overestimated, which is a common finding from other investigations.[165,216–218] Validation of step measurement has also been performed for overground walking (self-paced walking averaging 96.5 m/min), and for 3 of the most accurate models, the difference between observed steps and pedometer-measured steps was within 3%.[165]

The piezoelectric pedometer is perhaps the most sensitive of the 3 types, and it is recommended for those who walk at slower paces.[219] It has also been shown to be accurate across individuals of various body weights and waist circumferences.[195] A newer direction for the use of pedometers is to assess the number of steps per minute that an individual performs. Some enhanced pedometers have built-in functions that attempt to distinguish between physical activity intensity levels, such as by distinguishing aerobic steps (walking >60 steps/min and walking for >10 minutes continuously) from nonaerobic steps (all other accumulated steps plus aerobic steps). Validation research specifically focusing on such enhanced features is currently lacking, although some investigations have begun to evaluate steps-per-minute thresholds and their comparability with physical activity intensity categories, with a threshold of 100 steps/min, for instance, equated with moderate-intensity physical activity.[220–222] The use of pedometers to not only assess physical activity but also motivate behavior change through enhanced and wireless features is an exciting area of research and application as more products become available.

Multisensing Assessment Methods

There are a few objective assessment devices that have combined multiple measurement parameters. Investigations have been performed to determine whether the validity of physical activity assessment could be improved by combining heart rate with other assessment techniques. For instance, the improved accuracy in predicting energy expenditure by combining individually calibrated heart rate monitoring with an accelerometer, compared with using either method separately, was first shown by Avons et al[223] and refined by Haskell et al.[224] Various analytical approaches have been used to combine heart rate monitoring and accelerometer measures: (1) The use of accelerometer data to differentiate between active



Note: 1=Physical activity questionnaires; 2=Physical activity logs/diaries; 3=Heart Rate Monitoring; 4=Pedometers; 5=Accelerometer; 6=Multi-unit Sensors; 7=Doubly Labeled Water

Figure 2. Decision matrix guide to selecting a physical activity (PA) measurement instrument.

and inactive periods of the day[225,226]; (2) the use of acceleration data at low and moderate levels of intensity and heart rate data at higher intensity levels[227]; and (3) differentiation between upper- and lower-body movement with the use of multiple accelerometers.[224,228–230] Branched equation modeling approaches have also been developed, and their validity was assessed during various activities in adults in the laboratory and against the DLW method in free-living adults.[231,232]

The results from the latter suggest that there is no mean bias between PAEE measured from combined heart rate and movement sensing and PAEE determined by the DLW method.

Another multisensing device uses 5 accelerometers that are secured to the chest, both thighs, and the bottom of the feet. This device time stamps physical activity and energy expenditure data and was the first commercially available device to use machine-learning algorithms to identify activity types[203] and estimate energy expenditure.[204] Other recent developments include prototype multisensor boards that combine a triaxial accelerometer and sensors to assess barometric pressure, humidity, temperature, light, and global positioning. These devices apply a trained naïve Bayes classifier to identify activity type and estimate energy expenditure.[215] Some commercially available devices have combined a biaxial accelerometer with sensors to assess heart rate, heat flux, and galvanic skin response.[197] Validation work with such devices is promising.[197,203,204,215]

Selecting a Physical Activity Assessment Method: A Decision Matrix

Because there are many choices available to assess physical activity, selecting a physical activity assessment method can be a challenging proposition. To guide the selection, a decision matrix was developed to provide a systematic approach to

Table 8. Strengths and Limitations to Objective and Subjective Methodologies

Characteristics	Questionnaire	Diaries/Logs	Observation	Indirect Calorimetry	DLW	HR	Accelerometer	Pedometer	Multisensing Units
Strengths	• Low cost • Low burden • Convenient/easy • Applicable to large numbers of individuals • Single time point assessment • Valid to assess structured physical activity • Can successfully rank into high/low categories • Can assess different dimensions and domains	• Low cost • Detailed information on dimension and domains • Not subjected to memory or recall as much as other subjective methods • Provides a good subjective measure of physical activity and energy expenditure	• No recall necessary • Provides excellent contextual information • Provides detailed information on dimensions and domains	• Highly accurate and reliable measure of physical activity and energy expenditure • Suitable criterion measure of physical activity and energy expenditure	• "Gold standard" measure for total daily energy expenditure in free-living individuals • Low burden to patients or participants	• Low burden for short periods • Relatively inexpensive • Relationships strong with moderate to vigorous intensity	• Concurrent measure of movement • Provides detailed intensity, frequency, and duration data • Can store data for weeks at a time • Low burden • Relatively inexpensive	• Low cost • Low burden • Easy data processing • Applicable to large numbers of individuals • Can also be used to motivate people	• Accuracy improved compared with single sensing assessments
Weaknesses	• Recall and social desirability bias can occur • Needs to be population and culture specific • Low validity for assessing incidental or lifestyle physical activity	• Very high burden on patients and participants • Complex and time-consuming data reduction and analysis • Similar to questionnaires, they should be population and culture specific	• High burden on the observer • Training essential to successfully administer this technique • Can alter individual behavior of the one being assessed	• Expensive • High degree of technical expertise required • Short time assessment only permissible	• Expensive • Technical equipment and trained personnel required • Measures of resting metabolic rate and thermic effect of food required to derive PAEE • Unable to discern dimensions or domains	• Affected by nonactivity stimuli (emotion, medication, caffeine) • Weak relationship at low end of intensity realm • Subject to interference with signal	• Cannot account for all activities, such as cycling, stair use, or activities that require lifting a load • Upper-body activities neglected with hip or lower-back wear • Data reduction, transformation, and processing take time	• Simple pedometers cannot measure intensity/duration • Cannot measure mode/type • Not accurate for energy expenditure • Depending on device, false steps can be recorded • Some brands require user to write steps down	• Higher cost • Increased burden of wear for some devices • Depending on device, technical expertise is essential

DLW indicates doubly labeled water; HR, heart rate; and PAEE, physical activity–related energy expenditure.

evaluating the different methods with consideration of a wide range of factors (Figure 2).

At each step of the decision matrix, a list of the method types that provide the desired outcomes is given. The selection process starts with identifying the specific outcome measure(s) required by the user (for example, is the person meeting the physical activity guidelines for Americans?). This first decision requires the user to have a clear understanding of the dimensions of physical activity that need to be measured to capture the desired outcome. The second step involves making a decision about what exactly needs to be described, or in other words, how the data will be used and quantified to answer the question at hand. Certainly the specific outcomes desired and the level of accuracy required will vary in different settings (clinical, research, or public health). Several more decisions are necessary to differentiate between the different methods. The choice of the best method is influenced by the number of people to be assessed and the requirements of the patients/participants. Additionally, the choice of method involves decisions based on resource availability (expense of tools and personnel), processing requirements (time and equipment), and the need to provide immediate feedback to the patients/participants. To guide these decisions, the user will first refer to Table 8 to evaluate strengths and weaknesses of the different method types.

The decision matrix will assist users in selecting the best method type(s) to meet their needs. Users are then directed to refer back to Tables 4 through 7 to compare the characteristics and features of the different subjective and objective options. Finally, users can evaluate the practical considerations for different options by using Table 9 to narrow the choice ideally to one preferred method.

The following scenario was developed to provide an example of using the decision matrix guide to select a physical activity measurement method in one particular clinical setting. The same decision-making process can be used to select the best measurement tool for different settings as well, such as public health surveillance or physical activity behavioral change programs.

Scenario: Screening Adults, in a Clinical Practice Setting, for Assessment of Health Risks Associated With Insufficient Physical Activity

A group of physicians in an internal medicine clinic is well aware of the health benefits of leading a physically active lifestyle and has adopted the 2020 American Heart Association Impact Goals for ideal cardiovascular health of the clinic's patients.[10] In concert with these goals, the clinicians understand they need to assess the current physical activity levels of their patients. The physicians will use this information to identify patients who are not achieving sufficient levels of physical activity to maintain good health (ie, are at risk for coronary and metabolic diseases). For those identified as at risk, they will provide recommendations to increase their physical activity level. The clinicians value a method that can be implemented as part of a regular office visit, can be performed quickly within just a few minutes, and can be accomplished with limited resources.

Table 9. Practical Considerations for Use

Questionnaire	Diaries/Logs	Observation	Indirect Calorimetry	DLW	HR	Accelerometer	Pedometer	Multisensing Units
• What are the primary outcomes of the questionnaire? Do these match the desired information needed? • How will the questionnaire be administered (face to face, telephone, by mail)? • What is the time frame of the questionnaire (24 hours, past week, month, year)? • Is the questionnaire specific to the population under study? • Is there any validity and reliability evidence to support use? • How will data be reduced, cleaned, and analyzed?	• Clear instructions are essential • Mechanisms to promote compliance need to be considered, such as prompts • Considerable time and effort are needed to reduce, clean, and analyze data	• If more than one observer is used, need to train and establish interrater and intrarater reliability	• Systems require extensive calibration to ensure data integrity • Portable systems are available and can measure for a few hours, but they are burdensome and can impact activities undertaken by patients or participants	• Reliant on technical experts • Reliant on measures of RMR and estimations of the TEF • Patients required to collect urine samples	• Patients/participants may have sensitive skin • Calibration requires technical expertise • If individual calibration is used, may need prior physician consent	• Recommend 7 d of monitoring to obtain habitual physical activity profile • Positioning of the monitor is paramount and needs to conform to the calibration study characteristics • Record data in the highest resolution possible	• Similar to accelerometers, may need 7 d to assess • Careful consideration to validity needed; cheaper brands prone to error • If pedometer readings can be seen, likely to increase reactivity	• Need to wear for a number of days to obtain a physical activity profile

DLW indicates doubly labeled water; HR, heart rate; RMR, resting metabolic rate; and TEF, thermic effect of food.

Use of the decision matrix in this scenario would proceed as follows:

Steps 1 and 2: What is the primary outcome desired? What needs to be described?

- Outcome needed: determining whether the patient is meeting the criteria of the physical activity guidelines (≥150 min/wk of moderate-intensity or ≥75 min/wk of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity). Thus, the following dimensions of physical activity need to be assessed: intensity, duration, and frequency.

The decision matrix lists the following physical activity assessment methods as possibilities:

- Questionnaires, logs/diaries, heart rate monitors, accelerometers, or multiunit sensors

Steps 3, 4, and 5: How many patients will be assessed? What are the cost considerations? What can be expected of the patient?

- Number of patients: A conservative estimate is 20 patients per day for each physician within the clinic (ie, a "high" number).
- Cost considerations: The clinic has limited resources; thus, the method chosen needs to be inexpensive. At present, reimbursement for this measurement is not common, so no additional resources are expected.
- Patient burden: The clinicians expect the patient to be able to perform the assessment as part of the office check-in time at their regularly scheduled appointment. The method thus needs to take <5 minutes.

The decision matrix lists the following physical activity assessment method as a possibility:

- Questionnaires

Steps 6, 7, and 8: What are the clinic personnel requirements? How complex and time consuming is the data processing? When are the data needed?

- Personnel needed: Because no additional resources are expected, the assessment must be performed by existing staff within the clinic.
- Data processing requirements: The data processing requirements must be simple so that the assessment results can be calculated easily by existing personnel.
- Timeliness of results: The clinicians desire to have this information available when they meet with the patient on the same day to allow for counseling, as needed, to increase physical activity levels.

The decision matrix lists the following physical activity assessment method as a possibility:

- Questionnaires

In this scenario, after working through steps 1 to 9 of the decision matrix, it appears the best choice for physical activity assessment would be to use a questionnaire method. The clinicians would then review the options available, as shown in Table 4, that can produce the desired outcome (to meet physical activity guidelines) and can be completed by the patient in the office setting in a short period of time. For this purpose, a global questionnaire designed to discern physical activity guideline compliance would be ideal. Two questionnaires meet these criteria: the Exercise Vital Sign[26] and the Activity Vital Sign.[39] The clinicians should then evaluate these 2 options with respect to their strengths and weaknesses (Table 8) and the practical considerations for their use (Table 9). In this scenario, the major factors driving the decision were the feasibility and resource issues involved in collecting data with very limited resources on a large number of patients in a short period of time. This led to the clear choice of using a simple, inexpensive questionnaire method over the other 4 methods listed after steps 1 and 2 that would also produce the desired outcome. After reviewing the key references pertinent to these 2 measurement options, the clinicians are satisfied that their choice will suffice as a screening tool to identify patients who are insufficiently active.

The selection of the physical activity assessment method in this scenario was determined by the factors involved for this group of clinicians. However, if any of the factors were different, such as if more time or resources were available or if a method with a higher level of accuracy was desired, the decision reached would be different. For example, if time for completion was increased from 2 to 3 minutes to ≈10 minutes, one option that could be considered would be to use one of the short recall methods listed in Table 4 that also produce the desired outcome of deducing compliance with physical activity recommendations. Alternatively, if greater accuracy was required, greater resources were available, and the information was not needed the same day, then the clinicians could decide to use an objective accelerometer device, which is likewise able to produce the desired outcome of assessing compliance with national physical activity recommendations.

In summary, the decision matrix provides a systematic approach to guide the selection of physical activity assessment methods. Setting-specific requirements are used at each step in the process to differentiate between assessment types.

Summary

The deleterious health consequences of physical inactivity are vast, and they are of paramount clinical and research importance. Risk identification, benchmarks, efficacy, and evaluation of physical activity behavior change initiatives for clinicians and researchers all require a clear understanding of how to assess physical activity.

In the present report, we have provided a clear rationale for the importance of assessing physical activity levels, and we have documented key concepts in understanding the different dimensions, domains, and terminology associated with physical activity measurement. The assessment methods presented allow for a greater understanding of the vast number of options available to clinicians and researchers when trying to assess physical activity levels in their patients or participants.

The primary outcome desired is the main determining factor in the choice of physical activity assessment method. In combination with issues of feasibility/practicality, the availability of resources, and administration considerations, the desired outcome guides the choice of an appropriate assessment tool. The decision matrix, along with the accompanying tables, provides a mechanism for this selection that takes all of these factors into account. Clearly, the assessment method adopted and implemented will vary depending on circumstances, because there is no single best instrument appropriate for every situation.

In summary, physical activity assessment should be considered a vital health measure that is tracked regularly over time. All other major modifiable cardiovascular risk factors (diabetes mellitus, hypertension, hypercholesterolemia, obesity, and smoking) are assessed routinely. Physical activity status should also be assessed regularly. Multiple physical activity assessment methods provide reasonably accurate outcome measures, with choices dependent on setting-specific resources and constraints. The present scientific statement provides a guide to allow professionals to make a goal-specific selection of a meaningful physical activity assessment method.

Disclosures

Writing Group Disclosures

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This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (1) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
David Bassett	University of Tennessee	NIH†	None	Physical Activity and Public Health Course (CDC-funded course)*	None	None	None	None
David Buchner	University of Illinois	NIH RO1*	None	None	None	None	Physical Activity and Public Health Course*	None
Deborah Rohm Young	Kaiser Permanente Southern California	None	None	None	None	None	None	None

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (1) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

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