Type of activity: resistance, aerobic and leisure versus occupational physical activity

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ABSTRACT

HOWLEY, E. T. Type of activity: resistance, aerobic and leisure versus occupational physical activity. Med. Sci. Sports Exerc., Vol. 33, No. 6, Suppl., 2001, pp. S364–S369. Purpose: To define and describe the essential terminology associated with dose-response issues in physical activity and health. Methods: Recent consensus documents, position stands, and reports were used to provide reference definitions and methods of classifying physical activity and exercise. Results: The two principal categories of physical activity are occupational physical activity (OPA) and leisure-time physical activity (LTPA). OPA is usually referenced to an 8-h d, whereas the duration of LTPA is quite variable. LTPA includes all forms of aerobic activities, structured endurance exercise programs, resistance-training programs, and sports. Energy expenditure associated with aerobic activity can be expressed in absolute terms (kJ·min⁻¹), referenced to body mass (METs), or relative to some maximal physiological response (i.e., maximal heart rate (HR) or aerobic power (VO₂max)). The net cost of physical activity should be used to express energy expenditure relative to dose-response issues. The intensity of resistance training is presented in terms relative to the greatest weight that can be lifted one time in good form (1RM). The intensity of OPA followed the guidance of a previous consensus conference. The intensity of most LTPA can be categorized using the standard aerobic exercise classifications; however, for long-duration (2+ hours) LTPA, the classifications for OPA may be more appropriate. Conclusion: Physical activities should be classified in a consistent and standardized manner in terms of both energy expenditure and the relative effort required. Key Words: METs, % VO₂max, %HRR, %HRmax, 1RM, 10-12RM, NET ENERGY EXPENDITURE

There is a great deal of agreement, both from a preventive and a rehabilitative standpoint, that regular participation in physical activity and exercise results in positive health-related outcomes. An important question is, how much is needed to bring about a particular effect? To answer this question, physical activity or exercise interventions must be described in a manner that allows comparisons to be made across the continuum of exercise intensities, types of exercises, and fitness levels. The purpose of this paper is to clarify the various terms associated with physical activity and exercise, and provide guidelines for consistent interpretation of exercise intensity and volume in the context of dose-response issues.

BASIC TERMINOLOGY

The following definitions and descriptions are derived from previous publications in which dose-response issues were paramount (9,10,13,17,28) and from exercise physiology texts (23,30).

Physical activity (PA) is defined as any bodily movement produced by contraction of skeletal muscle that substantially increases energy expenditure. Leisure-time physical activity (LTPA) is a broad descriptor of the activities one participates in during free time, based on personal interests and needs. These activities include formal exercise programs as well as walking, hiking, gardening, sport, dance, etc. The common element is that these activities result in substantial energy expenditure, although the intensity and duration can vary considerably. Occupational physical activity (OPA) is that associated with the performance of a job, usually within the time frame of an 8-h work day. Dose-response refers to the relationship between increasing levels (doses) of PA on changes in the levels of a defined health parameter (e.g., risk factor, disease, anxiety level, and quality of life).

Exercise (or exercise training) is a subcategory of LTPA in which planned, structured, and repetitive bodily movements are performed to improve or maintain one or more components of physical fitness. Detraining describes the physiological, biochemical, and morphological changes after reduction or cessation of exercise training. Overtraining describes a condition in which an individual does more exercise than can be tolerated, resulting in a reduction in performance and a variety of physiological and psychological symptoms.

Aerobic exercise (training) involves large muscle groups in dynamic activities that result in substantial increases in heart rate and energy expenditure. Regular participation results in improvements in the function of the cardiovascular system and the skeletal muscles, leading to an increase in endurance performance. Anaerobic exercise (training) is done at very high intensities such that a large portion of the energy is provided by glycolysis and stored phosphocreatine. Interval training conducted at power outputs well
beyond an individual’s maximal aerobic power, as well as resistance training, are examples of such activities.

Resistance exercise (training) is designed specifically to increase muscular strength, power, and endurance by varying the resistance, the number of times the resistance is moved in a single group (set) of exercise, the number of sets done, and the rest interval provided between sets. Muscular power is a measure of the rate at which work is performed. Muscular strength is a measure of a muscle’s ability to generate force. It is generally expressed as maximal voluntary contraction (MVC) for isometric measurements and as the one-repetition maximum (1RM) for dynamic measurements. Muscular endurance is a measure of the ability of a muscle to make repeated contractions against a constant resistance.

Acute health effects or responses of physical activity refer to those positive health-related changes that occur in the hours after a session of physical activity. Chronic (training) effects associated with physical activity occur over time due to changes in the structure or function of various systems, independent of acute effects. There are considerable interindividual differences in responses to structured exercise programs.

Metabolic rate describes the rate of energy expenditure. It is usually estimated by indirect calorimetry, in which measurements of oxygen uptake and carbon dioxide production are used to calculate energy expenditure. Oxygen uptake is converted to kcal, using a constant of 5 kcal·L⁻¹, and to kJ by using a constant of 4.19 kJ·kcal⁻¹. Resting metabolic rate (RMR) is usually determined with the subject in the supine position, after an overnight fast and 8 h of sleep. An oxygen uptake of 3.5 mL·kg⁻¹·min⁻¹ is taken as an approximation of the RMR and is considered one MET. Exercise metabolic rate and the caloric costs of activities are determined from oxygen uptake measurements when the subject has achieved a steady state (i.e., the oxygen uptake meets the energy requirement).

Physical fitness is defined as a set of attributes (i.e., cardiorespiratory endurance, skeletal muscle endurance, skeletal muscle strength, flexibility, agility, body composition) that people have or achieve that relate to the ability to perform physical activity. Performance-related fitness is linked typically to those attributes (e.g., power, balance, and reaction time) that are associated with performance outcomes that vary with the sport (e.g., distance running vs weight lifting); however, those same attributes may also be tied to performance in certain occupations. In contrast, health-related fitness focuses on body composition, cardiorespiratory fitness, muscular strength and endurance, and flexibility (a measure of the ability to move a joint through its normal range of motion). Cardiorespiratory fitness reflects the ability of the cardiovascular and respiratory systems to supply oxygen to the working muscles during heavy dynamic exercise. It is usually measured by indirect calorimetry in a laboratory setting as maximal aerobic power or maximal oxygen uptake (\(V_O^2_{2max}\)), which is the highest rate of oxygen uptake achieved during heavy dynamic exercise. However, cardiorespiratory fitness can be estimated accurately from peak power achieved on a cycle ergometer or time on a standard treadmill test, and with somewhat less precision using submaximal tests in which the heart rate response is extrapolated to an age-predicted end point.

Body composition typically describes the amount of fat-free mass (FFM) and fat mass (FM) relative to total body mass. More detailed analyses can characterize bone mass, total body water, etc. Body composition also considers whether body fat is distributed predominately in the limbs or in the trunk; risk of cardiovascular and metabolic diseases is much greater with the accumulation of fat in the abdominal area.

Health is more difficult to define in contrast to the other terms related to dose-response issues. Two previous consensus conferences (9,10) defined health as a human condition with physical, social, and psychological dimensions, each characterized on a continuum with positive and negative poles. Positive health is associated with a capacity to enjoy life and to withstand challenges; it is not merely the absence of disease. Negative health is associated with morbidity and, in the extreme, with premature mortality. This definition was adopted by the Surgeon General’s report on Physical Activity and Health (28). For the purpose of examining the role of PA and fitness in a dose-response context, health is described or defined in terms of morbidity or mortality associated with chronic diseases (e.g., coronary heart disease, stroke, and cancer); risk factors or biological markers associated with these diseases (e.g., blood pressure, serum cholesterol, and body fatness); and other outcomes (e.g., quality of life).

**PHYSICAL ACTIVITY AND EXERCISE: CHARACTERIZING THE DOSE**

The characteristics of intensity, frequency, duration, and mode/type are used to describe the dose of physical activity or exercise needed to bring about a particular response. Frequency is easily described as the number of activity sessions per day, week, or month, and duration typically refers to the number of minutes of activity in each session. Intensity describes, in relative or absolute terms, the effort associated with the physical activity. Intensity is expressed in a wide variety of ways depending on whether it relates to LTPA, resistance training, or OPA. Part of the reason for the variety of expressions is the nature of the activity; the other relates to the time frame over which the activity takes place (i.e., 20–60 min for a fitness workout vs 8 h for a workday).

**Leisure-Time Physical Activity**

The dose of LTPA can be described in terms of both absolute and relative intensities but, more importantly, in terms of the volume or quantity of energy expended over the course of a day, week, or month. The following sections will expand on each of these characteristics of the dose of LTPA.

**Absolute intensity.** The absolute intensity of LTPA describes the actual rate of energy expenditure. Common expressions include: oxygen uptake (L·min⁻¹), oxygen uptake relative to body mass (mL·kg⁻¹·min⁻¹), kcal or kJ per
the energy cost of the work itself, it does not adequately
in terms of energy expenditure is very important in terms of
vary greatly. Although the expression of exercise intensity
across studies in which the rate of energy expenditure can
as the net cost to allow for more adequate comparisons
donducted at higher intensities. It is recommended that energy
a comparable net energy expenditure for activities con-
estimation of energy expenditure associated with the activ-
might equal 25–50% of total energy expenditure. Failure to
make adjustments for these activities will result in an over-
impact on overall energy expenditure. On the other hand,
for physical activities at the high end of the intensity con-
s tinuum (i.e., 10
for physical activities developed by Ainsworth et al. (1) has
recently been updated in both the number of major headings
and the number of specific activities (from 477 to 605) (2).
The MET values in the compendium can be used to obtain
the absolute energy expenditures associated with all types of
physical activities.

**Volume of activity.** The product of absolute intensity, duration, and frequency yields the total energy expenditure associated with a physical activity over a specified time and is taken as a measure of the volume of PA. Volume may be described in the following units:

**Kilocalories.** For a 60-kg person doing slow ballroom dancing (3 METs) for 60 min, 3 times per week, the volume is 540 kcal-wk⁻¹ for this activity (3 kcal-kg⁻¹·h⁻¹ × 60 kg × 3 h-wk⁻¹). The value would be higher for a heavier person.

**MET-min.** This is obtained by multiplying the number of minutes an activity is performed by the energy cost in METs. The above example yields 540 MET-min per week (3 METs × 180 min-wk⁻¹). For a 60-kg person, MET-min yields the same value as kcal.

**MET-hours.** This is calculated by multiplying the number of hours an activity is performed by the energy cost in METs. For the example above, it would be 9 MET-h-wk⁻¹ (3 METs × 3 h-wk⁻¹).

For some dose-response comparisons, it may be important to distinguish between the gross and the net cost of the physical activity. The gross cost of an activity is the total energy expenditure, which includes RMR and the cost of the activity itself. The net cost is that associated with the activity alone. The net cost is obtained by subtracting resting energy expenditure (one MET) from the gross cost. Clearly, for physical activities at the high end of the intensity continuum (i.e., 10+ METs), in which RMR represents 10% or less of total energy expenditure, adjusting the energy expenditure to reflect the net cost will have only a modest impact on overall energy expenditure. On the other hand, when working with activities at the lower end of the intensity continuum, for example, 2–4 METs, adjusting the values to represent the net cost is very important in that RMR might equal 25–50% of total energy expenditure. Failure to make adjustments for these activities will result in an overestimation of energy expenditure associated with the activity and an underestimation of the duration needed to match a comparable net energy expenditure for activities conducted at higher intensities. It is recommended that energy expenditure associated with physical activity be expressed as the net cost to allow for more adequate comparisons across studies in which the rate of energy expenditure can vary greatly. Although the expression of exercise intensity in terms of energy expenditure is very important in terms of the energy cost of the work itself, it does not adequately describe the physiological response demanded of the subject.

**Relative intensity.** Persons differing in fitness respond in markedly different ways to an exercise challenge set at a fixed absolute intensity. An exercise intensity of 10 kcal-min⁻¹ might be a warm-up for one person but require a maximal effort by another. This has been recognized for some time, and exercise physiologists have designed experiments to account for such variation by adjusting the intensity relative to some maximal physiological response. The relative intensity of aerobic activity has been described in terms of percentages of maximal oxygen uptake (VO₂max), oxygen uptake reserve (VO₂R), heart rate reserve (HRR), and maximal heart rate (HRmax). In addition, intensity has been classified relative to the subject’s perception of effort, using Borg’s Rating of Perceived Exertion (RPE) scale (3,4). These will now be considered in more detail.

**Percentage of maximal oxygen uptake (VO₂max).** Across a broad range of fitness levels, defined in terms of VO₂max, many physiological responses are normalized by expressing the intensity of exercise as a percentage of VO₂max (%VO₂max). This approach was used extensively over the second half of the 20th century in the design of experiments as well as in the development of exercise guidelines, as seen in the American College of Sports Medicine’s Guidelines for Exercise Testing and Prescription and its position stands. However, in the most recent updates of both of these documents, the relative intensity is also expressed as a percentage of oxygen uptake reserve (%VO₂R) (3,4).

**Percentage of oxygen uptake reserve (VO₂R).** VO₂R is calculated by subtracting one MET (3.5 mL·kg⁻¹·min⁻¹) from the subject’s VO₂max. The %VO₂R is a percentage of the difference between resting VO₂ and VO₂max, and is calculated by subtracting 1 MET from the measured oxygen uptake, dividing by the subject’s VO₂R and multiplying by 100%. For example, an individual with a VO₂max of 35 mL·kg⁻¹·min⁻¹ who is exercising at 24 mL·kg⁻¹·min⁻¹ would be at 65% VO₂R ((24–3.5)/(35–3.5)-100%). The %VO₂R corresponds to the heart rate response when it is expressed as a percentage of the HRR (26,27).

**Percentage of heart rate reserve (%HRR).** The HRR is calculated by subtracting resting HR from maximal heart rate. The %HRR is a percentage of the difference between resting and maximal heart rate, and is calculated by subtracting resting HR from the exercise HR, dividing by the HRR, and multiplying by 100%. Before the most recent ACSM position stand, the %HRR was believed to be closely linked to the %VO₂max on a one-to-one basis, that is, 70% HRR = 70% VO₂max. Swain et al. (26,27) pointed out that although this might be the case when vigorous exercise is done by fit individuals, it is not the case for low intensities of exercise, especially when performed by those at the low-end of the fitness scale. For example, a 3-MET activity for someone with a 5-MET maximal aerobic power, is 60% VO₂max but only 50% of VO₂R (2 METs/5 METs – 1 MET)-100%). It has been demonstrated clearly that the %
VO₂R is numerically identical to the %HRR across the fitness continuum.

**Percentage of maximal heart rate (%HR₉max).** Because of the linear relationship between HR (above ~110 b/min) and VO₂ during dynamic exercise, investigators and clinicians have long used a simple percentage of maximal HR (%HR₉max) as an estimate of the %VO₂max in setting exercise intensity (15,18).

**The rating of perceived exertion (RPE).** The RPE is not viewed as a substitute for prescribing exercise intensity by HR, but once the relationship between the heart rate and RPE has been established, RPE can be used in its place (5). However, the RPE may not consistently translate to the same intensity for different modes of exercise, so one should not expect an exact matching of the RPE to a %HR₉max or %HRR (3).

The categories of exercise intensity must consider the time frame over which an activity takes place. The ACSM’s position stand classifies intensities of aerobic activities based on a duration of up to 60 min. To review the literature in a consistent manner with regard to the issue of exercise intensity, one must be able to equate intensity across all of the other expressions of exercise intensity (3). These are shown on the left side of the table with intensities ranging from very light to maximal. The RPE values are based on Borg’s 6–20 RPE scale (8).

Taking the lead from the earlier consensus conferences on exercise, fitness and health (9,10), the Surgeon General’s report and the most recent ACSM position stand included absolute MET values for groups differing in VO₂max. Table 1 provides the absolute exercise intensities (in METs) for each of the intensity classifications for four groups that vary in VO₂max. On average, VO₂max decreases with age, and is lower in women, compared with men, across age. The 50th percentile values for VO₂max (in METs), based on the Canada Fitness Survey (12), are shown in Table 2.

The difference between the %VO₂max and the %VO₂R in Table 1 is inversely related to a person’s VO₂max. For example, one MET represents 20%, 10%, and 5% of VO₂max values of 5, 10, and 20 METs, respectively. For those at the high end of the fitness continuum, there is little difference between %VO₂R and %VO₂max values; however, the difference is considerable at lower intensities for those with low fitness levels. The %VO₂R was converted to %VO₂max using the following equation (Swain, D. P. Conversion of percent VO₂ reserve to percent VO₂max, personal communication, 2000):

\[
\% \ VO₂\max = \{(100\% - \%VO₂R) \ MET\max^{-1}\} + \%VO₂R
\]

The MET values listed for each fitness level equal the stated %VO₂max and %VO₂R values.

The %HR₉max values listed in Table 1 were derived from an equation by Londeree and Ames (20):

\[
\%HR₉max = 0.7305 \times (\%VO₂\max) + 29.95
\]

This equation is similar to those of Swain et al. (25) and Hellerstein and Franklin (18). There was little difference in the %HR₉max values calculated by the above equation across the four fitness groups for each of the intensity classifications, so the %VO₂max values for the 10-MET fitness group were used to provide the %HR₉max values for Table 1.

Table 1 allows an investigator to classify data on exercise intensity in a consistent manner, whether expressed in oxygen uptake (METs), heart rate, or ratings of perceived exertion. However, it is clear that if one uses a fixed metabolic rate (i.e., METs) to define an intensity category, the relative intensity changes dramatically as one moves across the fitness continuum. This was recognized in both of the earlier consensus conferences (9,10), as well as in the Report of the Surgeon General (28), and is addressed in Shepard’s presentation in the conference (24). Figure 1, based on a graph by Haskell (16), shows why one must use caution when interpreting an absolute intensity of exercise as being

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**Table 1.** Classification of physical activity intensity.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>% VO₂R</th>
<th>% HRmax</th>
<th>RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Light</td>
<td>&lt;20</td>
<td>&lt;50</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Light</td>
<td>20–39</td>
<td>50–63</td>
<td>10–11</td>
</tr>
<tr>
<td>Moderate</td>
<td>40–59</td>
<td>64–76</td>
<td>12–13</td>
</tr>
<tr>
<td>Hard</td>
<td>60–84</td>
<td>77–93</td>
<td>14–16</td>
</tr>
<tr>
<td>Very Hard</td>
<td>≥85</td>
<td>≥94</td>
<td>≥17–19</td>
</tr>
<tr>
<td>Maximal</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Modified from Table 1 of ACSM Position Stand (ref. 5).

* a %VO₂R - percent of oxygen uptake reserve; %HRmax - percent of heart rate reserve.
* b %HRmax = 0.7305 (%VO₂max) + 29.95 (ref. 20); values based on 10-MET group.
* c Borg Rating of Perceived Exertion 6–20 scale (ref. 8).
* d %VO₂max = [(100%-%VO₂R) METmax⁻¹] + %VO₂R; personal communication (D. P. Swain, 2000).
* e RM = repetitions maximum, the greatest weight that can be moved once in good form.

**Table 2.** 50th percentile values (in METs) for VO₂max. (continued)

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>20–29</th>
<th>30–39</th>
<th>40–49</th>
<th>50–59</th>
<th>60–69</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>12.3</td>
<td>12.3</td>
<td>10.3</td>
<td>9.7</td>
<td>8.0</td>
</tr>
<tr>
<td>Female</td>
<td>10.0</td>
<td>9.1</td>
<td>8.0</td>
<td>7.4</td>
<td>6.3</td>
</tr>
</tbody>
</table>

Based on data from the Canada Fitness Survey (12).
exercise, the intensity can be set at a percent of the 1RM value lifted one time in good form. Once this value is known for each repetition maximum (1RM), the greatest weight that can be used the product of the reps, sets, and resistance to obtain a "Intensity" refers to the amount of resistance; "repetitions" or "reps" defines the number of times a weight is lifted or a resistance is moved; and a "set" describes the number of times the desired number of repetitions is performed. Some use the product of the reps, sets, and resistance to obtain a measure of the volume of exercise done in a workout (7,14).

The counterpart to VO₂max in resistance training is the one repetition maximum (1RM), the greatest weight that can be lifted one time in good form. Once this value is known for each exercise, the intensity can be set at a percent of the 1RM value (like a percent of VO₂max for aerobic exercise). In much the same way that the duration of aerobic exercise is inversely related to intensity, the number of repetitions a person can perform is inversely related to the %1RM. For example, the following are typical estimates of the number of repetitions that can be done at a fixed percentage of 1RM: 95%: 2–3; 90%: 4; 85%: 6; 80%: 8–10; and 75%: 10–12 (6). Because of this inverse relationship between %1RM and the number of repetitions, intensity can also be defined as a specified RM, that is, doing one set of 10–12 RM. However, due to the variability in the number of repetitions that can be done at the same %1RM for different muscle groups (e.g., bench press vs leg curl), and between trained and untrained subjects, these estimates are simply guidelines, rather than hard and fast rules (19).

The intensity and volume of exercise in a resistance-training program can be adjusted by changing the weights or resistance, the repetitions per set, the number of sets, and the rest periods between sets (5,14). The ACSM position stand provides guidance in the classification of exercise intensity for resistance training. The classification is based on 8–12 repetitions for persons under 50–60 yr, and 10–15 repetitions for persons older than 50–60 yr. The ACSM listed relative intensity values for resistance-type exercise as a percent of maximal voluntary contraction (MVC), a measure of maximal isometric strength. This term was used interchangeably with 1RM, and Table 1 reflects this change.

### Research Directions

The intensity of aerobic physical activity is defined within a 60-min time frame, whereas the intensity of occupational activity is viewed over 8 h. There are a wide variety of activities that fall between these two extremes of duration (e.g., prolonged hikes and gardening activities), and there is a need to determine how one might classify intensity in these cases. For occupational activities involving lifting, the limits of energy expenditure have been set on the basis of both duration and the height of the lift. For example, the National Institute for Occupational Safety and Health has set the limit of energy expenditure at 2.2 kcal·min⁻¹ (9.2 kJ·min⁻¹) for frequent lifting over a vertical distance greater than 75 cm that is carried out for 2–8 h (29). These analyses should be considered in future reviews of the relative intensity of OPA.

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CLASSIFICATION OF PHYSICAL ACTIVITY