Clin. Cardiol. 13, 555-565 (1990)

Metabolic Equivalents (METS) in Exercise Testing, Exercise Prescription, and Evaluation of Functional Capacity

M. JETTÉ, K. SIDNEY,* G. BLÜMCHEN†

Department of Kinanthropology, School of Human Kinetics, University of Ottawa, Ottawa, Canada; *Present affiliation: Laurentian University, Sudbury, Ontario, Canada †Klinik Roderbirken, Leichlingen, Federal Republic of Germany

Summary: One metabolic equivalent (MET) is defined as the amount of oxygen consumed while sitting at rest and is equal to 3.5 ml O_2 per kg body weight × min. The MET concept represents a simple, practical, and easily understood procedure for expressing the energy cost of physical activities as a multiple of the resting metabolic rate. The energy cost of an activity can be determined by dividing the relative oxygen cost of the activity (ml O_2/kg/min) × by 3.5. This article summarizes and presents energy expenditure values for numerous household and recreational activities in both METS and watts units. Also, the intensity levels (in METS) for selected exercise protocols are compared stage by stage. In spite of its limitations, the MET concept provides a convenient method to describe the functional capacity or exercise tolerance of an individual as determined from progressive exercise testing and to define a repertoire of physical activities in which a person may participate safely, without exceeding a prescribed intensity level.

Key words: metabolic equivalents, energy cost, oxygen consumption, exercise prescription, functional capacity

Introduction

Metabolic equivalents (METS) are a simple, practical, and easily understood procedure to quantify the energy cost of activities. METS are also routinely utilized to describe the functional capacity or aerobic power of an individual and to provide a repertoire of activities in which he or she can safely participate. Since the term METS appears frequently in the North American literature and since some persons may not be completely familiar with the concept, a definition of the term and its utilization could prove useful. Our purpose, therefore, is to (1) define the concept of METS, (2) compare METS and watts of selected household and recreational activities, and (3) describe the use of METS in the formulation of an exercise prescription.

Definition

A MET is defined as the resting metabolic rate, that is, the amount of oxygen consumed at rest, sitting quietly in a chair, approximately 3.5 ml O_2/kg/min (1.2 kcal/min for a 70-kg person).* As such, work at 2 METS requires twice the resting metabolism or 7.0 ml O_2/kg/min and three METS requires three times the resting metabolism (10.5 ml O_2/kg/min), and so on.

Metabolic Equivalents of Activities

Tables I and II provide the energy cost in METS and the comparative values in watts for common household chores and leisure activities, respectively. The values for watts have been calculated for a 70-kg person. The METS values were adapted from an expert committee report submitted to the Canada Fitness Survey.[1] Most physical activities can be performed at a variable intensity ranging from light to heavy. Accordingly, Tables I and II also in-

Address for reprints:

Dr. Maurice Jetté
School of Human Kinetics
University of Ottawa
Ottawa, Ontario
Canada K1N 6N5

Received: January 17, 1990
Accepted with revision: March 5, 1990

*Since one liter of oxygen is equal to 5 kcal, 1 W is equal to 0.01435 kcal or 14 ml. One MET is equal to 17.5 W for a 70-kg person.

TABLE I Metabolic equivalents of household chores

Activity	METS[a]	Watts[b]	Intensity					
			Light		Moderate		Heavy	
			METS	W	METS	W	METS	W
Gardening			3	53	5	88	7	123
digging	4.4	77						
raking	3.5	61						
weeding	3.5	61						
Heavy housework			3	53	3.5	61	5	88
carpentry	5-7	88-123						
grocery shopping	2-7	35-123						
painting	4-5	70-88						
remodelling	4-5	70-88						
repairing	4-5	70-88						
washing floor	3.3	58						
washing windows	4.9	86						
Light housework			2	35	2.5	44	3	53
cooking	2.5	44						
dishes	2.1	37						
ironing	2.0	35						
making beds	3-5	53-88						
mowing lawn with power mower	3-5	53-88						
Mowing lawn (push mower)	5-7	88-123	3	53	4	70	5	88
Farm chores	4-5	70-88	3	53	4	70	5	88
Snow shovelling	5.1	89	4	70	6	105	8	140
Wood cutting	5-7	88-123	4	70	5	88	7	123

[a]Indicates energy expenditure as a multiple of resting metabolic rate.
[b]Value indicated is for a 70-kg individual.

TABLE II Approximate metabolic costs of recreational activities

Activity	METS[a]	Watts[b]	Intensity					
			Light		Moderate		Heavy	
			METS	W	METS	W	METS	W
Aerobic dancing			4	70	6	105	9	158
Low	3.9	68						
Medium	6.0	105						
Alpine skiing	5-9	88-158	4	70	6	105	8	140
Archery	4.3	75						
Backpacking (km/h) (5% slope, 20 kg)			6	105	8	140	10	175
6.4	8.0	140						
7.2	9.6	168						
8.0	11.6	203						
9.6	13.1	229						
11.2	15.5	271						
Badminton			3	53	6	105	9	158
Doubles	3-4	53-70						
Singles	4-5	70-88						
Competitive	6-7	105-123						
Ballet	6-8	105-140	5	88	6	105	8	140
Ball games			3	53	4	70	5	88

(continued)

TABLE II (continued)

Activity	METS[a]	Watts[b]	Intensity					
			Light		Moderate		Heavy	
			METS	W	METS	W	METS	W
Ball hockey			3	53	4	70	5	88
Ballroom dancing	3-5	53-88	3	53	4	70	5	88
Baseball	4-7	70-123	3	53	4	70	5	88
Basketball	11.1	194	6	105	8	140	11	193
Bicycling (km/h)			3	53	7	123	10	175
10	4.8	84						
15	5.9	103						
20	7.1	124						
25	8.4	147						
30	9.8	172						
Bocce			2	35	2.5	44	3	53
Body building			3	53	5	88	7	123
Bowling	2-4	35-70	2	35	2.5	44	3	53
Boxing	13.4	235	6	105	9	158	12	210
Broomball	6.3	110	5	88	7	123	9	158
Canoeing	3-11	53-193	3	53	4	70	6	105
Car driving	2	35						
Catch (ball)			3	53	4	70	5	88
Cricket	6.1	107	3	53	4	70	5	88
Croquet	2-3	35-53	2	35	2.5	44	3	53
Cross-country skiing (km/h)			5	88	9	158	13	228
4	5.5	96						
6	7.7	135						
8	9.9	173						
10	12.2	214						
12	14.3	250						
14	16.5	289						
Curling	7.4	130	4	70	5	88	6	105
Disco and popular dancing	3-8	53-140	3	53	5	88	7	123
Equestrianism	7	123	3	53	5	88	7	123
Exercise classes			4	70	6	105	9	158
Fencing	6-10	105-175	5	88	7	123	10	175
Figure skating	12.9	226	4	70	6	105	10	175
Fishing								
From bank	2-3	35-53						
In stream	3-4	53-70						
From boat	2-3	35-53						
Floor hockey (forwards)	10.3	180	6	105	8	140	10	175
Folkdancing	4.8	84	3	53	5	88	7	123
Football (American)	6-7	105-123	5	88	6	105	7	123
Football (touch)	7-8	123-140	5	88	6	105	8	140
Freestyle skiing			4	70	6	105	9	158
Frisbee			3	53	4	70	5	88
Golf								
Carrying clubs	5.1	89						
Pulling cart	3-4	53-70						
Riding cart	2-3	35-53						
Gymnastics	7	123	5	88	7	123	10	175
Handball (4-wall)	8-12	140-210	6	105	8	140	11	193
Hiking	6	105	3	53	6	105	8	140
Home calisthenics	2-6	35-105	3	53	5	88	8	140

(continued)

TABLE II (continued)

Activity	METS[a]	Watts[b]	Intensity					
			Light		Moderate		Heavy	
			METS	W	METS	W	METS	W
Horseback riding			3	53	5	88	7	123
Walk	3.2	56						
Trot	6.9	121						
Gallop	8.6	151						
Horseshoes	2-3	35-53	2	35	2.5	44	3	53
Hunting	3-7	53-123	3	53	5	88	7	123
Ice hockey	12.9	226	6	105	8	140	10	175
Jogging (level) (km/h)			7	123	10	175	12	210
9	8.8	154						
11	11.2	196						
Judo	10.5	184	6	105	8	140	12	210
Karate	8-12	140-210	5	88	8	140	12	210
Kayaking (km/h)			6	105	8	140	11	193
12.5	7.8	137						
15.0	11.0	193						
Lacrosse (forward)	12.6	221	6	105	8	140	10	175
Modern dancing	4.8	84	5	88	6	105	8	140
Motorcycling	2.2	39	2.5	44	4	70	7	123
Mountaineering	7-8	123-140	7	123	8	140	10	175
Orienteering			8	140	10	175	12	210
Racquetball	8-12	140-210	6	105	9	158	12	210
Ringette (forward)	12.6	221	5	88	7	123	9	158
Rollerskating (km/h)			5	88	6.5	114	8	140
12.9	5.7	100						
13.9	7.6	133						
16.1	9.5	166						
17.7	10.5	184						
Rope skipping (/min)			7	123	10	175	12	210
66	9.8	172						
84	10.5	184						
100	11.0	193						
120	11.4	200						
125	11.7	205						
130	11.8	207						
135	12.0	210						
145	12.1	212						
Rowing (km/h)			7	123	10	175	13	228
4	5.5	96						
8	10.3	180						
12	13.5	236						
16	16.4	287						
20	19.1	334						
Rugby	12.6	221	6	105	8	140	11	193
Running (level) (km/h)			12	210	14	245	16	280
13	12.9	226						
15	14.6	256						
Sailing (small boat)	3-4	53-70	3	53	4	70	6	105
Scuba diving	11	193	4	70	5	88	6	105
Sculling	4-10	70-175	4	70	6	105	10	175
Skateboarding			5	88	6.5	114	8	140

(continued)

TABLE II (continued)

Activity	METS[a]	Watts[b]	Intensity					
			Light		Moderate		Heavy	
			METS	W	METS	W	METS	W
Skating (ice) (km/h)			4	70	7	123	13	228
18	4.0	70						
25	4.8	84						
28	9.2	161						
32	10.8	189						
36	15.2	266						
Snorkeling			4	70	5	88	6	105
Snowmobiling	2-3	35-53	3	53	3.5	61	5	88
Snowshoeing (4 km/h)	9.5	166	5	88	7	123	10	175
Soccer	10.3	180	5	88	7	123	11	193
Softball	3-6	53-105	3	53	4	70	5	88
Squaredancing	4.8	84	3	53	5	88	7	123
Squash	8-12	140-210	6	105	9	158	12	210
Swimming (beach)			2	35	3	53	4	70
Swimming (pool) (km/h)			3	53	5	88	9	158
2.0	4.3	75						
2.5	6.8	119						
3.0	8.9	156						
3.5	11.5	201						
4.0	13.6	238						
Synchronized swimming			4	70	6	105	8	140
Legs only	8.7	152						
Arms only	9.8	172						
Table tennis	4.7	82	4	70	6	105	9	158
Tag games			3	53	4	70	5	88
Tennis	6.8	119	4	70	6	105	10	175
Singles	6-7	105-123						
Doubles	4-5	70-88						
Tobogganing	7.0	123	5	88	6	105	7	123
Track and field			4	70	6	105	8	140
Marathon	13.3	233						
High jump	4.1	72						
Long jump	15.0	263						
Shot put	3.8	67						
Trail biking	6-8	105-140	4	70	5	88	7	123
Volleyball	6	105	5	88	6	105	8	140
Walking for exercise (km/h)			3	53	4	70	5	88
3	1.8	32	3	53	4	70	5	88
5	3.2	56						
7	5.3	93						
Walking upstairs	4.7	82	4	70	6	105	8	140
Waterpolo	9.8	172	6	105	8	140	11	193
Waterskiing	7.9	138	5	88	7	123	9	158
Weightlifting	3-7	53-123	3	53	5	88	7	123
Weight training	10.9	191	3	53	5	88	7	123
Windsurfing			4	70	5	88	7	123
Wrestling	8-12	140-210	6	105	9	158	12	210
Yoga	3.2	56						

[a]Indicates energy expenditure as a multiple of resting metabolic rate.
[b]Value indicated is for a 70-kg individual.

clude for the various activities, the MET values, as assigned by the expert committee, for three levels of intensity: *light*; when the activity results in only minimal perspiration and only a slight increase in breathing above normal; *moderate*; when the activity results in definite perspiration and above normal breathing; *heavy*; when the activity results in heavy perspiration and heavy breathing. These MET values indicating intensity level enable the clinician to be more specific when prescribing exercise by providing the patient with subjective, yet specific, feelings as to the desired intensity of participation.

For instance, a person participating in a game of tennis with only a slight change from normal state would be exercising at approximately 4 METS. A patient showing slight perspiration, accompanied by increased breathing, would be exercising at 6 METS. However, a person who shows heavy perspiration and heavy breathing while performing would be working at 10 METS.

This procedure, however, is not without limitations. One major inconsistency in Table II, which should be oted, is that some activities of relatively low intensity, such as bowling, bocce, and croquet are shown in the "heavy" intensity category with an intensity of 3 METS. Other activities, on the other hand, such as badminton, baseball, hiking, and folk dancing, are classified in the "light" intensity category also with an intensity of 3 METS. In Tables I and II, activities classified as "heavy" range from a low of 3 METS to a high of 16 METS. Activities classified as "light" have a similar range of 3 to 12 METS.

Classification of Activities

McArdle *et al.*[2] have presented a classification system (Table III) for rating the difficulty of sustained physical activity in terms of its intensity. In addition to METS, the exercise intensity classifications are expressed VO_2 and watts. For men, light work is considered as that eliciting an energy expenditure of up to 4 METS (1 liter of O_2/min). Today, most industrial jobs and household chores require less than three times the resting energy expenditure (i.e., 3 METS) and can thus be regarded as light work. Heavy work is defined as that requiring 6 to 8 times the resting oxygen consumption (i.e., 6–8 METS). Unduly heavy work is any task requiring an increase in metabolism greater than tenfold above resting value (i.e., 10 METS). Compared with men, the classifications of physical activity in terms of exercise intensity are lower for women accounted for by their lower level of physical work capacity.

With respect to physical training, activities demanding only 1–4 METS are generally considered to be of low intensity, and therefore, not suitable for developing cardiorespiratory fitness in normals. However, they may provide a sufficient training stimulus for persons whose functional capacity is less than 6 METS. Activities in the 5–8 METS range are considered to be of moderate intensity, and for most sedentary persons, especially patients and elderly individuals, generally provide a suitable training stimulus. Naturally, activities should be considered in light of the fitness level of the participant: they may

TABLE III Five-level classification of physical activity in terms of exercise intensity

	Energy expenditure			
Level	kcal/min	ml/kg/min	W	METS
Men				
Light	2.0–4.9	6.1–15.2	28–69	1.6–3.9
Moderate	5.0–7.4	15.3–22.9	70–104	4.0–5.9
Heavy	7.5–9.9	23.0–30.6	105–139	6.0–7.9
Very heavy	10.0–12.4	30.7–38.3	140–174	8.0–9.9
Unduly heavy	12.5–	38.4–	175–	10.0–
Women				
Light	1.5–3.4	5.4–12.5	21–48	1.2–2.7
Moderate	3.5–5.4	12.6–19.8	49–76	2.8–4.3
Heavy	5.5–7.4	19.9–27.1	77–104	4.4–5.9
Very heavy	7.5–9.4	27.2–34.4	105–132	6.0–7.5
Unduly heavy	9.5–	34.5–	133–	7.6–

Note: ml/kg based on 65-kg man and 55-kg woman; one MET is equivalent to 250 ml O_2 per minute, or the average resting oxygen consumption.

Source: Adapted from Ref. 2, McArdle *et al.*, *Exercise Physiology: Energy, Nutrition, and Human Performance*, Lea & Febiger, 1986, reprinted with permission.

be too vigorous for the unfit person and not sufficiently vigorous for the very fit person. Activities requiring an energy expenditure of 8 METS and above are considered to be of high intensity.

Utilization of METS in Describing Functional Capacity

The exercise intensity in METS for activities such as walking, jogging, running, cycle ergometer, and stepping is directly related to speed of movement, resistance, or mass lifted (see Tables IV to VII). In exercise testing, ergometers present the patient with a defined quantity of work. The exercise intensity is gradually and progressively increased from stage to stage in either a continuous mode or at intervals. At each stage, observations of heart rate, ECG, blood pressure, and signs and symptoms are noted. The increases in intensity from stage to stage are normally about 1 to 2 METS (or more) in healthy populations and as small as one half to one MET in individuals with disease.

Using a test protocol with smaller increments in exercise intensity is preferable to a protocol using larger increments, since it is possible to more precisely define the subject's exercise tolerance (functional capacity) and/or the

TABLE IV Energy requirements in METS for horizontal and uphill jogging/running[a]

	mph	5	6	7	7.5	8	9	10
%Grade	m/min	134	161	188	291	215	241	268
Outdoors on solid surface								
0		8.6	10.2	11.7	12.5	13.3	14.8	16.3
2.5		10.3	12.3	14.1	15.1	16.1	17.9	19.7
5.0		12.0	14.3	16.5	17.7	18.8	21.0	23.2
7.5		13.8	16.4	18.9	20.2	21.6	24.1	26.6
10.0		15.5	18.5	21.4	22.8	24.3	27.2	
12.5		17.2	20.6	23.8	25.4	27.1		
On the treadmill								
0		8.6	10.2	11.7	12.5	13.3	14.8	16.3
2.5		9.5	11.2	12.9	13.8	14.7	16.3	18.0
5.0		10.3	12.3	14.1	15.1	16.1	17.9	19.7
7.5		11.2	13.3	15.3	16.4	17.4	19.4	21.4
10.0		12.0	14.3	16.5	17.7	18.8	21.0	23.2
12.5		12.9	15.4	17.7	19.0	20.2	22.5	24.9
15.0		13.8	16.4	18.9	20.3	21.6	24.1	26.6

[a]Differences in energy expenditures are accounted for by the effects of wind resistance.
Source: From Ref. 9, ACSM, 1980, *Guidelines for Graded Exercise Testing and Exercise Prescription.* Lea & Febiger, reprinted with permission.

TABLE V Energy expenditure in METS and W during cycle ergometry

	Exercise rate							
Body weight	300	450	600	750	900	1050	1200	(kg/m/min^{-1})
(kg)	50	75	100	125	150	175	200	(W)
50	5.1	6.9	8.6	10.3	12.0	13.7	15.4	
60	4.3	5.7	7.1	8.6	10.0	11.4	12.9	
70	3.7	4.9	6.1	7.3	8.6	9.8	11.0	
80	3.2	4.3	5.4	6.4	7.5	8.6	9.6	
90	2.9	3.8	4.8	5.7	6.7	7.6	8.6	
100	2.6	3.4	4.3	5.1	6.0	6.9	7.7	

Note: VO_2 for zero load pedaling is approximately 550 ml/min for 70–80-kg subjects.
Source: From Ref. 9, ACSM, 1980, *Guidelines for Graded Exercise Testing and Exercise Prescription,* Lea & Febiger, reprinted with permission.

TABLE VI Approximate energy requirements in METS for horizontal and grade walking

%Grade	mph (m/min)	1.7 45.6	2.0 53.7	2.5 67.0	3.0 80.5	3.4 91.2	3.75 100.5
0		2.3	2.5	2.9	3.3	3.6	3.9
2.5		2.9	3.2	3.8	4.3	4.8	5.2
5.0		3.5	3.9	4.6	5.4	5.9	6.5
7.5		4.1	4.6	5.5	6.4	7.1	7.8
10.0		4.6	5.3	6.3	7.4	8.3	9.1
12.5		5.2	6.0	7.2	8.5	9.5	10.4
15.0		5.8	6.6	8.1	9.5	10.6	11.7
17.5		6.4	7.3	8.9	10.5	11.8	12.9
20.0		7.0	8.0	9.8	11.6	13.0	14.2
22.5		7.6	8.7	10.6	12.6	14.2	15.5
25.0		8.2	9.4	11.5	13.6	15.3	16.8

Source: From Ref. 9, ACSM, 1980, *Guidelines for Graded Exercise Testing and Exercise Prescription*, Lea & Febiger, reprinted with permission.

TABLE VII Energy expenditure in METS during stepping at different rates on steps of different heights

Step height (cm)	Steps/min 12	18	24	30
0	1.2	1.8	2.4	3.0
4	1.5	2.3	3.1	3.8
8	1.9	2.8	3.7	4.6
12	2.2	3.3	4.4	5.5
16	2.5	3.8	5.0	6.3
20	2.8	4.3	5.7	7.1
24	3.2	4.8	6.3	7.9
28	3.5	5.2	7.0	8.7
32	3.8	5.7	7.7	9.6
36	4.1	6.2	8.3	10.4
40	4.5	6.7	9.0	11.2

Source: From Ref. 9, ACSM, 1980, *Guidelines for Graded Exercise Testing and Exercise Prescription.* Lea & Febiger, reprinted with permission.

onset of adverse signs and symptoms. This, in turn, makes exercise prescription more precise, more effective, and safer.

Protocols such as the Balke[3] and Jetté[4] types advance exercise intensity in constant increments. These protocols provide a satisfactory number of possible workloads for patients, with the early (and easier) exercise intensities serving as a warm-up for more strenuous exercise stages that follow. The exercise tolerance of a patient should be determined from the exercise intensity achieved in METS rather than by total treadmill time. Alternatively, functional capacity can be measured directly if oxygen uptake measurements are made. Figure 1 shows the exercise intensity equivalents in terms of METS and milliliters of oxygen for various testing protocols.

The METS system can thus be utilized to explain to a patient his/her functional capacity. For example, a 40-year-old, 70-kg male whose maximal aerobic power is measured at 21 ml O_2/kg/min (1.5 l/min O_2 or 105 W) would have a functional capacity equivalent to 6 METS (21 ml $O_2 \div 3.5$ ml $O_2 = 6$ METS). This could then be interpreted to the patient that he/she has achieved a rate of energy expenditure equal to 6 times resting metabolic rate. On the basis of normative data, this value would be classified as poor (Table VIII). This patient could be classified as Functional Class 2 (Table IX).

Having determined functional capacity from the exercise test, the patient could be advised, after consulting tables of energy expenditure (Tables I and II), which physical activities can be considered safe and/or suitable (i.e.,

Functional class[7]	O_2 cost ml/kg/min	METS	Bicycle ergometer (W) (70-kg man)	Bench stepping CAFT*[10] 3-min stages Male A[a]	Male stage	Female A[a]	Female stage	Treadmill protocols Bruce 3-min stages MPH	Bruce %GR	Jetté[4] 2-min stages MPH	Jetté %GR	Fox[8] Naughton 2-min stages MPH	Fox %GR	Balke[3] 3-min stages 3 MPH %GR	METS
								5.5	20						
	56.0	16						5.0	18						16
	52.5	15								3.75	22				15
	49.0	14								3.75	20				14
	45.5	13						4.2	16	3.75	18				13
Class I	42.0	12	225							3.75	16			22.5	12
	38.5	11	200							3.50	16			20.0	11
	35.0	10	175	26	7					3.50	14			17.5	10
	31.5	9		24	6	22	6	3.4	14	3.50	12			15.0	9
	28.0	8	150	22	5	20	5			3.50	10			12.5	8
	24.5	7	125	19	4	19	4	2.5	12	3.50	7.5	2.0	17.5	10.0	7
Class II	21.0	6	100	17	3	17	3			3.00	7.5	2.0	14.0	7.5	6
	17.5	5	75	14	2	14	2	1.7	10	3.00	5	2.0	10.5	5.0	5
	14.0	4	50	11	1	11	1					2.0	7.0	2.5	4
Class III	10.5	3	25					1.7	5	3.00	2.5	2.0	3.5	0.0	3
	7.0	2						1.7	0			2.0	0.0		2
Class IV	3.5	1										1.0	0.0		1

FIG. 1 Metabolic equivalents in exercise testing and evaluation of functional capacity. *CAFT = Canadian Aerobic Fitness Test; A[a] = ascents per minute (double 20 cm step).

TABLE VIII Normative data for cardiorespiratory fitness for males aged 30-49

	30-39		40-49	
	O_2ml/kg/min	METS	O_2ml/kg/min	METS
Excellent	>53	>15	>53	>15
Above average	45-52	13-15	43-52	12-15
Average	38-44	11-13	33-42	9-12
Below average	30-37	9-12	23-32	7-9
Poor	<30	<9	<23	<7

Source: From Jetté M: *Clinical Fitness Research Appraisal Program, Norms for Fitness Tests.* Department of Kinanthropology, University of Ottawa, November 1983.

TABLE IX Summary of criteria for specific activity scale classifications

Class 1:	Patient can perform to completion an activity requiring ≥7 metabolic equivalents
Class 2:	Patient can perform to completion any activity requiring ≥5 metabolic equivalents but cannot or does not perform to completion activities requiring ≥7 metabolic equivalents
Class 3:	Patient can perform to completion any activity requiring ≥2 metabolic equivalents but cannot or does not perform to completion any activities requiring ≥5 metabolic equivalents
Class 4:	Patient cannot or does not perform to completion activities requiring ≥2 metabolic equivalents

Source: From Ref. 6, Goldman *et al.*, 1981, *Circulation* 64, 1227, reprinted with permission from the American Heart Association, Inc.

effective) for physical training. It is also appropriate to explain which activities should either not be performed, or performed only with due caution.

Utilization of the METS Procedure in the Formulation of an Exercise Prescription

Work intensity is a most important factor in the establishment of a conditioning or rehabilitation exercise program. For aerobic training, a proper dosage of exercise is considered to vary from 40% of maximum METS for poorly conditioned and/or symptomatic persons to perhaps 85% of maximum METS for well-conditioned athletic persons. A training intensity of 60–70% of maximum METS, the average level of anaerobic threshold, is typically prescribed for most healthy, asymptomatic individuals when performing continuous aerobic training. Balke[3] recommends the following sliding scale for prescribing an acceptable training intensity:

$$\text{Training intensity} = \frac{60 + \text{max METS}}{100} \times \text{max METS}$$

For example, if the functional capacity of a patient is 6 METS, the training intensity would be $(60+6)/100 \times 6 = 4$ METS. For aerobic training, the patient would be counselled to engage in activities which demand an average energy expenditure of 4 METS. The exercise prescription could be accompanied by a recommended or target heart rate (or range) corresponding to 4 METS as determined during progressive exercise testing.[5]

The advantage of the sliding scale method is that it allows persons with higher levels of functional capacity to automatically train at a greater relative exercise intensity than persons with a lower functional capacity. For the patient with an exercise tolerance of 6 METS, the prescribed average conditioning intensity would be 4 METS; individuals with functional capacities of 5, 10, and 15 METS would train at average intensities of 3.25, 7.0, and 11.25 METS, respectively.

For the first few weeks of training, the exercise prescription is normally adjusted 1 MET lower than the calculated exercise intensity until the participant has become accustomed to exercise and the exercise leader has become familiar with the participant's exercise response.[6] Such precaution minimizes muscle soreness and the potential for debilitating injuries and discomfort, and thereby enhances program adherence.

Usually, such activities as walking, jogging, cycling, and swimming are prescribed during the early phases of conditioning since the energy cost of these activities is well known and effort can be simply controlled by telling the participants to cover a fixed distance in a given time. On the other hand, games and sports often involve an element of competition and require a variable or intermittent expenditure of energy. Such activities are not recommended in the initial phases of conditioning, but can be included later to sustain motivation once a minimal function capacity of 5 METS has been attained.

Patients with a functional capacity of less than 3 METS, often seen following major surgery or debilitating illness, are usually encouraged to exercise several times each day, with sessions lasting for only about five minutes. Persons with a functional capacity of 3 to 5 METS, on the other hand, are advised to exercise once or twice daily. Individuals with a functional capacity from 5 to 8 METS may exercise on alternate days, three days per week. Once a functional capacity of 8 METS is attained, a less rigorously supervised exercise program can be recommended.

Physical conditioning lowers heart rate and rating of perceived exertion (RPE) for a given MET level. Consequently, the participants have to increase the exercise MET level progressively by walking, running, cycling, or swimming faster in order to elicit heart rates (or RPE values) in the desired training range.

Limitations of the METS System

A number of limitations affect the utility of METS as a method of describing exercise intensity and estimating the energy expenditure of physical activities. A larger person would be expected to have a larger resting oxygen uptake compared with a smaller person. Individuals with the same body mass, but differing in percent body fat and lean body mass (LBM), will have different resting metabolic rates, with resting energy expenditures proportion-

al to the quantity of muscle present (i.e., LBM). For simplicity, however, individual differences in resting energy expenditures are disregarded. Moreover, even when oxygen uptake is expressed relative to body weight, the baseline value of 3.5 ml O_2/kg/min is only an approximate average value for sitting at rest.

As is true for the other units, energy expenditure values for a given activity vary not only according to body size, but also level of fitness, skill, and whether or not the activity is performed in a competitive situation. Activities involving high levels of skill, such as swimming, cross-country skiing, squash, and tennis are particularly subject to a wide range of energy expenditure. The published energy cost of activities is also significantly affected by various environmental conditions, including cold, heat, humidity, wind, altitude, playing surface, and terrain, as well as clothing and equipment worn.

Even with these limitations, the MET concept represents a simple, practical, and easily understood procedure for expressing the energy cost of physical activities as a multiple of the resting metabolic rate. Its utilization provides a convenient method to describe the functional capacity or exercise tolerance of an individual as determined from progressive exercise testing and to define a repertoire of physical activities in which a person may participate safely, without exceeding a prescribed intensity level.

Acknowledgments

The assistance of J. Quenneville and R. Holden in the preparation of this manuscript is gratefully acknowledged.

References

1. Bouchard C, Godin G, Landry F, Shephard R, Skinner J: Multiples of the Resting Metabolic Rate (METS) of Physical Activities. Report submitted to Canada Fitness Survey. Ottawa, Canada (1983)
2. McArdle W, Katch F, Katch V: *Exercise Physiology: Energy, Nutrition, and Human Performance*. Lea & Febiger, Philadelphia, (1986) 138
3. Balke B: Prescribing physical activity. In *Sports Medicine* (Eds. A Ryan, F Allman). Academic Press, New York, (1974) 505
4. Jetté M: A comparison between predicted VO_2 max from the Astrand Procedure and the Canadian Home Fitness Test. *Can J Appl Spt Sci* 4, 3, 214 (1979)
5. American College of Sports Medicine: *Guidelines for Graded Exercise Testing and Exercise Prescription*, 3rd ed. Lea & Febiger, Philadelphia (1986)
6. Froelicher VF, Marcondes GD: *Manual of Exercise Testing*. Year Book Medical Publishers, Chicago (1989)
7. Goldman L, Hashimoto B, Cook F, Loscalzo A: Comparative reproducibility and validity of systems for assessing cardiovascular functional class: Advantages of a new specific activity scale. *Circulation* 64, 1227 (1981)
8. Fox S, Naughton J, Gorman P: Physical activity and cardiovascular health III. The exercise prescription: Frequency and type of activity. *Mod Concepts Cardiovasc Dis* 31, 25 (1972)
9. American College of Sports Medicine: *Guidelines for Graded Exercise Testing and Exercise Prescription*, 2nd Edition, Lea & Febiger, Philadelphia (1980)
10. Jetté M: The Energy Requirements of the Canadian Home Fitness Test and Their Application to the Evaluation of Work Performance. *Can J Public Health* 74, 401 (1983)