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Chapter 4

Energy Costs of Exercise and Sport

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Introduction

In the middle of the 18th century, Lavoisier conceived the first law of thermodynamics, that energy can be neither created nor destroyed but only changed from one form to another. This principle of the conservation of energy was later formulated by Mayer in 1842 and Helmholtz in 1847, but it remained for Joule, a brewer, to provide experimental data to support the concept (Fenn & Rahn 1964). When Lavoisier and Laplace demonstrated that muscular exercise consumes oxygen and produces carbon dioxide (Chapman & Mitchell 1965), the stage was set for learning how to measure energy expenditure. It was clear then that the energy in the food consumed should equal the energy expended.

Energy is expended in three ways in humans and other warm-blooded animals. A certain amount of energy is required at rest to maintain body temperature and involuntary muscular contraction for functions such as circulation and respiration. This energy level represents the resting metabolic rate. Second, some energy is required to digest and assimilate food. This process, formerly called *specific dynamic action* and now referred to as *dietary induced thermogenesis* or *thermic effect of food*, adds about 10% to the resting metabolic rate. These two represent but a small part of the total energy expenditure and can be altered only very slightly in individuals. By far the most important source of variation between individuals in energy expenditure (when adjusted for body size) is the muscular activity carried out. The sources of this activity are one's daily work, leisure pursuits, and transportation to and from work or other destinations (which some investigators include as part of leisure time activity).

In the International System of Units (SI), the unit of measurement for heat production is the joule (named for James Prescott Joule, who did pioneering work in metabolism).

One observation about energy expenditure is essential to keep in mind. The intake or expenditure of joules is related to body size. A small person who is very active may expend a similar number of kilojoules in 24 h as a large person who is sedentary. So if exercise is to be expressed as energy expenditure in joules or calories, body size must be taken into account. To this end, energy expended or ingested is sometimes given as kilojoules or kilocalories per unit of body weight or, in the case of oxygen (O_2) uptake, as millilitres of O_2 per kilogram of body weight. The use of METs (an abbreviation for 'metabolic equivalent') is another approach to correcting for body weight. A MET represents the ratio of energy expended in kilojoules divided by resting energy expenditure in kilojoules, either measured or estimated from body size. In estimating resting (not basal) energy expenditure, a value of 4.2 kJ per kilogram of body weight per hour or 3.5 ml O_2 utilized per kilogram of body weight per minute gives reasonably satisfactory results in most cases. Although neither method is perfect, the MET approach is more popular and probably more useful. Although he did not use

the term MET, LaGrange (1905) almost a century ago expressed the strenuousness of activities as a ratio of exercise metabolism to resting metabolism. The World Health Organization adopted the same principle in its physical activity index. Among exercise physiologists, it is almost universally accepted to use METs to express energy expenditure in relation to body weight. In Appendix 4.1, the energy cost of activities is expressed in METs as well as kilojoules per kilogram of body weight.

Methods of measurement

The direct measurement of energy expenditure (heat production) by a living animal or human being is possible. Although the engineering problems are formidable, the heat produced while the subject is in a sealed, insulated chamber can be measured.

A room calorimeter measures the heat produced by the subject at rest or during exercise by circulating water through pipes in the insulated chamber and carefully measuring, at frequent intervals, the temperature of the ingoing and outgoing water and the water flow. Sophisticated engineering is required to prevent heat loss from the chamber by other means. The latent heat of the water vaporized must be determined by measuring the vapour in the ventilating air current. Calorimeters have been built in which air flow and temperature are measured by means of thermocouples using the thermal gradient principle (Carlson & Hsieh 1970; Jéquier *et al.* 1987). Energy exchange during muscular exercise can be measured by installing an exercise device (treadmill, cycle ergometer, etc.) in the chamber.

Webb (Webb 1980; Webb *et al.* 1980) also describes an insulated, water-cooled suit worn by the subject in which the flow of water through the suit and the temperature of the incoming and outgoing water are measured to determine heat production. The suit has been modified by Hambraeus *et al.* (1991). When energy is transformed from food to heat and muscular work, oxygen is consumed and thus the oxygen consumed could be measured to ascertain energy expenditure. The term *indirect calorimetry* is applied to the method of estimating energy expenditure from oxygen consumption and carbon dioxide production because heat production is not measured directly.

A room calorimeter can be constructed in which expired air is analysed to estimate heat production. Atwater and Benedict (1905) showed that by measuring the oxygen consumed and carbon dioxide produced, heat production could indeed be estimated with reasonable accuracy. This kind of calorimeter is usually referred to as a respiration chamber.

However, room calorimeters and respiration chambers are confining. Even Webb's water-cooled suit, because of the computer and other necessary equipment, is confined to the laboratory. Hence, although the energy cost of some activities (walking at various grades on a treadmill, riding a stationary cycle at various resistances and speeds, certain calisthenic exercises, for examples) can be measured with calorimeters or respiration chambers, the energy cost of many sports activities or occupational tasks cannot be measured in this way.

There are several simpler techniques for measuring oxygen uptake. One, called the *closed circuit method*, requires the subject to be isolated from outside air. The respirometer originally contains pure oxygen, and as the subject breathes in this closed system the carbon dioxide is continuously removed as it passes through soda lime. The gas volume gradually decreases, and the rate of decrease is a measure of the rate of oxygen consumption. Regnault and Reiset developed this system in 1849, and by measuring the carbon dioxide absorbed they discovered the respiratory quotient (Fenn & Rahn 1964). This method works reasonably well for measuring resting or basal metabolic rate, but absorbing the large volume of carbon dioxide produced during prolonged, strenuous exercise becomes a problem. The *open circuit method* described next is more suited to measuring exercise metabolism.

Two procedures in the open circuit method have been developed. In one, the flow-through

Fig. 4.1 In most games, the exercise intensity flucuates, and total energy expenditure depends on many factors. In games such as soccer, the most important of these are body mass and total distance covered. Photo © Allsport / A. Bello.

technique (Kinney 1980), a large volume of the equivalent of outside air passes through a hood worn by the subject. The subject inspires and expires into the airstream flowing through the hood. Air flow and percentage of oxygen and carbon dioxide are precisely measured to calculate $\dot{V}o_2$ and RQ. It is necessary to have accurate gas analysers, particularly the one for carbon dioxide, because its concentration may be between 0% and 0.5%. This method is especially useful for long-term measurements with the subject at rest or doing only mild exercise.

The second procedure, the time-honoured Douglas bag method (although a Douglas bag may not necessarily be used), has been found to be accurate and theoretically sound. With this procedure, the subject generally wears a nose clip and mouthpiece or a face mask. Outside air or its equivalent is inhaled through the mouthpiece or mask containing a one-way valve and exhaled into a Douglas bag or Tissot tank. It is important that the mouthpiece and connected tubing provide minimal resistance to airflow, or the cost of breathing will increase the energy expenditure. The volume of air in the bag or tank is measured to calculate ventilation. A sample of exhaled air is obtained to measure the O_2 and CO_2 concentrations. This is usually done with a Haldane, modified Haldane, or Micro-Scholander apparatus. These techniques use reagents to absorb the carbon dioxide and oxygen, respectively, with the volume of the sample measured before and after the gases are absorbed.

In the laboratory, modern electronic equipment usually replaces the Douglas bag and chemical analysers, whereby ventilation and oxygen and carbon dioxide percentages are determined instantaneously and continuously. Chemical analysers are generally used to analyse standard gas mixes to calibrate the electronic equipment. The electronic equipment confines the procedure to laboratory or clinic. The Douglas bag method is not as restricting because a bag can be carried on the back or by an assistant close by. This method thus can be used in the field.

Nathan Zuntz (1847–1920) recognized the advantage of having the subject carry a self-contained unit if $\dot{V}o_2$ is to be measured during exercise. He developed what was probably the first such unit, which resembled a large rucksack (Zuntz & Leowy 1909). This was a forerunner of the portable calorimeter designed by Kofranyi and Michaelis (1940). Improvements were made during the subsequent 10 years, resulting in the

model by Müller and Franz (1952). This also resembles a rucksack but is smaller and lighter than Zuntz's apparatus.

The Müller–Franz calorimeter registers ventilation and siphons off a small percentage of the expired air into a small attached bag for later analysis. This apparatus functions reasonably well during rest or moderate exercise. At airflows of about 80–100 l·min^{-1}, the meter begins to under-record ventilation (Orsini & Passmore 1951; Insull 1954; Montoye *et al.* 1958) and hence underestimate energy expenditure. At severe exercise, where instantaneous flows can reach 200 l or more per minute, the instrument seriously underestimates energy expenditure. There is also a potential error due to diffusion of the gas through the bag, which becomes more serious the longer the delay in analysing the gas. In addition to these limitations, there may be some interference in particular activities (the calorimeter weighs about 3 kg), although the instrument can be carried in a bicycle basket or by an assistant. Also, the rates of energy expenditure are averaged over the entire collection period.

Wolff (1958) improved the Kofranyi–Michaelis respirometer. His integrating motor pneumotachograph (IMP) is available from J. Langham Thompson Ltd, Bushey Heath, Herts, UK. The IMP has some of the limitations of the Kofranyi–Michaelis respirometer. Ventilation is integrated electrically rather than mechanically lowering the expiratory resistance. Also, samples with smaller percentages are possible. This group (Humphrey & Wolff 1977) later developed a more advanced instrument, the oxylog, available from P.K. Morgan Ltd, Rainham, Kent, UK. This battery-operated, self-contained, portable instrument weighs about the same as the Kofranyi–Michaelis respirometer, but it is engineered for on-line measurement of oxygen consumption. Carbon dioxide is not measured. It has been found to be reasonably accurate in field measurements during rest and up to moderately strenuous exercise (Harrison *et al.* 1982; McNeill *et al.* 1987; Collins *et al.* 1988). The error was reported to be 2–3% at 4 METs, but the error increases at lower and higher workloads (Patterson & Fisher 1979). Ikegami *et al.* (1988) added a telemetry capacity to the oxylog so $\dot{V}o_2$ could be recorded remotely at 1-min intervals.

Nutritionists and others have estimated energy expenditure by measuring the energy in food consumed. However, this method estimates an average energy expenditure over days or weeks and hence is not suitable for the measurement of the energy cost of individual activities. Similarly the use of doubly labelled water (Montoye *et al.* 1996) which some consider the gold standard for estimating habitual energy expenditure, also is not useful for measuring energy expenditure of specific activities because it too only provides an average energy expenditure over a week or two.

Because of the difficulties encountered in measuring $\dot{V}o_2$ in the field, there is interest in the simpler but less direct method—recording physiological data associated with energy expenditure. Advancements in telemetry and other aspects of bioengineering have made such techniques more attractive.

From the beginning of their existence, humans must have observed that pulse rate and ventilation increase during strenuous activity. Systolic blood pressure, electromyographs, and body temperature are also roughly proportional to the intensity of exercise. All of these variables can be telemetered, or entered on portable recorders.

Of the physiological variables, heart rate (HR) is the easiest to measure in the field. The relationship between HR and energy expenditure was shown as early as 1907, when Benedict (1907) reported that changes in pulse rate were correlated with changes in heat production in any one individual. He later suggested that pulse rate may provide a practical and satisfactory method for estimating total metabolism.

Murlin and Greer in 1914 confirmed Benedict's results. They measured respiratory metabolism and HR simultaneously in subjects who were resting and doing moderate work. Their results indicated that HR was a good index of oxygen consumption. Thus, when work can be carefully controlled (as, for example, on a treadmill or bicycle), $\dot{V}o_2$ and HR are closely related and the

relationship is linear over much of the range when the measurements are taken on one individual (Montoye 1970). The linear relationship of HR with $\dot{V}o_2$ can be understood from the Fick equation: $\dot{V}o_2 = HR \cdot SV\ (a - \dot{V}o_{2diff.})$. Over a wide range of exercise, stroke volume and $a - \dot{V}o_{2diff.}$ do not change greatly; consequently, the increase in HR reflects an increase in $\dot{V}o_2$. Some investigators have presented data showing that relationship is not linear over the full range from rest to strenuous activity (Henderson & Prince 1914; Booyens & Hervey 1960; Malhotra *et al.* 1963; Bradfield *et al.* 1969; Berg 1971; Viteri *et al.* 1971; Warnold & Lenner 1977). Most agree that during exercise HR is more consistent and there is a greater tendency toward linearity than when resting values are included.

Under many conditions, considerable error may be expected when energy expenditure is estimated from the heart rate. There is some day-to-day variation in HR at a given energy expenditure. To this must be added other sources of error. High ambient temperature and humidity or emotion may raise the HR with little effect on oxygen requirement of the work. Training lowers the HR at which tasks of a given energy cost are performed. For example, active workers exercise at lower rates than sedentary men when the workload is equal (Taylor & Parlin 1966; Taylor 1967). Females have higher rates during exercise than males (Montoye 1975). Fatigue (Lundgren 1947; Booyens & Hervey 1960) and state of hydration (Lundgren 1947) affect the HR–$\dot{V}o_2$ relationship. Heart rates are higher for a given energy expenditure in anaemic children (Gandra & Bradfield 1971). Furthermore, certain kinds of activities, such as work with the arms only, will elicit higher HR than work done with the legs and arms, even though the oxygen cost is the same (Durin & Namyslowski 1958; Payne *et al.* 1971; Vokac *et al.* 1975; Anderson *et al.* 1981; Collins *et al.* 1991). Andrews (1971) has shown that HR–$\dot{V}o_2$ slopes were the same for arm and leg exercise but the intercepts were different. Static exercise increases HR above that expected on the basis of oxygen requirement (Hansen & Maggio 1960; Mass *et al.* 1989).

Saris *et al.* (1982) showed that over 5 h, changing the strenuousness of activities has an effect on the accuracy of the HR-to-energy expenditure conversion, especially for quiet activities after moderate exercise: the energy expenditure is overestimated. This phenomenon may contribute to the overestimation of total energy expenditure regardless of what $\dot{V}o_2$–HR regression equation is used.

If one wishes to express the energy expenditure in kilojoules from the oxygen utilized (i.e. not measuring heat produced), it must be recognized that the kilojoules of heat produced by the utilization of 1 litre of oxygen varies with the foodstuffs consumed. The combustion of 1 litre of oxygen yields 19.59 kJ (4.68 kcal) from fat alone, 18.75 kJ (4.48 kcal) from protein alone, and 21.18 kJ (5.06 kcal) from carbohydrate starch alone. Even this is not precise because within each of these three main food sources, the kilojoules of heat from 1 litre of oxygen can vary. For example, considering different types of macronutrients, Brody (1974) gives 18.4 kJ (4.4 kcal) for cottonseed oil and corn oil, 19.3 kJ (4.6 kcal) for butterfat, 21.18 kJ (5.06 kcal) for starch, and 21.26 kJ (5.08 kcal) for sucrose. Similarly, the production of heat from 1 litre of carbon dioxide varies with the foodstuffs metabolized. For precise conversion of oxygen utilization to energy expenditure, the proportions of fat, carbohydrates, and protein being utilized can be determined by the nitrogen that appears in the urine during the time of observation. About 1 g of nitrogen is excreted for every 6.25 g of protein metabolized.

The ratio of the volume of carbon dioxide produced to the volume of oxygen consumed, the so-called *respiratory quotient* (RQ), gives a reasonable approximation of the percentage of carbohydrate and fat being burned, the ratio being 0.7 when pure fat is the source of energy and 1.00 when it is pure carbohydrate. These ratios assume a 'steady state,' which exists when the oxygen uptake equals the oxygen requirement of the tissues and there is no accumulation of lactic acid. Heart rate, ventilation, and cardiac output remain at fairly constant levels during a steady

state. RQ is not representative of the foodstuffs being oxidized in a non-steady state, such as at the start of exercise or during the onset of acidosis of alkalosis as may occur during strenuous exercise or some disease states. The term *respiratory exchange ratio* (RER) rather than RQ is used when a steady state does not exist.

Variations in the caloric equivalents of different fat, different carbohydrate, and different protein sources can be ignored because the error produced is very small. This is because in a normal diet the mixture of different types of fat, carbohydrate, and protein balances out the differences in caloric equivalents. Even the error introduced by not measuring the percentage of protein being used can be ignored in most instances because the caloric equivalents of oxygen are similar for carbohydrates and protein. No matter how diverse the actual composition of the food oxidized, the error in estimating energy expenditure is unlikely to be more than 2–4%. An error of 100% in the estimation of urinary excretion of nitrogen leads to only a 1% error in energy expenditure.

A table of energy costs of exercise and sport

A list of energy costs of various activities is presented in Appendix 4.1. This is a modification of the list shown in appendix C of the publication by Montoye and others (1996) which in turn was a modification of the list by Ainsworth *et al.* (1993). Appreciation is hereby acknowledged for the willingness of these authors to allow the lists to be modified once again and reproduced in this chapter.

Many of the values of this list came from the following sources: Bannister and Brown (1968); the 7-Day Recall Physical Activity Questionnaire (Blair *et al.* 1985); Durnin and Passmore (1967); Howley and Glover (1974); the American Health Foundation's Physical Activity List (Leon 1981); McArdle *et al.* (1988); Passmore and Durnin (1955); Tecumseh Questionnaire (Reiff *et al.* 1967a, 1967b). Some values have been added from the following sources: Collins *et al.* (1991); Geissler *et al.* (1981); Getchell (1968); Goff *et al.* (1956); Mandli *et al.* (1989); Nelson *et al.* (1988); Seliger (1968); Stray-Gundersen and Galanes (1991); Veicsteinas *et al.* (1984); VonHofen *et al.* (1989); Watts *et al.* (1990); Wigaeus and Kilbom (1980).

Much of the data in this appendix are derived from actual measurement by indirect calorimetry. However, where data are not available, the figures are based on educated guesses. For some activities, the values are not the values obtained exclusively during execution of the activities. For example, folk dancing requires a higher value than that shown. However, in an hour of folk dancing, considerable time is spent standing, receiving directions, and so on, so the value shown represents the estimated average value. On the other hand, walking usually is done continuously, so its values represent the actual energy cost of doing the activity.

Adults (usually young adults) served as subjects in determining most of the metabolic costs of activities that have been reported in the literature. Little data is based on children and the elderly. The energy expended by children in kilojoules per kilogram of body weight in performing even common activities such as walking is significantly higher than when the same activities are done by adults (Montoye 1982). This is probably because of children's greater ratio of surface area to body weight and poorer coordination than adults. Even if the resting energy expenditure is also higher in children, the MET values of activities in the table are probably a little low for children. Data from Torún *et al.* (1983) have shown the same results. This has also been shown to be true for infants (Torún *et al.* 1983). Data on energy cost of activities are needed to create a table for children.

Data on the energy cost of elderly adults are also needed. Although walking at the same rate may elicit an energy expenditure not much different than in young adults, the elderly generally walk slower, play tennis at less intensity, skate less vigorously, and the like, so the estimate of habitual energy expenditure in the elderly requires other energy cost values.

The numerical values in the third column is the MET rating (the energy cost of the activity divided by the resting, not basal, energy expenditure). The last columns contain the approximate energy cost of the activity expressed as kilojoules or kilocalories per hour per kilogram of body mass.

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Appendix 4.1 A compendium of the energy costs of different physical activities.

Activity category	Specific activity (kcal $h^{-1} \cdot kg^{-1}$)	METs	$kJ \cdot h^{-1} \cdot kg^{-1}$ ($kcal \cdot h^{-1} \cdot kg^{-1}$) body wt
Bicycling	Mountain biking	8.5	35 (8.3)
Bicycling	$<16\,km \cdot h^{-1}$, general, leisure, to work or for pleasure	4.0	17 (4.0)
Bicycling	$16–19\,km \cdot h^{-1}$, leisure, slow, light effort	6.0	25 (5.9)
Bicycling	$19.1–22.4\,km \cdot h^{-1}$, leisure, moderate effort	8.0	33 (7.8)
Bicycling	$22.5–25.5\,km \cdot h^{-1}$, racing or leisure, fast, vigorous effort	10.0	42 (10.0)
Bicycling	$25.6–30.5\,km \cdot h^{-1}$, racing/not drafting or $>30.5\,km \cdot h^{-1}$ drafting, very fast, racing general	12.0	50 (11.9)
Bicycling	$>30.5\,km \cdot h^{-1}$, racing, not drafting	16.0	67 (15.9)
Bicycling	Unicycling	5.0	21 (5.0)
Conditioning exercise	Bicycling, stationary, general	5.0	21 (5.0)
Conditioning exercise	Bicycling, stationary, 50 W, very light effort	3.0	13 (3.1)
Conditioning exercise	Bicycling, stationary, 100 W, light effort	5.5	23 (5.5)
Conditioning exercise	Bicycling, stationary, 150 W, moderate effort	7.0	29 (6.9)
Conditioning exercise	Bicycling, stationary, 200 W, vigorous effort	10.5	44 (10.5)
Conditioning exercise	Bicycling, stationary, 250 W, very vigorous effort	12.5	52 (12.4)
Conditioning exercise	Calisthenics (e.g. push-ups, pull-ups, sit-ups), heavy, vigorous effort	8.0	33 (7.8)

Activity category	Specific activity	METs	kJ·h^{-1}·kg^{-1} (kcal·h^{-1}·kg^{-1}) body wt
Conditioning exercise	Calisthenics, home exercise, light or moderate effort, general (e.g. back exercises), going up and down from floor	4.5	19 (4.5)
Conditioning exercise	Circuit training, general	8.0	33 (7.8)
Conditioning exercise	Weight lifting (free weight, nautilus or universal-type), power lifting or body building, vigorous effort	6.0	25 (5.9)
Conditioning exercise	Health club exercise, general	5.5	23 (5.5)
Conditioning exercise	Stair-treadmill ergometer, general	6.0	25 (5.9)
Conditioning exercise	Rowing, stationary ergometer, general	9.5	40 (9.5)
Conditioning exercise	Rowing, stationary, 50 W, light effort	3.5	15 (3.6)
Conditioning exercise	Rowing stationary, 100 W, moderate effort	7.0	29 (6.9)
Conditioning exercise	Rowing, stationary, 150 W, vigorous effort	8.5	35 (8.3)
Conditioning exercise	Rowing, stationary, 200 W, very vigorous effort	12.0	50 (11.9)
Conditioning exercise	Ski machine, general	9.5	40 (9.5)
Conditioning exercise	Slimnastics	6.0	25 (5.9)
Conditioning exercise	Stretching, hatha yoga	4.0	17 (4.0)
Conditioning exercise	Teaching aerobics exercise class, assumes participation	6.0	25 (5.9)
Conditioning exercise	Water aerobics, water calisthenics	4.0	17 (4.0)
Conditioning exercise	Weight lifting (free, nautilus or universal-type), light or moderate effort, light workout, general	3.0	13 (3.1)
Conditioning exercise	Whirlpool, sitting	1.0	4 (0.9)
Dancing	Aerobic, ballet or modern, twist	6.0	25 (5.9)
Dancing	Aerobic, general	6.0	25 (5.9)
Dancing	Aerobic, low impact	5.0	21 (5.0)
Dancing	Aerobic, high impact	7.0	29 (6.9)
Dancing	General	4.5	19 (4.5)
Dancing	Ballroom, fast (e.g. disco, folk, square)	5.5	23 (5.5)
Dancing	Ballroom, slow (e.g. waltz, foxtrot, slow dancing)	3.0	13 (3.1)
Fishing and hunting	Fishing, general	5.0	21 (5.0)
Fishing and hunting	Digging worms with shovel	4.0	17 (4.0)
Fishing and hunting	Fishing from river bank and walking	5.0	21 (5.0)
Fishing and hunting	Fishing from boat, sitting	2.5	10 (2.4)
Fishing and hunting	Fishing from river bank, standing	3.5	15 (3.6)
Fishing and hunting	Fishing in stream, in waders	6.0	25 (5.9)
Fishing and hunting	Fishing, ice, sitting	2.0	8 (1.9)
Fishing and hunting	Hunting, bow and arrow or crossbow	2.5	10 (2.4)
Fishing and hunting	Hunting, deer, elk, large game	6.0	25 (5.9)
Fishing and hunting	Hunting, duck, wading	2.5	10 (2.4)
Fishing and hunting	Hunting, general	5.0	21 (5.0)
Fishing and hunting	Hunting, pheasants or grouse	6.0	25 (5.9)
Fishing and hunting	Hunting, rabbit, squirrel, prairie chick, racoon, small game	5.0	21 (5.0)
Fishing and hunting	Pistol shooting or trap shooting, standing	2.5	10 (2.4)
Home activities	Carpet sweeping, sweeping floors	2.5	10 (2.4)
Home activities	Cleaning, heavy or major (e.g. washing car, washing windows, mopping, cleaning garage), vigorous effort	4.5	19 (4.5)
Home activities	Cleaning, house or cabin, general	3.5	15 (3.6)
Home activities	Cleaning, light (dusting, straightening up, vacuuming, changing linen, carrying out rubbish), moderate effort	2.5	10 (2.4)
Home activities	Washing dishes, standing or in general (not broken into stand/walk components)	2.3	9 (2.1)

Activity category	Specific activity	METs	kJ·h⁻¹·kg⁻¹ (kcal·h⁻¹·kg⁻¹) body wt
Home activities	Washing dishes, clearing dishes from table (walking)	2.3	9 (2.1)
Home activities	Cooking or preparing food, standing or sitting or in general (not broken into stand/walk components)	2.5	10 (2.4)
Home activities	Serving food, setting table (implied walking or standing)	2.5	10 (2.4)
Home activities	Cooking or food preparation, walking	2.5	10 (2.4)
Home activities	Putting away groceries (e.g. carrying groceries, shopping without a trolley)	2.5	10 (2.4)
Home activities	Carrying groceries upstairs	8.0	33 (7.8)
Home activities	Food shopping, with trolley	3.5	15 (3.6)
Home activities	Shopping (non-grocery shopping), standing	2.0	8 (1.9)
Home activities	Shopping (non-grocery shopping), walking	2.3	9 (2.1)
Home activities	Ironing	2.3	9 (2.1)
Home activities	Sitting, knitting, sewing, light wrapping (presents)	1.5	6 (1.4)
Home activities	Laundry, folding or hanging clothes, putting clothes in washer or dryer, packing suitcase (implied standing)	2.0	8 (1.9)
Home activities	Putting away clothes, gathering clothes to pack, putting away laundry (implied walking)	2.3	9 (2.1)
Home activities	Making beds	2.0	8 (1.9)
Home activities	Making maple syrup (tapping trees, carrying buckets, carrying wood, etc.)	5.0	21 (5.0)
Home activities	Moving furniture, household	6.0	25 (5.9)
Home activities	Scrubbing floors on hands and knees	5.5	23 (5.5)
Home activities	Sweeping garage, pavement or outside of house	4.0	17 (4.0)
Home activities	Moving household items, carrying boxes	7.0	29 (6.9)
Home activities	Packing/unpacking boxes, occasional lifting of household items, light–moderate effort (standing)	3.5	15 (3.6)
Home activities	Putting away household items, moderate effort (implied walking)	3.0	13 (3.1)
Home activities	Move household items upstairs, carrying boxes or furniture	9.0	38 (9.0)
Home activities	Light (e.g. pumping gas, changing light bulb, etc.), standing	2.5	10 (2.4)
Home activities	Light, non-cleaning (e.g. getting ready to leave, shutting/locking doors, closing windows, etc.), walking	3.0	13 (3.1)
Home activities	Playing with child(ren), light effort (sitting)	2.5	10 (2.4)
Home activities	Playing with child(ren), light effort (standing)	2.8	12 (2.8)
Home activities	Playing with child(ren), moderate effort (walking/running)	4.0	17 (4.0)
Home activities	Playing with child(ren), vigorous effort (walking/running)	5.0	21 (5.0)
Home activities	Child care: sitting/kneeling—dressing, bathing, grooming, feeding, occasional lifting of child, light effort	3.0	13 (3.1)
Home activities	Child care: standing—dressing, bathing, grooming, feeding, occasional lifting of child, light effort	3.5	15 (3.6)
Home activities	Weaving at a loom, sitting	2.0	8 (1.9)
Home repair	Car body work	4.5	19 (4.5)
Home repair	Car repair	3.0	13 (3.1)
Home repair	Carpentry, general, workshop	3.0	13 (3.1)
Home repair	Carpentry, outside house, installing rain gutters	6.0	25 (5.9)
Home repair	Carpentry, finishing or refinishing cabinets or furniture	4.5	19 (4.5)
Home repair	Carpentry, sawing hardwood	7.5	31 (7.4)
Home repair	Caulking, chinking log cabin	5.0	21 (5.0)
Home repair	Caulking, except log cabin	4.5	19 (4.5)
Home repair	Cleaning, gutters	5.0	21 (5.0)

Activity category	Specific activity	METs	$kJ \cdot h^{-1} \cdot kg^{-1}$ ($kcal \cdot h^{-1} \cdot kg^{-1}$) body wt
Home repair	Excavating garage	5.0	21 (5.0)
Home repair	Hanging storm windows	5.0	21 (5.0)
Home repair	Laying or removing carpet	4.5	19 (4.5)
Home repair	Laying tile or linoleum	4.5	19 (4.5)
Home repair	Painting, outside house	5.0	21 (5.0)
Home repair	Painting, papering, plastering, scraping, inside house, hanging sheet rock, remodelling	4.5	19 (4.5)
Home repair	Putting on and removing of sailboat tarpaulin	3.0	13 (3.1)
Home repair	Roofing	6.0	25 (5.9)
Home repair	Sanding floors with a power sander	4.5	19 (4.5)
Home repair	Scraping and painting sailboat or power boat	4.5	19 (4.5)
Home repair	Spreading dirt with a shovel	5.0	21 (5.0)
Home repair	Washing and waxing hull of sailboat, car, powerboat, airplane	4.5	19 (4.5)
Home repair	Washing fence	4.5	19 (4.5)
Home repair	Wiring, plumbing	3.0	13 (3.1)
Inactivity, quiet	Lying quietly, reclining (watching television), lying quietly in bed—awake	1.0	4 (0.9)
Inactivity, quiet	Sitting quietly (riding in a car, listening to a lecture or music, watching television or a film)	1.0	4 (0.9)
Inactivity, quiet	Sleeping	0.9	4 (0.9)
Inactivity, quiet	Standing quietly (standing in a line)	1.2	5 (1.2)
Inactivity, light	Writing, reclining	1.0	4 (0.9)
Inactivity, light	Talking or talking on phone, reclining	1.0	4 (0.9)
Inactivity, light	Reading, reclining	1.0	4 (0.9)
Lawn and garden	Carrying, loading or stacking wood, loading/unloading or carrying lumber	5.0	21 (5.0)
Lawn and garden	Chopping wood, splitting logs	6.0	25 (5.9)
Lawn and garden	Clearing land, hauling branches	5.0	21 (5.0)
Lawn and garden	Digging sandpit	5.0	21 (5.0)
Lawn and garden	Digging, spading, filling garden	5.0	21 (5.0)
Lawn and garden	Gardening with heavy power tools, tilling a garden (see Occupation, Shovelling)	6.0	25 (5.9)
Lawn and garden	Laying crushed rock	5.0	21 (5.0)
Lawn and garden	Laying sod	5.0	21 (5.0)
Lawn and garden	Mowing lawn, general	5.5	23 (5.5)
Lawn and garden	Mowing lawn, riding mower	2.5	10 (2.4)
Lawn and garden	Mowing lawn, walk, hand mower	6.0	25 (5.9)
Lawn and garden	Mowing lawn, walking, power mower	4.5	19 (4.5)
Lawn and garden	Operating snow blower, walking	4.5	19 (4.5)
Lawn and garden	Planting seedlings, shrubs	4.0	17 (4.0)
Lawn and garden	Planting trees	4.5	19 (4.5)
Lawn and garden	Raking lawn	4.0	17 (4.0)
Lawn and garden	Raking roof with snow rake	4.0	17 (4.0)
Lawn and garden	Riding snow blower	3.0	13 (3.1)
Lawn and garden	Collecting grass/leaves	4.0	17 (4.0)
Lawn and garden	Shovelling snow by hand	6.0	25 (5.9)
Lawn and garden	Trimming shrubs or trees, manual cutter	4.5	19 (4.5)
Lawn and garden	Trimming shrubs or trees, power cutter	3.5	15 (3.6)
Lawn and garden	Walking, applying fertilizer or seeding a lawn	2.5	10 (2.4)
Lawn and garden	Watering lawn or garden, standing or walking	1.5	6 (1.4)

Activity category	Specific activity	METs	kJ·h^{-1}·kg^{-1} (kcal·h^{-1}·kg^{-1}) body wt
Lawn and garden	Weeding, cultivating garden	4.5	19 (4.5)
Lawn and garden	Gardening, general	5.0	21 (5.0)
Lawn and garden	Tidying up yard, light effort (implied walking/standing)	3.0	13 (3.1)
Miscellaneous	Card playing, playing board games (sitting)	1.5	6 (1.4)
Miscellaneous	Drawing or writing, casino gambling (standing)	2.0	8 (1.9)
Miscellaneous	Reading, book, newspaper, etc. (sitting)	1.3	5 (1.2)
Miscellaneous	Writing, desk work (sitting)	1.8	7.5 (1.8)
Miscellaneous	Talking or talking on the phone (standing)	1.8	7.5 (1.8)
Miscellaneous	Talking or talking on the phone (sitting)	1.5	6 (1.4)
Miscellaneous	Studying, general, including reading and/or writing (sitting)	1.8	7.5 (1.8)
Miscellaneous	In class, general, including note-taking or class discussion (sitting)	1.8	7.5 (1.8)
Miscellaneous	Reading (standing)	1.8	7.5 (1.8)
Music playing	Accordion	1.8	7.5 (1.8)
Music playing	Cello	2.0	8 (1.9)
Music playing	Conducting	2.5	10 (2.4)
Music playing	Drums	4.0	17 (4.0)
Music playing	Flute (sitting)	2.0	8 (1.9)
Music playing	Horn	2.0	8 (1.9)
Music playing	Piano or organ	2.5	10 (2.4)
Music playing	Trombone	3.5	15 (3.6)
Music playing	Trumpet	2.5	10 (2.4)
Music playing	Violin	2.5	10 (2.4)
Music playing	Woodwind	2.0	8 (1.9)
Music playing	Guitar, classical, folk (sitting)	2.0	8 (1.9)
Music playing	Guitar, rock and roll band (standing)	3.0	13 (3.1)
Music playing	Marching band, playing an instrument, baton twirling (walking)	4.0	17 (4.0)
Music playing	Marching band, drum major (walking)	3.5	15 (3.6)
Occupation	Bakery, general	4.0	17 (4.0)
Occupation	Bookbinding	2.3	9 (2.1)
Occupation	Building road (including hauling debris, driving heavy machinery)	6.0	25 (5.9)
Occupation	Building road, directing traffic (standing)	2.0	8 (1.9)
Occupation	Carpentry, general	3.5	15 (3.6)
Occupation	Carrying heavy loads, such as bricks	8.0	33 (7.8)
Occupation	Carrying moderate loads up stairs, moving boxes (7–18 kg)	8.0	33 (7.8)
Occupation	Chambermaid	2.5	10 (2.4)
Occupation	Coal mining, drilling coal, rock	6.5	27 (6.4)
Occupation	Coal mining, erecting supports	6.5	27 (6.4)
Occupation	Coal mining, general	6.0	25 (5.9)
Occupation	Coal mining, shovelling coal	7.0	29 (6.9)
Occupation	Construction, outside, remodelling	5.5	23 (5.5)
Occupation	Electrical work, plumbing	3.5	15 (3.6)
Occupation	Farming, baling hay, cleaning barn, poultry work	8.0	33 (5.5)
Occupation	Farming, chasing cattle, non-strenuous	3.5	15 (3.6)
Occupation	Farming, driving harvester	2.5	10 (2.4)
Occupation	Farming, driving tractor	2.5	10 (2.4)
Occupation	Farming, feeding small animals	4.0	17 (4.0)
Occupation	Farming, feeding cattle	4.5	19 (4.5)

Activity category	Specific activity	METs	kJ · h⁻¹ · kg⁻¹ (kcal · h⁻¹ · kg⁻¹) body wt
Occupation	Farming, forking straw bales	8.0	33 (5.5)
Occupation	Farming, milking by hand	3.0	13 (3.1)
Occupation	Farming, milking by machine	1.5	6 (1.4)
Occupation	Farming, shovelling grain	5.5	23 (5.5)
Occupation	Fire fighter, general	12.0	50 (11.9)
Occupation	Fire fighter, climbing ladder with full gear	11.0	46 (10.9)
Occupation	Fire fighter, hauling hoses on ground	8.0	33 (7.8)
Occupation	Forestry, chopping with axe, fast	17.0	71 (16.9)
Occupation	Forestry, chopping with axe, slow	5.0	21 (5.0)
Occupation	Forestry, removing bark from trees	7.0	29 (6.9)
Occupation	Forestry, carrying logs	11.0	46 (10.9)
Occupation	Forestry, felling trees	8.0	33 (7.8)
Occupation	Forestry, general	8.0	33 (7.8)
Occupation	Forestry, hoeing	5.0	21 (5.0)
Occupation	Forestry, planting by hand	6.0	25 (5.9)
Occupation	Forestry, sawing by hand	7.0	29 (6.9)
Occupation	Forestry, sawing, power	4.5	19 (4.5)
Occupation	Forestry, trimming trees	9.0	38 (9.0)
Occupation	Forestry, weeding	4.0	17 (4.0)
Occupation	Furriery	4.5	19 (4.5)
Occupation	Horse grooming	6.0	25 (5.9)
Occupation	Locksmith	3.5	15 (3.6)
Occupation	Machine tooling, machining, working sheet metal	2.5	10 (2.4)
Occupation	Machine tooling, operating lathe	3.0	13 (3.1)
Occupation	Machine tooling, operating punch press	5.0	21 (5.0)
Occupation	Machine tooling, tapping and drilling	4.0	17 (4.0)
Occupation	Machine tooling, welding	3.0	13 (3.1)
Occupation	Masonry, concrete	7.0	29 (6.9)
Occupation	Masseur, masseuse (standing)	4.0	17 (4.0)
Occupation	Moving, pushing heavy objects, 40 kg or more (desks, moving van work)	7.0	29 (6.9)
Occupation	Operating heavy duty equipment/automated, not driving	2.5	10 (2.4)
Occupation	Orange grove work	4.5	19 (4.5)
Occupation	Printing (standing)	2.3	9 (2.1)
Occupation	Police, directing traffic (standing)	2.5	10 (2.4)
Occupation	Police, driving a squad car (sitting)	2.0	8 (1.9)
Occupation	Police, riding in a squad car (sitting)	1.3	5 (1.2)
Occupation	Police, making an arrest (standing)	8.0	33 (7.8)
Occupation	Shoe repair, general	2.5	10 (2.4)
Occupation	Shovelling, digging ditches	8.5	35 (8.3)
Occupation	Shovelling, heavy (more than 7 kg · min⁻¹)	9.0	38 (9.0)
Occupation	Shovelling, light (less than 4.5 kg · min⁻¹)	6.0	25 (5.9)
Occupation	Shovelling, moderate (4.5–7 kg · min⁻¹)	7.0	29 (6.9)
Occupation	Light office work, in general (chemistry lab work, light use of hand tools, watch repair or microassembly, light assembly/repair) (sitting)	1.5	6 (1.4)
Occupation	Meetings, general, and/or with talking involved (sitting)	1.5	6 (1.4)
Occupation	Moderate (e.g. heavy levers, riding mower/forklift, crane operation), sitting	2.5	10 (2.4)
Occupation	Light (e.g. bartending, store clerk, assembling, filing, photocopying, putting up Christmas tree), standing	2.5	10 (2.4)

Activity category	Specific activity	METs	kJ · h⁻¹ · kg⁻¹ (kcal · h⁻¹ · kg⁻¹) body wt
Occupation	Light/moderate (e.g. assemble/repair heavy parts, welding, stocking, car repair, packing boxes for moving, etc.), patient care (as in nursing), standing	3.0	13 (3.1)
Occupation	Moderate (e.g. assembling at fast rate, lifting 20 kg, hitching/twisting ropes), standing	3.5	15 (3.6)
Occupation	Moderate/heavy (e.g. lifting more than 20 kg, masonry, painting, paper hanging), standing	4.0	17 (4.0)
Occupation	Steel mill, fettling	5.0	21 (5.0)
Occupation	Steel mill, forging	5.5	23 (5.5)
Occupation	Steel mill, hand rolling	8.0	33 (7.8)
Occupation	Steel mill, merchant mill rolling	8.0	33 (7.8)
Occupation	Steel mill, removing slag	11.0	46 (10.9)
Occupation	Steel mill, tending furnace	7.5	31 (7.4)
Occupation	Steel mill, tipping molds	5.5	23 (5.5)
Occupation	Steel mill, working in general	8.0	33 (7.8)
Occupation	Tailoring, cutting	2.5	10 (2.4)
Occupation	Tailoring, general	2.5	10 (2.4)
Occupation	Tailoring, hand sewing	2.0	8 (1.9)
Occupation	Tailoring, machine sewing	2.5	10 (2.4)
Occupation	Tailoring, pressing	4.0	17 (4.0)
Occupation	Truck driving, loading and unloading truck (standing)	6.5	27 (6.4)
Occupation	Typing, electric, manual or computer	1.5	6 (1.4)
Occupation	Using heavy power tools such as pneumatic tools (jackhammers, drills, etc.)	6.0	25 (5.9)
Occupation	Using heavy tools (not power) such as shovel, pick, tunnel bar, spade	8.0	33 (7.8)
Occupation	Walking on job, less than 3 km · h⁻¹ (in office or lab area), very slow	2.0	8 (1.9)
Occupation	Walking on job, 5 km · h⁻¹, in office, moderate speed, not carrying anything	3.5	15 (3.6)
Occupation	Walking on job, 6 km · h⁻¹, in office, brisk speed, not carrying anything	4.0	17 (4.0)
Occupation	Walking, 4 km · h⁻¹, slowly and carrying light objects less than 10 kg	3.0	13 (3.1)
Occupation	Walking, 5 km · h⁻¹, moderately and carrying light objects less than 10 kg	4.0	17 (4.0)
Occupation	Walking, 6 km · h⁻¹, briskly and carrying objects less than 10 kg	4.5	19 (4.5)
Occupation	Walking or walking downstairs or standing, carrying objects about 10–22 kg	5.0	21 (5.0)
Occupation	Walking or walking downstairs or standing, carrying objects about 23–33 kg	6.5	27 (6.4)
Occupation	Walking or walking downstairs or standing, carrying objects about 34–44 kg	7.5	31 (7.4)
Occupation	Walking or walking downstairs or standing, carrying objects about 45 kg and over	8.5	35 (8.3)
Occupation	Working in scene shop, theatre actor, backstage, employee	3.0	13 (3.1)
Running	Jog/walk combination (jogging component of less than 10 min)	6.0	25 (5.9)
Running	Jogging, general	7.0	29 (6.9)
Running	8 km · h⁻¹ (7.5 min · km⁻¹)	8.0	33 (7.8)

Activity category	Specific activity	METs	$kJ \cdot h^{-1} \cdot kg^{-1}$ ($kcal \cdot h^{-1} \cdot kg^{-1}$) body wt
Running	9.6 km · h⁻¹ (6.25 min · km⁻¹)	10.0	42 (10.0)
Running	10.8 km · h⁻¹ (5.5 min · km⁻¹)	11.0	46 (10.9)
Running	11.3 km · h⁻¹ (5.3 min · km⁻¹)	11.5	48 (11.4)
Running	12 km · h⁻¹ (5.0 min · km⁻¹)	12.5	52 (12.4)
Running	12.8 km · h⁻¹ (4.7 min · km⁻¹)	13.5	56 (13.3)
Running	13.8 km · h⁻¹ (4.3 min · km⁻¹)	14.0	59 (14.0)
Running	14.5 km · h⁻¹ (4.1 min · km⁻¹)	15.0	63 (15.0)
Running	16.1 km · h⁻¹ (3.7 min · km⁻¹)	16.0	67 (15.9)
Running	17.5 km · h⁻¹ (3.4 min · km⁻¹)	18.0	75 (17.8)
Running	Running, cross-country	9.0	38 (9.0)
Running	Running, general	8.0	33 (7.8)
Running	Running, in place	8.0	33 (7.8)
Running	Running upstairs	15.0	63 (15.0)
Running	Running on a track, team practice	10.0	42 (10.0)
Running	Running, training, pushing wheelchair, marathon wheeling	8.0	33 (7.8)
Running	Running, wheeling, general	3.0	13 (3.1)
Self-care	Getting ready for bed, in general (standing)	2.5	10 (2.4)
Self-care	Sitting on toilet	1.0	4 (0.9)
Self-care	Bathing, sitting	2.0	8 (1.9)
Self-care	Dressing, undressing, standing or sitting	2.5	10 (2.4)
Self-care	Eating, sitting	1.5	6 (1.4)
Self-care	Talking and eating or eating only, standing	2.0	8 (1.9)
Self-care	Grooming (e.g. washing, shaving, brushing teeth, urinating, washing hands, putting on make-up), sitting or standing	2.5	10 (2.4)
Self-care	Showering, towelling off, standing	4.0	17 (4.0)
Sexual activity	Active, vigorous effort	1.5	6 (1.4)
Sexual activity	General, moderate effort	1.3	5 (1.2)
Sexual activity	Passive, light effort, kissing, hugging	1.0	4 (0.9)
Sports	Archery (non-hunting)	3.5	15 (3.6)
Sports	Badminton, competitive	7.0	29 (6.9)
Sports	Badminton, social singles and doubles, general	4.5	19 (4.5)
Sports	Basketball, game	8.0	33 (7.8)
Sports	Basketball, non-game, general	6.0	25 (5.9)
Sports	Basketball, officiating	7.0	29 (6.9)
Sports	Basketball, shooting baskets	4.5	19 (4.5)
Sports	Basketball, wheelchair	6.5	27 (6.4)
Sports	Billiards	2.5	10 (2.4)
Sports	Bowling	3.0	13 (3.1)
Sports	Boxing, in ring, general	12.0	50 (11.9)
Sports	Boxing, punching bag	6.0	25 (5.9)
Sports	Boxing, sparring	9.0	38 (9.0)
Sports	Broomball	7.0	29 (6.9)
Sports	Children's games (hopscotch, 4-square, dodgeball, playground apparatus, t-ball, tetherball, marbles, jacks, arcade games)	5.0	21 (5.0)
Sports	Coaching: football, soccer, basketball, baseball swimming, etc.	4.0	17 (4.0)
Sports	Cricket (batting, bowling)	5.0	21 (5.0)
Sports	Croquet	2.5	10 (2.4)
Sports	Curling	4.0	17 (4.0)
Sports	Darts, wall or lawn	2.5	10 (2.4)
Sports	Drag racing, pushing or driving a car	6.0	25 (5.9)

Activity category	Specific activity	METs	$kJ \cdot h^{-1} \cdot kg^{-1}$ ($kcal \cdot h^{-1} \cdot kg^{-1}$) body wt
Sports	Fencing	6.0	25 (5.9)
Sports	Football, competitive	9.0	38 (9.0)
Sports	Football, touch, flag, general	8.0	33 (7.8)
Sports	Football or baseball, playing catch	2.5	10 (2.4)
Sports	Frisbee playing, general	3.0	13 (3.1)
Sports	Frisbee, ultimate	3.5	15 (3.6)
Sports	Golf, general	4.5	19 (4.5)
Sports	Golf, carrying clubs	5.5	23 (5.5)
Sports	Golf, miniature, driving range	3.0	13 (3.1)
Sports	Golf, pulling clubs	5.0	21 (5.0)
Sports	Golf, using power cart	3.5	15 (3.6)
Sports	Gymnastics, general	4.0	17 (4.0)
Sports	Handball, competitive	12.0	50 (11.9)
Sports	Handball, team	8.0	33 (7.8)
Sports	Hang gliding	3.5	15 (3.6)
Sports	Hockey, field	8.0	33 (7.8)
Sports	Hockey, ice	8.0	33 (7.8)
Sports	Horseback riding, general	4.0	17 (4.0)
Sports	Horseback riding, saddling horse	3.5	15 (3.6)
Sports	Horseback riding,trotting	6.5	27 (6.4)
Sports	Horseback riding, walking	2.5	10 (2.4)
Sports	Horseshoe pitching, quoits	3.0	13 (3.1)
Sports	Jai alai	12.0	50 (11.9)
Sports	Judo, jujitsu, karate, kick boxing, tae kwan do	10.0	42 (10.0)
Sports	Juggling	4.0	17 (4.0)
Sports	Kickball	7.0	29 (6.9)
Sports	Lacrosse	8.0	33 (7.8)
Sports	Moto-cross	4.0	17 (4.0)
Sports	Orienteering	9.0	38 (9.0)
Sports	Paddleball, competitive	12.0	50 (11.9)
Sports	Paddleball, casual, general	6.0	25 (5.9)
Sports	Polo	8.0	33 (7.8)
Sports	Racketball, competitive	12.0	50 (11.9)
Sports	Racketball, casual, general	7.0	29 (6.9)
Sports	Rock climbing, ascending rock	11.0	46 (10.9)
Sports	Rock climbing, rapelling	8.0	33 (7.8)
Sports	Rope jumping, fast	12.0	50 (11.9)
Sports	Rope jumping, moderate, general	10.0	42 (10.0)
Sports	Rope jumping, slow	8.0	33 (7.8)
Sports	Rugby	10.0	42 (10.0)
Sports	Shuffleboard, lawn bowling	3.0	13 (3.1)
Sports	Skateboarding	5.0	21 (5.0)
Sports	Skating, roller	7.0	29 (6.9)
Sports	In-line skating, 16 $km \cdot h^{-1}$	7.5	31 (7.4)
Sports	In-line skating, 18 $km \cdot h^{-1}$	8.5	35 (8.3)
Sports	In-line skating, 19 $km \cdot h^{-1}$	10.0	42 (10.0)
Sports	Rollerskiing, 16 $km \cdot h^{-1}$, no grade	8.0	33 (7.8)
Sports	Rollerskiing, 18 $km \cdot h^{-1}$, no grade	10.0	42 (10.0)
Sports	Rollerskiing, 19 $km \cdot h^{-1}$, no grade	11.0	46 (10.9)
Sports	Rollerskiing, 14.5 $km \cdot h^{-1}$, 6% grade	12.0	50 (11.9)
Sports	Sky diving	3.5	15 (3.6)
Sports	Soccer, competitive	10.0	42 (10.0)

Activity category	Specific activity	METs	kJ · h^{-1} · kg^{-1} (kcal · h^{-1} · kg^{-1}) body wt
Sports	Soccer, casual, general	7.0	29 (6.9)
Sports	Softball or baseball, fast or slow pitch general	5.0	21 (5.0)
Sports	Softball, officiating	4.0	17 (4.0)
Sports	Softball, pitching	6.0	25 (5.9)
Sports	Squash	12.0	50 (11.9)
Sports	Table tennis, ping-pong	4.0	17 (4.0)
Sports	Tai chi	4.0	17 (4.0)
Sports	Tennis, general	7.0	29 (6.9)
Sports	Tennis, doubles	6.0	25 (5.9)
Sports	Tennis, singles	8.0	33 (7.8)
Sports	Trampoline	3.5	15 (3.6)
Sports	Volleyball, competitive, in gymnasium	4.0	17 (4.0)
Sports	Volleyball, non-competitive; 6–9 member team, general	3.0	13 (3.1)
Sports	Volleyball, beach	8.0	33 (7.8)
Sports	Wrestling (one match = 5 min)	6.0	25 (5.9)
Transportation	Driving car or light truck (not a semi)	2.0	8 (1.9)
Transportation	Flying airplane	2.0	8 (1.9)
Transportation	Motor scooter, motor cycle	2.5	10 (2.4)
Transportation	Pushing plane in and out of hangar	6.0	25 (5.9)
Transportation	Driving heavy truck, tractor, bus	3.0	13 (3.1)
Walking	Backpacking, general	7.0	29 (6.9)
Walking	Carrying infant or 7-kg load (e.g. suitcase), on level ground or downstairs	3.5	15 (3.6)
Walking	Carrying load upstairs, general	9.0	38 (9.0)
Walking	Carrying 0.5–7-kg load upstairs	5.0	21 (5.0)
Walking	Carrying 7.5–10.5-kg load upstairs	6.0	25 (5.9)
Walking	Carrying 11–22-kg load upstairs	8.0	33 (7.8)
Walking	Carrying 22.5–34-kg load upstairs	10.0	42 (10.0)
Walking	Carrying > 34-kg load upstairs	12.0	50 (11.9)
Walking	Climbing hills with 0–4-kg load	7.0	29 (6.9)
Walking	Climbing hills with 4.5–9-kg load	7.5	31 (7.4)
Walking	Climbing hills with 9.5–19-kg load	8.0	33 (7.8)
Walking	Climbing hills with > 19-kg load	9.0	38 (9.0)
Walking	Downstairs	3.0	13 (3.1)
Walking	Hiking, cross-country	6.0	25 (5.9)
Walking	Marching, rapidly, military	6.5	27 (6.4)
Walking	Pushing or pulling buggy with child	2.5	10 (2.4)
Walking	Race walking	6.5	27 (6.4)
Walking	Rock or mountain climbing	8.0	33 (7.8)
Walking	Upstairs, using or climbing up ladder	8.0	33 (7.8)
Walking	Using crutches	4.0	17 (4.0)
Walking	Less than 3 km · h^{-1} on level ground, strolling, household walking, very slow	2.0	8 (1.9)
Walking	3 km · h^{-1} on level ground, slow pace, firm surface	2.5	10 (2.4)
Walking	4 km · h^{-1}, firm surface	3.0	13 (3.1)
Walking	4 km · h^{-1}, downhill	3.0	13 (3.1)
Walking	5 km · h^{-1}, on level ground, moderate pace, firm surface	3.5	15 (3.6)
Walking	5.5 km · h^{-1}, on level ground, brisk pace, firm surface	4.0	17 (4.0)
Walking	5.5 km · h^{-1}, uphill	6.0	25 (5.9)
Walking	6 km · h^{-1}, on level ground, firm surface, very brisk pace	4.0	17 (4.0)
Walking	7 km · h^{-1}, on level ground, firm surface, very brisk pace	4.5	19 (4.5)
Walking	For pleasure, work break, walking the dog	3.5	15 (3.6)

Activity category	Specific activity	METs	kJ · h⁻¹ · kg⁻¹ (kcal · h⁻¹ · kg⁻¹) body wt
Walking	On grass track	5.0	21 (5.0)
Walking	To work or school	4.0	17 (4.0)
Water activities	Boating, power	2.5	10 (2.4)
Water activities	Canoeing, on camping trip	4.0	17 (4.0)
Water activities	Canoeing, portaging	7.0	29 (6.9)
Water activities	Canoeing, rowing, 3–6 km · h⁻¹, light effort	3.0	13 (3.1)
Water activities	Canoeing, rowing, 6.5–9 km · h⁻¹, moderate effort	7.0	29 (6.9)
Water activities	Canoeing, rowing, >9 km · h⁻¹, vigorous effort	12.0	50 (11.9)
Water activities	Canoeing, rowing, for pleasure, general	3.5	15 (3.6)
Water activities	Canoeing, rowing, in competition, or crew or sculling	12.0	50 (11.9)
Water activities	Diving, springboard or platform	3.0	13 (3.1)
Water activities	Kayaking	5.0	21 (5.0)
Water activities	Paddleboat	4.0	17 (4.0)
Water activities	Sailing, boat and board sailing, wind-surfing, ice sailing, general	3.0	13 (3.1)
Water activities	Sailing, in competition	5.0	21 (5.0)
Water activities	Sailing, Sunfish/Laser/Hobby Cat, keel boats, ocean sailing, yachting	3.0	13 (3.1)
Water activities	Skiing, water	6.0	25 (5.9)
Water activities	Skindiving or scuba diving as frogman	12.0	50 (11.9)
Water activities	Skindiving, fast	16.0	67 (15.9)
Water activities	Skindiving, moderate	12.5	52 (12.4)
Water activities	Skindiving, scuba diving, general	7.0	29 (6.9)
Water activities	Snorkeling	5.0	21 (5.0)
Water activities	Surfing, body or board	3.0	13 (3.1)
Water activities	Swimming laps, freestyle, fast, vigorous effort	10.0	42 (10.0)
Water activities	Swimming laps, freestyle, slow, moderate or light effort	8.0	33 (7.8)
Water activities	Swimming, backstroke, general	8.0	33 (7.8)
Water activities	Swimming, breaststroke, general	10.0	42 (10.0)
Water activities	Swimming, butterfly, general	11.0	46 (10.9)
Water activities	Swimming, crawl, fast (75 m · min⁻¹), vigorous effort	11.0	46 (10.9)
Water activities	Swimming, crawl, slow (50 m · min⁻¹), moderate or light effort	8.0	33 (7.8)
Water activities	Swimming, lake, ocean, river	6.0	25 (5.9)
Water activities	Swimming, leisurely, not lap swimming, general	6.0	25 (5.9)
Water activities	Swimming, sidestroke, general	8.0	33 (7.8)
Water activities	Swimming, synchronized	8.0	33 (7.8)
Water activities	Swimming, treading water, fast, vigorous effort	10.0	42 (10.0)
Water activities	Swimming,treading water, moderate effort, general	4.0	17 (4.0)
Water activities	Swimming, underwater, 1.5 km · h⁻¹	7.0	29 (6.9)
Water activities	Water polo	10.0	42 (10.0)
Water activities	Water volleyball	3.0	13 (3.1)
Water activities	Whitewater rafting, kayaking, or canoeing, non-competitive	5.0	21 (5.0)
Winter activities	Moving ice house (set up/drill holes, etc.)	6.0	25 (5.9)
Winter activities	Skating, ice, 15 km · h⁻¹ or less	5.5	23 (5.5)
Winter activities	Skating, ice, general	7.0	29 (6.9)
Winter activities	Skating, ice, rapidly, more than 9 km · h⁻¹	9.0	38 (9.0)
Winter activities	Skating, speed, competitive	15.0	63 (15.0)
Winter activities	Skating, figure	9.0	38 (9.0)
Winter activities	Ski jumping (climbing up carrying skis)	7.0	29 (6.9)
Winter activities	Skiing, general	7.0	29 (6.9)

Activity category	Specific activity	METs	kJ · h^{-1} · kg^{-1} (kcal · h^{-1} · kg^{-1}) body wt
Winter activities	Skiing, cross-country, 4 km · h^{-1}, slow or light effort, ski walking	7.0	29 (6.9)
Winter activities	Skiing, cross-country, 6–8 km · h^{-1}, moderate speed and effort, general	8.0	33 (7.8)
Winter activities	Skiing, cross-country, 8.1–13 km · h^{-1}, brisk speed, vigorous effort	9.0	38 (9.0)
Winter activities	Skiing, cross-country, 13 km · h^{-1}, racing	14.0	59 (14.0)
Winter activities	Skiing, cross-country, hard snow, uphill, maximum effort	16.5	69 (16.4)
Winter activities	Skiing, downhill, light effort	5.0	21 (5.0)
Winter activities	Skiing, downhill, moderate effort, general	6.0	25 (5.9)
Winter activities	Skiing, downhill, vigorous effort, racing	8.0	33 (7.8)
Winter activities	Sledding, tobogganing, bobsledding, luge	7.0	29 (6.9)
Winter activities	Snow shoeing	8.0	33 (7.8)
Winter activities	Snowmobiling	3.5	15 (3.6)