

Chronicle of the Institute of Medicine physical activity recommendation: how a physical activity recommendation came to be among dietary recommendations¹⁻³

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ABSTRACT

Under a contract from the US Department of Health and Human Services, a multidisciplinary expert panel was appointed to review “the scientific literature regarding macronutrients and energy and develop estimates of daily intake that are compatible with good nutrition throughout the life span and that may decrease the risk of chronic disease.” Within the overall context of the charge, the panel sought to quantify rates and components of daily energy expenditure in healthy adults with body mass indexes (in kg/m²) of 18.5–25, in growing children (in the 5th–85th percentiles of weight-for-length), and in pregnant and lactating women. The recommendation for adults became the daily energy intake necessary to cover total daily energy expenditure (TEE). For special cases, dietary macronutrients and energy to support child growth and pregnancy and lactation by women were considered. TEE was based on the results of doubly labeled water studies, and the TEE results were presented in units of physical activity level (PAL = TEE/BEE) and Δ PAL, where BEE is the basal rate of energy expenditure extrapolated to 24 h. Most adults (66%) maintaining a BMI in the healthful range had PAL values >1.6, or the equivalent of ≥ 60 min of physical activity of moderate intensity each day. Hence, on the basis of the doubly labeled water data and the results of epidemiologic studies, the physical activity recommendation for adults was judged to be 60 min/d. The recommendation for children was for a minimum of 60 min/d. In conclusion, dietary and physical activity recommendations for healthful living are inextricably intertwined. Adequate physical activity provides protection against chronic diseases and helps to balance energy expenditure and intake. *Am J Clin Nutr* 2004;79(suppl):921S–30S.

KEY WORDS Energy, energy expenditure, doubly labeled water, metabolism, macronutrient nutrition, dietary energy intake, exertion

INTRODUCTION

The National Institutes of Health, Health Canada, and the National Academy of Sciences Institute of Medicine (IOM) Food and Nutrition Board convened a multidisciplinary expert panel under a contract from the US Department of Health and Human Services to “review the scientific literature regarding macronutrients and energy and develop estimates of daily intake that are compatible with good nutrition throughout the life span and that may decrease the risk of chronic disease.” In this article, we recount some of the deliberations of the IOM Macronutrient Panel (1).

The IOM Macronutrient Panel estimated energy requirements at sedentary, low active, active, and very active levels of energy expenditure, but recommended the active level of physical activity because it is associated with a healthy body mass index (BMI) and because epidemiologic evidence indicates that the active level of physical activity is compatible with minimizing the risks of several chronic diseases. Accepting a healthy BMI [in kg/m² (wt/ht²)] range of 18.5 to <25 for the adult population (2, 3), the IOM panel developed estimated energy requirements (EERs) and the physical activity recommendation by considering 4 basic principles. First, the energy requirement was defined as that necessary to maintain a stable body weight in the normal range and a level of physical activity consistent with good health. In children and in pregnant and lactating women, additional energy is needed for the deposition of tissues and secretion of milk. As previously, the energy requirement was based on energy expenditure, not energy intake. Second, for the first time, the traditional factorial approach to derive EERs was abandoned, and data on total energy expenditure (TEE) measured by the doubly labeled water (DLW) technique were used instead. Third, of the components of TEE, activity energy expenditure is the most variable among individuals and moreover is individually determined. Consequently, physical activity is the primary means by which a person can vary energy expenditure to balance dietary energy intake once basal energy expenditure (BEE) and obligatory thermogenesis in the healthy population are covered. Finally, with the recognition that physical activity provides health benefits that cannot be realized by controlling either the

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² Presented at the ASNS/ASCN Public Information Committee Symposium “The Weight Debate: Balancing Food Composition and Physical Activity,” held in Washington, DC, at Experimental Biology 2004, April 19, 2004.

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amounts or proportions of dietary macronutrients, it was necessary to include a physical activity recommendation among the dietary recommendations formulated by the Macronutrient Panel.

Given the secular trends in obesity and related chronic diseases in the US and presumably Canadian populations (4), a more explicit physical activity recommendation may be helpful to health care professionals. The IOM physical activity recommendation is to be considered alongside the other recommendations in the report, such as the importance of minimizing the consumption of cholesterol and *trans* and saturated fatty acids. As well, the IOM physical activity recommendation is to be considered alongside long-standing advice to moderate energy intake if the habitual level of physical activity is inadequate to prevent the accretion of body fat and undesirable weight gain.

THE PROCESS TO ESTIMATE ENERGY REQUIREMENTS

Energy intake is essential for life. Energy is required to sustain the body's various functions, including the maintenance of core body temperature, respiration, circulation, deposition of tissues during growth and pregnancy, milk secretion, and physical work. Estimation of how much energy an individual needs is critical for nutritional planning and assessment in individuals and populations.

Recommendations for the nutrient intakes of individuals are generally set to provide enough to meet or exceed the requirements of almost all healthy individuals in a given sex and life-stage group as well as enough to allow reasonably fast recovery of losses that may have been incurred. For most nutrients, individual requirements correspond to the population average requirement plus 2 SDs to ensure that the requirements provide for the needs of nearly all ($\approx 95\%$) of the healthy individuals in the population. This is reasonable for nutrients for which modest excess intakes present no health risks. However, excess energy intake is eventually deposited in the form of body fat, which provides a means of maintaining metabolism during periods of limited food intake but can also result in obesity.

Desirable levels of energy intake should be commensurate with energy expenditure, so as to achieve energy balance. Although frequently applied in the past, this is not appropriate as a sole criterion, which can be easily understood by considering the rationale used in the 1985 Technical Report published by the FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements (5). It states that

“The energy requirement of an individual is a level of energy intake from food that will balance energy expenditure when the individual has a body size and composition, and level of physical activity, consistent with long-term good health; and that would allow for the maintenance of economically necessary and socially desirable physical activity. In children and pregnant or lactating women the energy requirement includes the energy needs associated with the deposition of tissues or the secretion of milk at rates consistent with good health.”

This definition implies that desirable energy intakes should support healthy body weights and composition and adequate

levels of physical activity. Implicit in this statement is that desirable energy intakes for obese individuals are less than their energy expenditure, because weight loss and the establishment of a lower body weight is desirable for them. For underweight individuals, on the other hand, desirable energy intakes are greater than their energy expenditure to permit weight gain and maintenance of a higher body weight. Thus, it seems logical to base recommended energy intakes on the amounts needed to maintain energy balance in adult men and women maintaining desirable body weights, taking into account the increments in energy expenditure elicited by their habitual level of physical activity.

Another fundamental difference between energy and other nutrients deserves to be noted. Body weight provides a readily monitored indicator of the adequacy or inadequacy of habitual energy intake in each individual, whereas a comparably obvious and individualized indicator of inadequate or excessive intake is not readily available in the case of other nutrients. There are 2 central challenges for the derivation of an energy requirement. First, unlike in the case of other nutrients, the expenditure of energy is determined individually and can be altered by changes in body weight and level of physical activity. Any definition of an energy requirement, therefore, must specify the goal for setting the requirement. The “outcome” used by the IOM Macronutrient Panel was the maintenance of a stable weight within a healthy BMI range and level of physical activity consistent with long-term good health. This constrains the whole fitting process because it defines the (normative) data that were used to define the EER. Second, also unlike in the case of most nutrients, sustained consumption of even small amounts of energy in excess or below the amounts dissipated can have consequences for health, precluding the inclusion of an extra allowance to ensure adequate intakes for all individuals. Thus, a correct estimate of average or expected individual requirements is essential.

In principle, energy intake data from weight-stable subjects (ie, those in energy balance) could be used to predict energy requirements for weight maintenance. However, it is now widely recognized that the energy intakes reported in dietary surveys underestimate usual energy intake (6). The most compelling evidence about underreporting has come from measurements of TEE by the DLW method (7, 8). Underreporting of food intake can range from 10% to 45% depending on the age, sex, and body composition of the sample (9).

Previous recommendations for energy intake (5, 10) used the factorial method to assess TEE. This method calculates TEE based on the basal metabolic rate (BMR) and information on the time devoted to different activities and the energy costs of each activity throughout a 24-h period. Thus, typical energy requirements for different levels of physical activity could be defined. However, recognized problems with the factorial method threaten the validity of the energy requirement predictions based on it (11). The first problem is the accuracy of the equations used to predict BMR. The most recent equations for predicting BMR from weight and height were published by Schofield et al (12). BMR data for 7549 individuals were used to develop prediction equations for separate age and sex groups: 0–3 y, 10–18 y, 30–60 y, and >60 y. Although the Schofield equations predict BMR reasonably well in some populations, they seem to overestimate BMR in tropical populations by 8–10% (13, 14).

However, other studies do not corroborate these findings (15). Studies of recent immigrants from tropical to temperate climates have found their BMR (kcal/kg body wt) to be that expected for well-nourished individuals when differences in body composition are taken into account (16, 17).

The second problem with the factorial method is that a wide range of activities are performed during normal life, and it is not feasible to measure the energy cost of each. Another concern with the factorial method is that measurement of the energy costs of specific activities itself imposes constraints (due to mechanical impediments associated with performing an activity while wearing unfamiliar equipment) that may alter the measured energy costs of different activities. In addition, energy expenditure during sleep, once considered to be equivalent to BMR, is generally somewhat lower (−5% to −10%) than BMR (18). Last, the factorial method does not account for the amount of energy expended in spontaneous physical activities. Thus, the factorial method is bound to underestimate usual energy needs (11, 19). Most comparisons of TEE based on DLW determinations have resulted in significantly higher measured values than those predicted by use of the factorial method (9, 11).

Because of the limitations of the factorial method and the growing availability of DLW data, the IOM Macronutrient Panel decided to estimate energy requirements from DLW-derived measurements of TEE. TEE is the sum of BEE, the thermic effect of food, physical activity, thermoregulation, and the energy expended in synthesizing new tissues or in producing milk.

EERs were based on measurements of TEE obtained in DLW studies, taking into account the energy content of new body constituents during growth and pregnancy and of the milk produced during lactation. Energy expenditures depend on sex and age and vary primarily as a function of body size and physical activity, both of which vary greatly between individuals.

The DLW method is a relatively new technique that measures TEE in free-living individuals. The DLW method was originally proposed and developed by Lifson for use in small animals (20, 21). It has been adapted for human studies and is extensively used (22). Two stable-isotopic forms of water ($H_2^{18}O$ and 2H_2O) are administered, and their disappearance rates from a body fluid (ie, urine or blood) are monitored for a period of time, optimally equivalent to 1–3 half-lives of these isotopes (ie, 7–21 d in most humans). The disappearance rate of 2H_2O relates to water flux, whereas that of $H_2^{18}O$ reflects water flux plus the carbon dioxide production rate because of the rapid equilibration of the body water and bicarbonate pools by carbonic anhydrase. The difference between the 2 disappearance rates can therefore be used to calculate the carbon dioxide production rate, and with knowledge of the composition of the diet, TEE can be calculated. A critical mass of DLW data has now accumulated over a wide range of age groups and body sizes, so that the estimates of energy requirements provided in the IOM report could be based on DLW measurements of TEE. The development of the DLW techniques and the existence of a body of DLW data on a range of individuals gave us the opportunity to explore how TEE varies with characteristics in healthy individuals, and therefore allowed us to estimate individual energy expenditure when individual characteristics are known.

TABLE 1
Physical activity level (PAL) categories and walking equivalence¹

PAL category	PAL value	Walking equivalence for individuals weighing:		
		44 kg	70 kg	120 kg
		<i>miles/d at 3–4 miles/h</i>		
Sedentary	1.25 (1.0–1.39) ²	0	0	0
Low active	1.5 (1.4–1.59)	2.9	2.2	1.5
Active	1.75 (1.6–1.89)	9.9	7.3	5.3
Very active	2.2 (1.9–2.5)	22.5	16.7	12.3

¹ Walking equivalence for PAL values is in addition to the energy spent for the generally unscheduled activities that are a part of normal daily life. 3–4 miles/h \approx 5–6.5 km/h. See Table 5–12 in the Institute of Medicine report (1).

² \bar{x} ; range in parentheses (all such values).

THE DLW DATABASES

Published studies that included DLW measurements of TEE were initially located by using MEDLINE (National Library of Medicine, Bethesda, MD) to identify those studies that used the terms *DLW*, *total energy expenditure*, or both in their titles, abstracts, or key words. Simultaneously, panel members polled colleagues for other studies. Initial screening eliminated studies on disease or abnormal nutritional or activity states. Investigators involved with these studies were contacted for permission to use their raw data, specifically, data on TEE, BMR, sex, age, height, and weight. These data were screened to remove duplicates, physiologically impossible values, and individuals engaged in extreme levels of physical activity (those in the military, elite athletes, and those in astronaut training). The data themselves and their sources are detailed in the IOM report (1).

Because energy expenditure obviously depends on activity level, it was essential to take physical activity into account. The level of physical activity is commonly described by the ratio of TEE to BEE (TEE/BEE). This ratio is known as the physical activity level (PAL). Describing physical activity habits in terms of the PAL is not entirely satisfactory because the increments in energy expenditure brought about by most physical activities are directly proportional to body weight, whereas BEE is proportional to body weight^{0.75}. However, PAL is a convenient notion and it was used in this report to describe and account for physical activity habits.

Because the database contained both TEE and BEE, we could calculate PAL for most individuals. Because of the difficulty in estimating activity in the real world, we categorized individuals into 4 activity classes based on their PAL and used these categories as an independent variable in our regressions. The PAL categories were defined as sedentary (PAL \geq 1.0 to < 1.4), low active (PAL \geq 1.4 to < 1.6), active (PAL \geq 1.6 to < 1.9), and very active (PAL \geq 1.9 to < 2.5) (Table 1). The sedentary category was defined to include BEE, the thermic effect of food, and the energy expended in physical activities that are required for independent living. For an adult weighing 70 kg, the low-active category was defined to be an exertion equivalent to walking 2

TABLE 2Description of the normative doubly labeled water database for persons with a healthy BMI (18.5–25, in kg/m²)¹

Age (y)	Mean weight	Mean height	Mean BMI	Mean BEE	Mean TEE	Mean physical activity level
	<i>kg (lb)</i>	<i>m (in)</i>	<i>kg/m²</i>	<i>kcal/d</i>	<i>kcal/d</i>	
0–0.5 (<i>n</i> = 116)	6.9 (15)	0.64 (25)	16.86	—	501	—
0.6–1.0 (<i>n</i> = 72)	9.0 (20)	0.72 (28)	17.20	—	713	—
1–2 (<i>n</i> = 132)	11.0 (24)	0.82 (32)	16.19	—	869	—
Males						
3–8 (<i>n</i> = 129)	20.4 (45)	1.15 (45)	15.42	1035	1441	1.39
9–13 (<i>n</i> = 28)	35.8 (79)	1.44 (57)	17.20	1320	2079	1.56
14–18 (<i>n</i> = 10)	58.8 (130)	1.70 (67)	20.37	1729	3116	1.80
19–30 (<i>n</i> = 48)	71.0 (156)	1.80 (71)	22.02	1769	3081	1.74
31–50 (<i>n</i> = 59)	71.4 (157)	1.78 (70)	22.55	1675	3021	1.81
51–70 (<i>n</i> = 24)	70.0 (154)	1.74 (69)	22.95	1524	2469	1.63
≥71 (<i>n</i> = 38)	68.9 (152)	1.74 (69)	22.78	1480	2238	1.52
Females						
3–8 (<i>n</i> = 227)	22.9 (50)	1.20 (47)	15.63	1004	1487	1.48
9–13 (<i>n</i> = 89)	36.4 (80)	1.44 (57)	17.38	1186	1907	1.60
14–18 (<i>n</i> = 42)	54.1 (119)	1.63 (64)	20.42	1361	2302	1.69
19–30 (<i>n</i> = 82)	59.3 (131)	1.66 (65)	21.42	1361	2436	1.80
31–50 (<i>n</i> = 61)	58.6 (129)	1.64 (65)	21.64	1322	2404	1.83
51–70 (<i>n</i> = 71)	59.1 (130)	1.63 (63)	22.18	1226	2066	1.70
≥71 (<i>n</i> = 24)	54.8 (121)	1.58 (62)	21.75	1183	1564	1.33

¹ BEE, basal energy expenditure; TEE, total energy expenditure. Summary of data in Appendix I, Tables I-1 through I-5 in the Institute of Medicine report (1). For adults (aged ≥19 y), the observed BEE was used to calculate the mean BEE. BEE and physical activity level were not used for infants. For children, BEE was predicted on the basis of the following equations: girls, BEE (kcal/d) = 189 – 17.6 × age (y) + 625 × Ht (m) + 7.9 × Wt (kg); boys, BEE (kcal/d) = 68 – 43.3 × age (y) + 712 × Ht (m) + 19.2 × Wt (kg). See Table 5–10 in the Institute of Medicine report (1).

miles/d (≈3 km) at a rate of 3–4 miles/h (≈5–6.5 km/h) or the equivalent energy expenditure in other activities, in addition to the activities that are part of independent living. The active category reflected physical activities equivalent to walking some 7 miles/d (≈11 km), and the very active category was equivalent to walking 17 miles/d (≈27 km/d), all at the rate of 3–4 miles/h (≈5–6.5 km/h). As described in chapter 12 of the IOM report (1), these distances vary with body weight and can be substantially reduced by walking faster or by performing other physical activities of vigorous intensities. Retrospectively, these categories corresponded roughly to quartiles in the database. It is important to note, however, that substantial fidgeting and other spontaneous activities may contribute to PAL, but may not produce the health benefits of sustained, vigorous exercise. Therefore, some individuals may achieve the low-active category without regular exercise.

Additionally, each individual was classified according to age, sex, BMI status, and the physiologic state of the women, ie, nonpregnant, nonlactating, pregnant, or lactating. A healthy BMI range for adults was considered to be from 18.5 to 25; this range corresponded to 13–21% body fat in men and 23–31% body fat in women according to bioimpedance data on adults in the third National Health and Nutrition Examination Survey. Healthy weights in the US population corresponded to the 5th to 85th BMI percentiles for children aged 3–18 y and the 3rd to 97th weight-for-length percentiles for children aged 0–2 y (23).

The normative DLW database is described in **Table 2**. Mean TEE, BEE, and PAL for individuals with healthy BMIs are presented by age-sex groupings. It is important to note that the mean PAL was in the active range for all groupings, except for the very young (those aged <8 y) and the elderly (those aged >71 y). In 66% of the adult men and women with BMIs within the healthy range of 18.5–25, PALs were categorized as either active or very active.

Although it is realized that these individuals do not constitute a representative sample of the North American population, the data are representative of rates of energy expenditure in healthy individuals of both sexes across a wide range of ages, body sizes, and lifestyles. In fact, use of a set of data representative of the North American population would be inappropriate in establishing requirements for healthy subjects given the high prevalence of overweight and obesity and chronic diseases in the population at large.

DEVELOPMENT OF PREDICTIVE EQUATIONS FOR TEE

The data were examined initially (histograms of variables and scatter plots of original data and of residuals) to identify potential outliers, the necessity of transformations (log and quadratic were considered), assumptions, and patterns (24). Stepwise multiple linear regression (25) was used to identify sex, age, height, and weight as the important variables for predicting TEE, and

physiologic considerations suggested that the form of the best predictive equation was nonlinear:

$$\text{TEE} = A + B \times \text{age} + \text{PA} \times (D \times \text{Wt} + E \times \text{Ht}) \quad (1)$$

where TEE is in kcal/d, age is in y, weight (Wt) is in kg, and height (Ht) is in m. In this equation, *A* is the constant term; *B* is the age coefficient; PA is the physical activity coefficient, which depends on whether the individual is in the sedentary, low-active, active, or very active PAL category; *D* is the weight coefficient; and *E* is the height coefficient. In this equation, the relative importance of height and weight is constant for given activity levels, but the magnitude of their combined contribution changes for different PALs. Because of the interdependencies between the PAL constants and the height and weight coefficients, the coefficient for the sedentary PAL category is set to 1.0.

The data were fitted to this equation by using nonlinear (conditional) regression with the Levenberg-Marquardt method for searching for convergence based on minimizing the sum of residuals squared. For each fit, an R-squared was calculated as the ratio of the explained sum of squared error to the total sum of squared error, and asymptotic standard errors of the coefficients were calculated (26).

Initially, age- and sex-specific equations were generated to predict TEE for various life stages. Examination of the normative DLW database showed an initial increase of TEE with age until about age 20 y, followed by a decline, with this transition occurring later in women than in men (*see* Figure 5-5 in the IOM report; 1). Increased TEE is related to greater heights (*see* Figure 5-6 in the IOM report; 1) and weights (*see* Figure 5-7 in the IOM report; 1). For adults, TEE was independent of BMI in analyses adjusted for height. Analyses indicated that the best predictions for TEE were obtained by fitting all of the data separately for adults (ages ≥ 19 y), children and adolescents (ages 3–18 y), and young children (ages 0–2 y). Sex-specific equations were found to be unnecessary in children < 3 y of age. Final model choice was guided by goodness-of-fit, distribution of residuals, consistency with biological constraints, and compatibility between equations. (Although prediction of TEE was our major objective, it was necessary to estimate BMR for the children because of a large amount of missing BMR data.)

An estimate of the imprecision of these equations was based on the residual error of the fits (the variability that remained after the effects of sex, age, height, weight, and PAL category were removed). This “SE of fit” estimates the variability of predicted energy requirement of individuals having the same sex, age, height, weight, and PAL category. This variability is due to our use of age to estimate maturation stage, height and weight to estimate body size and composition, and TEE/BMR ranges to estimate PAL classification, in addition to other inherent biological variability and experimental errors. The EERs represent the expected or average energy requirement of individuals with certain specific characteristics. The SE of fit represents how variable the measurements of energy requirement of individuals with similar characteristics might be. To estimate the true between-individual variability, it is necessary to partition this observed variability into biological and experimental; in light of limited data, and following the suggestion of the 1985

TABLE 3

Physical activity coefficients used in the prediction equations for total energy expenditure

	Sedentary	Low active	Active	Very active
Male children	1.0	1.13	1.26	1.42
Female children	1.0	1.16	1.31	1.56
Male adults	1.0	1.11	1.25	1.48
Female adults	1.0	1.12	1.27	1.45

FAO/WHO/UNU Expert Consultation (5), we estimate values for individual SDs that are 70% of the observed SE of fit. (This follows the assumption that the residual variance is equally split within and between errors.)

THE PREDICTIVE EQUATIONS FOR TEE

The resultant predictive equations are as follows.

For 0–2 y of age:

$$\text{TEE} = 89 \times \text{Wt (kg)} - 100 \quad (2)$$

For males aged 3–18 y:

$$\text{TEE} = 88.5 - 61.9 \times \text{age (y)} + \text{PA} \times [26.7 \times \text{Wt (kg)} + 903 \times \text{Ht (m)}] \quad (3)$$

For females aged 3–18 y:

$$\text{TEE} = 135.3 - 30.8 \times \text{age (y)} + \text{PA} \times [10.0 \times \text{Wt (kg)} + 934 \times \text{Ht (m)}] \quad (4)$$

For men aged ≥ 19 y:

$$\text{TEE} = 662 - 9.53 \times \text{age (y)} + \text{PA} \times [15.9 \times \text{Wt (kg)} + 540 \times \text{Ht (m)}] \quad (5)$$

For women aged ≥ 19 y:

$$\text{TEE} = 354 - 6.91 \times \text{age (y)} + \text{PA} \times [9.36 \times \text{Wt (kg)} + 726 \times \text{Ht (m)}] \quad (6)$$

Where the physical activity factors (PA) and the respective SDs for the equations are given in **Tables 3** and **4**.

TABLE 4

Estimated SDs of individual estimated energy requirements for individuals of a specific age, height, weight, and physical activity level category, including a correction for within-individual variability¹

Age	BMI (kg/m ²)	Males	Females
3–18 y	<85th percentile	58	68
3–18 y	≥ 85 th percentile	69	75
3–18 y	≥ 3 rd percentile	67	70
≥ 19 y	18.5–25	199	162
≥ 19 y	>25	208	160
≥ 19 y	≥ 18.5	202	160

¹ Note that these SDs are measures of the statistical error about the fitted equations and are equivalent to the SE of the fit.

DERIVATION OF THE PHYSICAL ACTIVITY RECOMMENDATION

The IOM physical activity recommendation was based on the amount of activity required to raise an individual from the sedentary to the active PAL category. On average, 60 min of moderate activity would be required to raise an individual from the sedentary to the active PAL category. Higher-intensity activities would require less time.

As noted above, the average PAL among normal-weight adults participating in the DLW studies was 1.7, which falls within the active PAL category. This level of physical activity is equivalent to brisk walking for 7 miles/d (≈ 11 km/h) at 3–4 miles/h (≈ 5 –6.5 km/h) in addition to the physical activities required for independent living. This level of physical activity was associated with maintenance of body weight within a healthy BMI range. Although energy balance is achievable at lower PAL values, most individuals in the DLW studies achieved energy balance at levels of activity energy expenditure in the active or very active categories. Maintaining an active lifestyle provides an important means for individuals to balance food energy intake with energy expenditure. Attainment of energy balance in the sedentary or low-active categories is feasible but may require food restriction and jeopardize the intake of other essential nutrients.

Because walking is the most significant physical activity in the lives of most persons, walking was taken as the reference activity. However, the effect of other activities on the PAL can be estimated from the following equations for men and women, which make allowances for excess postexercise oxygen consumption (the 1.15 coefficient in the equations below) and the thermic effect of food (the division by 0.90 in the equations below) and the effect of body weight on metabolic equivalent (MET) values (the 0.95 or 0.91 coefficients) (1, 27):

$$\text{Men: } \Delta\text{PAL} = (\#\text{METs} - 1) \times 1.34 \times (\text{min}/1440 \text{ min}), \text{ where } 1.34 = 1.15/0.9/0.95 \quad (7)$$

$$\text{Women } \Delta\text{PAL} = (\#\text{METs} - 1) \times 1.42 \times (\text{min}/1440 \text{ min}), \text{ where } 1.42 = 1.15/0.9/0.91 \quad (8)$$

It is apparent from these equations that less time in higher-intensity physical activities is required to raise an individual from the sedentary category (PAL < 1.39) to the active category (PAL of 1.6–1.9). Also, any physical activity, be that occupational, recreational, intentional, or spontaneous, that raises energy expenditure over basal contributes to the PAL. The PAL reflects a summation of all accumulated physical activity in a 24-h period.

It is also apparent that 30 min of moderately intensive exercise ($\Delta\text{PAL} = 0.099$ for walking 30 min at 4 miles/h, or ≈ 6.5 km/h) would raise the PAL of an individual from the sedentary category (PAL < 1.39) to the low-active category, but would be insufficient to raise it to the active PAL category. At least 60 min of moderate activity is required to raise the PAL from the sedentary to the active category. Hence, the IOM recommendation for physical activity is greater than the recommendation in the Surgeon General's report (SGR; 28) but similar to the Canadian *Physical Activity Guide* (29).

It should also be emphasized that in developing a DLW database to determine rates of energy expenditure in the healthy

human population, no specific information on types, durations, or intensities of physical activity was obtained. Therefore, to portray the results in terms that others could use to make specific physical activity recommendations, the data were expressed in PAL units. Tables 12-1 and 12-2 in the IOM report were intended to be used to predict how much of particular forms of physical activity was necessary to change the PAL. As well, those tables and related figures (ie, Figures 12-2 through 12-6 in the IOM report) show how speed of locomotion and body mass affect the rate of energy expenditure. Many examples were given for walking because this is a common activity and because the energy cost of transport (ie, kcal/mile) is approximately constant for walking speeds in the range of 2–4 miles/h. Faster walking, jogging, and running elicit progressively greater increments in energy expenditure. It is to be remembered that the IOM PAL recommendation is for daily physical activities in the amount equivalent to that elicited by brisk walking for 60 min. The report provides examples of how that energy expenditure (ie, ΔPAL) can be achieved in less time if an individual engages in activities of higher intensity than brisk walking. Table 12-2 provides a template for practitioners to estimate daily and weekly energy expenditures of individuals engaged in various forms and durations of physical exercise plus routine physical activity (1). Moreover, although not grounded on the DLW database, the IOM report makes extensive reference to experimental studies showing that physical activities of greater intensity than walking result in more extensive physiologic and biochemical adaptations than does customary walking.

Note also that the mean PALs obtained by using DLW for healthy (BMI: 18.5–25) and overweight (BMI > 25) adult groups both approximated 1.7. The relatively high PALs observed among the overweight and obese subjects in the DLW database may be in part because walking and many other activities of daily life raise the PAL more rapidly (ie, in less time) in overweight and obese subjects than in normal-weight subjects. Increments in energy expenditure induced by weight-bearing activities are proportional to total body mass, whereas BEE is related to lean body mass (*see* Figures 12-3 and 12-4 in the IOM report; 1). The IOM report did not make dietary and physical activity recommendations for overweight and obese individuals, because that was not in the charge given to the panel. However, the TEE data are available (*see* Appendix I of the IOM report) and should be useful to others in deriving such recommendations.

BIOLOGICAL PLAUSIBILITY AND THE IMPORTANCE OF A PHYSICAL ACTIVITY RECOMMENDATION

The evolutionary history of the human race has been one in which physical activity played a major role in biological success. Even as the epidemic of obesity grows in our contemporary society (30), increasing evidence emerges that physical activity is necessary for the growth, development, and maintenance of physiologic function of numerous tissues, cells and cell organelles, and signaling pathways. It has long been obvious that regular physical activity and physical training increase muscle mass and decrease body fat mass (31). Similarly, evidence is growing that inadequate amounts and intensities of physical activity lead to atrophy and dysfunction of cells and cell systems. Much of the epidemiologic data showing the role of physical activity in lessening the incidence and severity of chronic diseases (eg, coronary heart disease, type 2 diabetes, and some

forms of cancer) are to be found in the 1996 *Report of the Surgeon General* (28). More recent epidemiologic reports and the wealth of information derived from clinical and experimental studies are cited in the IOM report (*see* Table 12-7; 1) and in recent reviews (32, 33). Simply, there does not seem to be an organ system, cell, or tissue—from bones in the lower limbs (34) to growth factors in the brain (35, 36)—that does not benefit from an appropriate amount and quality of physical activity.

Several consensus statement reports and reviews have summarized the vast literature supporting the benefits of physical activity on health promotion and disease prevention and treatment (1, 28, 32, 33, 37). Briefly, regular physical activity has major effects on glucose tolerance and insulin action by increasing expression of the glucose transporter isoform 4 (GLUT4) and the translocation of GLUT4 proteins to the muscle cell surface, where they facilitate glucose clearance and metabolism (38, 39). Similarly, regular physical activity promotes lipid tolerance, which means lowering basal concentrations of plasma triacylglycerols and lipoproteins as well as dampening the responses to high-fat meals (40). These adaptive changes are likely attributable to increases in muscle capillarity, the expression of lipoprotein lipase, muscle fatty acid transporters, and an elaboration of the muscle mitochondrial reticulum where fatty acids are oxidized (41).

Regular physical activity promotes vigor, mood, and a general sense of well-being (36). Part of this *joie de vivre* may be from the induction of endorphins (endogenous opioids) or the expression of neural growth factors (35), but exercise also lowers the level of anxiety, perhaps by decreasing sympathetic nervous system activity (36) and by enhancing the ability to clear lactic acid, which is produced in response to sympathetic stimulation of glycolytic metabolism (42, 43).

Physical exercise has long been known to enhance cardiovascular and metabolic capacity (44), and the molecular mechanisms responsible for these effects are now being elucidated. For instance, the positive effect of regular physical activity for managing intermittent claudication (45) is likely because exercise promotes the endothelial function of blood vessels by increasing the expression of endothelial nitric oxide synthase and extracellular superoxide dismutase (46, 47).

Given the beneficial effects of physical activity in promoting the function of organ systems, cells, and cell signaling systems, it is not surprising that changing behavior through dietary and physical activity intervention can be as or more effective than drugs for retarding the development of type 2 diabetes (48). Similarly, it should not be surprising that physical inactivity is as much a risk factor as hypertension or cigarette smoking, whereas exercise training reduces mortality from coronary heart disease, regardless of preexisting disease (49–51). That those who are physically active have reduced risks of colon, breast, and possibly other forms of cancer (52–55) may be attributable to increased gastrointestinal motility and excretion of mitogens and carcinogens, increased turnover of body lipid depots, and the overall enhanced immunovigilance that accrues with physical activities of the form, intensity, and duration recommended in the IOM report (Chapter 12 in reference 1). Hence, a physical activity recommendation among dietary macronutrient recommendations has importance far beyond its effects on energy turnover and energy balance.

BROADENING OF DIETARY COMPOSITION RECOMMENDATIONS: THE ACCEPTABLE MACRONUTRIENT DISTRIBUTION RANGES

Realizing from the analysis of the DLW database that men and women could maintain BMIs in the healthy range over a broad range of energy expenditures, the panel found new flexibility in making dietary recommendations. The use of physical activity to manipulate energy expenditure means, in some cases, that the recommendation for dietary energy intake can be increased. Both statements imply that using physical activity to raise the level of energy expenditure means that a person needs to eat more to maintain his or her body weight. Notably, physical activity is important for managing body weight by both older and small persons who might miss key micronutrients when consuming restrictive diets. Further, physical activity results in the above-mentioned anabolic and regulatory processes in skeletal muscle, develops cardiovascular system improvements, improves blood lipoprotein profiles in older adults, and leads to increased expression of many beneficial enzymes and enzyme systems in diverse organs and organ systems from bones and muscles to brain. The adaptations to physical activity and exercise are important for children, the aged, and people in general.

Under the basic premise that dietary energy intake balances energy expenditure, recommendations for dietary composition could be relaxed. To this effect, a new concept, the acceptable macronutrient distribution ranges (carbohydrate: 45–65% of energy, fat: 20–35% of energy, and protein: 10–35% of energy), was developed. The IOM report contains separate chapters justifying these acceptable macronutrient distribution ranges and the recommended dietary allowances for protein and particular classes of essential amino and fatty acids. A recommendation for an adequate fiber intake was also presented, and the need to limit consumption of cholesterol, *trans* fatty acids, saturated fatty acids, and total fat was emphasized (1).

THE IOM PHYSICAL ACTIVITY RECOMMENDATION COMPARED WITH ACTIVITY RECOMMENDATIONS OF OTHER ORGANIZATIONS

The landmark SGR *Physical Activity and Health* (28) clearly articulated and justified the use physical activity as a disease prevention modality. The impetus of the physical activity recommendation in the SGR was such that diverse organizations including the Centers for Disease Control and Prevention and the American College of Sports Medicine adopted a 30-min/d baseline physical activity standard. Thus, it was a logical step for the IOM Macronutrient Panel to attempt to combine dietary and physical activity considerations in defining human energy needs. Regrettably, although the recommendation to maintain an active PAL (ie, in the 1.6–1.9 range) is in fact consistent with that in the SGR and with other recent recommendations (Table 5), the physical activity recommendation in the IOM macronutrient report has been widely misunderstood and criticized. Comparison of the IOM physical activity recommendation with other recent recommendations reveals generally good agreement.

Specifically, recommendation 3 in Chapter 2 of the SGR (28) states: “Recommendations from experts agree that for better health, physical activity should be performed regularly. The most recent recommendations advise people of all ages to include a **minimum** of 30 minutes of physical activity of moderate intensity (such

TABLE 5

Comparison of physical activity level (PAL) and dietary energy intake recommendations of different panels offering recommendations¹

Report	PAL	Walking equivalence <i>min/d</i>	Dietary energy
SGR	—	>30 (more and more vigorous are better)	No recommendation
IOM	1.6–1.7	60	Balance
WHO	1.75	—	Balance
IASO	1.7	45–60	Balance

¹ SGR, Surgeon General's report (28); IOM, Institute of Medicine (1); WHO, World Health Organization (3); IASO, International Association for the Study of Obesity (56).

as brisk walking) on most, if not all, days of the week. It is also acknowledged that for most people, greater health benefits can be obtained by engaging in physical activity of more vigorous intensity or of longer duration.”

Our interpretation is that the IOM and SGR physical activity recommendations, the former based on quantitative energetics and the later on epidemiologic data, are entirely consistent. The SGR is to be credited for showing with epidemiologic data that daily physical activity reduces the risk of chronic disease. The IOM recommendation contributes the advantage of being able to use quantitative data on energy turnover based on DLW data. The values given in the SGR (Table 4-10 in reference 28) and in the IOM report (Figure 12-2 in reference 1) to describe the energy expenditure associated with various physical activities are consistent. The main difference between the 2 reports is that the IOM report attempts to also take into account evidence about the amount of physical activity associated with the maintenance of a normal body weight or healthy BMI.

Health Canada's *Physical Activity Guide* (29) states: “Scientists say accumulate 60 minutes of physical activity every day to stay healthy and improve health.” The guide goes on to state that “the time needed (in activity) depends on effort: Light Effort (e.g., light walking, volleyball) 60 minutes; Moderate Effort (e.g., brisk walking, swimming) 30–60 minutes; Vigorous Effort (e.g., jogging, hockey) 20–30 minutes.” As well, the *Physical Activity Guide* recommends endurance (4–7 d/wk), flexibility (4–7 d/wk), and strength-conditioning activities (2–4 d/wk). Thus, the exercise recommendations in Canada's *Physical Activity Guide* are consistent with, if not more comprehensive than, those in the IOM report.

Page 124 of the World Health Organization technical report on obesity (3) states: “Analyses of over 40 national physical activity studies worldwide show that there is a significant relationship between the average BMI of adult men and their PAL, with the likelihood of becoming overweight being substantially reduced at PALs of 1.8, or above. The relationship for women, though not statistically significant, is similar, but their physical activity tends to be lower (mean PAL 1.6). It has been suggested, therefore, that people should remain physically active throughout life and sustain a PAL of 1.75 or more to avoid excessive weight gain.” The physical activity recommendation in the World Health Organization technical report is therefore also consistent with the IOM report.

Finally, the International Association for the Study of Obesity (IASO) convened an expert panel to evaluate data from a variety

of sources to assess the amounts of physical activity necessary to maintain healthy body weights or reduce unnecessary body fat in adults. The IASO panel reached a very similar conclusion about the amount of physical activity necessary to prevent weight gain in adult populations (56). In its summary, the IASO report states:

“The current physical activity guideline for adults of ~30 minutes of moderate intensity activity daily, preferably all days of the week, is of importance for limiting health risks for a number of chronic diseases including coronary heart disease and diabetes. However for preventing weight gain or regain this guideline is likely to be insufficient for many individuals in the current environment. There is compelling evidence that prevention of weight regain in formerly obese individuals requires 60–90 minutes of moderate intensity activity or lesser amounts of vigorous intensity activity. Although definitive data are lacking, it seems likely that moderate intensity activity of approximately 45 to ~60 minutes per day, or 1.7 PAL (Physical Activity Level) is required to prevent the transition to overweight or obesity. For children, even more activity time is recommended.”

LIMITATIONS TO THE USE OF DLW DATA TO MAKE THE PHYSICAL ACTIVITY RECOMMENDATION FOR THE POPULATION

For the first time, DLW data were used to make quantitative estimates of daily energy expenditure for healthy individuals and to derive corresponding physical activity recommendations. Obviously, there are limitations to this and any new approach. Although we have already noted that the data in Appendixes I-1 through I-5 of the IOM report are not representative of the North American population, there can be little doubt that the DLW data available reflect the range of energy expenditures prevailing in healthy individuals of both sexes across a wide range of ages, body sizes, and lifestyles. The data are cross-sectional and their interpretation involved the assumption that the subjects were in approximate energy balance at the time of the measurement, although little is known about participant histories prestudy or what happened to them subsequently. Further, it was assumed that individuals in apparent energy balance at the time of the DLW study would remain in balance given constant dietary and physical activity habits; evidence derived from long-term longitudinal studies will need to be acquired to justify that assumption. Given these and other limitations, to complement currently available information, data were provided in an open format so that the database can be expanded with the results of future investigations.


Although it is clear from our analysis that 30 min/d of accumulated physical activity of mild to moderate intensity is unlikely to prevent excessive weight gains, there is no certainty that our recommendation of 60 min/d will be optimal to prevent weight gain in most individuals. Again, our results (Table 2) are that two-thirds of the participants in the study population with a desirable BMI had PALs > 1.6, and therefore expended ≥60 min/d in moderate activities or the equivalent. This level of physical activity associated with a healthy BMI is consistent with data emerging on the level of physical activity necessary to promote weight loss or prevent regain. Previous (57) and recent reports, such as that of Jeffery et al (58), show that more and more vigorous physical activity (eg, 2500 kcal/wk) is necessary to promote long-term weight loss than the conventional (eg, 1000 kcal/wk) recommendation. Because the lifestyles and life situations of many individuals may preclude them from accruing the

equivalent of ≥ 60 min of daily accumulated physical activity, and because there is a growing need for many individuals in the population to reduce body fat, it remains fundamental that both energy intake and expenditure be considered for the realization of long-term body weight management and related health goals.

The IOM report provides extensive equations, figures, and tables of how to predict the impact on the PAL and Δ PAL of various forms and durations of physical activity, the PAL being roughly equivalent to an amount of accumulated physical activity that need not be accomplished in a single session but that could be distributed among the waking hours. This approach has the advantage of explaining how the physical activity recommendation can be incorporated into the lives of most individuals. Still, like most reports making physical activity recommendations, the IOM report lacks specificity regarding the effects of the intensity of physical activity on physiologic outcomes. Letter carriers and Olympic as well as senior middle distance runners are physically active, but, typically, postal workers, clerks, and others are active at low intensities for hours during the day, whereas athletes commonly train hard during peak intervals and may or may not be physically active the rest of the day. Implicit in the reports cited to establish plausibility for including a physical activity recommendation among dietary recommendations is the factor of exercise intensity in affecting changes in the expression of metabolic and structural enzymes and regulatory factors. Cognizant of the benefits of vigorous exercise in shaping body structures and metabolic processes, the SGR recommended a minimum of 30 min of physical activity of moderate intensity on most, if not all, days of the week. But the SGR also asserted that greater health benefits can be obtained by engaging in more vigorous physical activities of greater duration. In converting the DLW-derived metabolic data to PAL and Δ PAL values, the authors of the IOM report also described how different exercise modes could equate to a PAL of 1.6–1.7 in < 60 min of physical activity per day. Still, like the SGR and other recommendations, the IOM report is unable to identify ideal forms, intensities, and durations of physical activity appropriate to positively affect the mortality or morbidity of chronic diseases.

CONCLUSIONS

Using epidemiologic, clinical, and laboratory methods, different expert committees have independently arrived at similar conclusions about the need for physical activity in daily life. The IOM Macronutrient Panel made a physical activity recommendation along with dietary recommendations; the physical activity recommendation was based on independent analysis and proved to be consistent with the conclusions of other expert panels. The most recent IOM report is, in fact, consistent with previous reports of the Food and Nutrition Board and the National Research Council that acknowledged the healthful effects of physical activity and the utility of physical activity for balancing energy intake and expenditure. To reiterate from the Introduction, the most recent IOM report is distinguished by its reliance on studies using DLW technology to estimate energy expenditure in healthy children and adults and its use of DLW-derived estimates of TEE to make dietary energy recommendations. The results are that healthy children and adults maintain BMIs in the favorable range over a wide range of daily energy expenditures. The panel's conclusion is that the minimal amount of accumulated physical activity generally recommended to achieve a degree of protection from

chronic diseases (ie, 30 min/d) is insufficient for most persons to maintain body weight in the desirable BMI range (from 18.5 to < 25 kg/m²). The equivalent of 60 min of accumulated physical activity each day is required for most persons to prevent undesirable body fat accretion. The recommendations of the IOM panel acknowledge the interrelatedness of prudent dietary and physical activity habits as intrinsic to recommendations for healthful living. The authors of the IOM Macronutrient Report acknowledge the limitations of the recommendation for physical activity sufficient to balance energy expenditure and intake, but emphasize that the physical activity recommendation needs to be considered among other dietary recommendations in the report as well as the long-recognized necessity to manage dietary energy and macronutrient input to achieve long-term energy balance. Our concerted effort should be on implementation of the IOM macronutrient and physical activity recommendations to promote the general well-being and reverse the trends of obesity and related chronic diseases in the US and Canadian populations. 

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