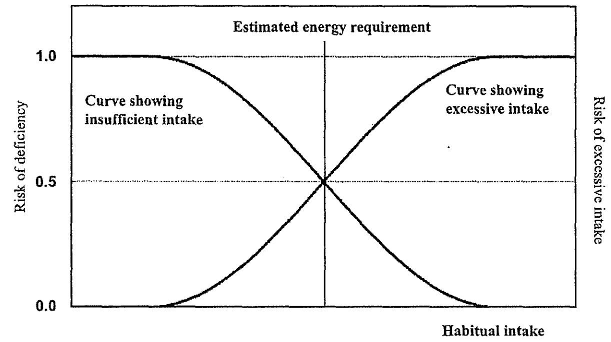

Fig. 1. Theoretical model for understanding estimated energy requirement. Left and right vertical axes show probability of insufficient and excessive intake for individuals, respectively.

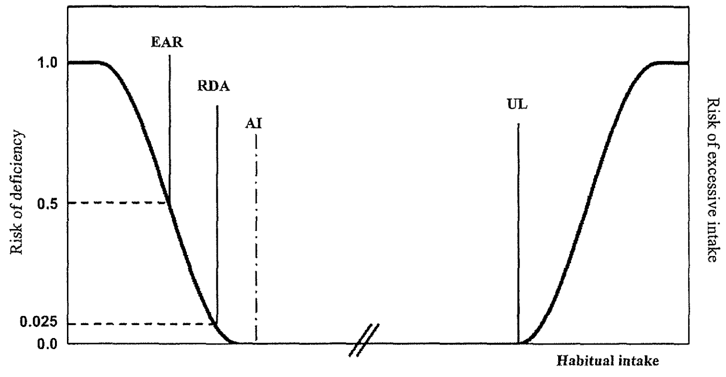

Fig. 2. Theoretical model for understanding EAR, RDA, AI, and UL for nutrients. EAR, estimated average requirement; RDA, recommended dietary allowance; AI, adequate intake; UL, tolerable upper intake level.

nutrition, while excessive intake leads to body weight gain and obesity. Energy intake is optimized when intake equals expenditure (i.e., when energy balance is achieved), resulting in no weight change. The energy requirement that expresses optimal intake is established mainly using values obtained using the doubly labeled water method to assess samples of the Japanese population and the reference of values of populations of other countries. As it is impossible to measure an individual's required intake accurately; the energy value is an estimated value, and thus referred to as the *estimated* energy requirement (EER). The EER is established based on sex, age group, and physical activity level (PAL). The EER is recommended for use in practical settings in place of the true energy requirement because the latter is not possible to determine precisely. An energy intake close to the EER results in a high probability of body weight maintenance, whereas as intake above or below EER results in a high probability of body weight gain or loss, respectively, as illustrated in Fig. 1. By applying this concept to a group, the probability can be converted into the percentage of a population with excessive or insufficient energy intake of energy. PAL is categorized into 3 levels (low, moderate, and high).

2. Nutrients

2-1. Basic concept. The EAR was established only for evaluating insufficient nutrient intake, not ensuring adequate or optimal intake, and thus cannot be the only value used in practice. The recommended dietary allowance (RDA) was thus established for use in a practical setting, while the adequate intake (AI) was established for nutrients for which neither the EAR nor RDA can be established. As is discussed later, the AI is more similar to the RDA than the estimated average requirement (EAR) in its application. All 3 DRIs are used for evaluating nutrient deficiency. For those nutrients for which excessive intake has been reported to pose a health hazard, the tolerable upper intake level (UL) was established. However, the UL cannot be determined for several nutrients that may pose a health hazard because of insufficient data for value determination. Figure 2 illustrates a theoretical model of the EAR, RDA, AI, and UL. Applying this figure to a group gives the percentage of individuals with health problems due to insufficient or excessive intake.

Several nutrients are included because of their role in the primary prevention of lifestyle-related diseases. However, both the quantity and the quality of research into the values for these nutrients for this purpose has been insufficient (*1*). For this reason, the index established for this purpose is referred to as the *tentative* dietary goal for preventing lifestyle-related diseases (DG).

Table 1. Basic concepts of indices and characteristics of nutrients.

Objective	Prevention of deficiency	Prevention of health problems due to excessive intake	Primary prevention of lifestyle-related diseases
Indices	EAR, RDA, AI	UL	DG
Main methods, laboratory studies, epidemiologic studies for establishing evidence	Laboratory studies, epidemiologic studies (including intervention studies)	Case reports	Epidemiologic studies (including intervention studies)
Importance of certain nutrients regarding targeted health problems	Important	Important	Not consistently important due to existence of many other related environmental factors
Typical period associated with health problems	Several months	Several months	Several years to several decades
Number of reports of target health problems	Very few to many	Very few to few	Many
Possibility of developing target health problems from typical food intake	Yes	Very little	Yes
Possibility of developing target health problems even with intake of supplements and fortified foods	Yes (supplements include only a limited number of nutrients)	Yes (particular attention is needed)	Yes (supplements include only a limited number of nutrients)
Strength of need to consider established values	Consider when possible (depending on needs)	Must be considered	Consider along with various related factors
Possibility of developing target health problems at established intake	Low possibility when intake is approximate to or above RDA or AI	Very low possibility when intake is below UL but not 0%	Possible because related factors may also contribute development of problems

EAR, estimated average requirement; RDA, recommended dietary allowance; AI, adequate intake; UL, tolerable upper intake level; DG, tentative dietary goal for preventing lifestyle-related diseases.

The characteristics of and concepts related to these DRIs are summarized in Table 1 (*2*). From an application point of view, DRIs related to insufficient and excessive intake should be given the highest priority; only when these DRIs have been found reliable should primary prevention of lifestyle-related diseases be considered. Table 2 shows the list of nutrients and each of the DRIs established for individuals aged 1 y and above. For infants aged 0 to 11 mo, DRIs were established for 30 nutrients excluding saturated fatty acid, cholesterol, carbohydrate, and dietary fiber.

2-2. EAR. The EAR is defined as the estimated average requirement of an entire defined population (e.g., Japanese men aged 30 to 49 y) based on the distribution of the required intake as measured in a sample population. In other words, it is defined as the intake that satisfies the requirement for 50% (and at the same time does not satisfy that of 50%) of individuals in a certain population. Intake equal to the EAR does not necessarily suggest development of classical nutrient deficiency. The definition of deficiency varies among nutrients.

2-3. RDA. The RDA is defined as the intake that satisfies the requirement of nearly all (97 to 98%) individuals of a certain population. The RDA is theoretically calculated using the standard deviation (SD) of the distribution of the required intake as observed in an experimental study from which the EAR was determined using the following formula:

$$RDA=EAR\times(1+2\times SD)$$

However, because experimental studies can rarely successively determine the SD, an estimated value is generally used instead. The RDA can also be determined using the coefficient of variation (CV) of the EAR and the following formula:

$$RDA=EAR\times(1+2\times CV)$$

The CVs used in the DRIs are shown in Table 3.

Table 2. Nutrients listed and indices used in the Dietary Reference Intakes for individuals aged 1 y and over.[1]

Nutrient			EAR	RDA	AI	UL	DG
Group	Sub-group	Nutrient					
Protein			✓	✓	—	—	—
Fat		Total fat	—	—	—	—	✓
		Saturated fatty acids	—	—	—	—	✓
		n-6 fatty acids	—	—	✓	—	✓
		n-3 fatty acids	—	—	✓	—	✓
		Cholesterol	—	—	—	—	✓
Carbohydrates		Carbohydrates	—	—	—	—	✓
		Dietary fiber	—	—	—	—	✓
Vitamin	Fat-soluble vitamins	Vitamin A	✓	✓	—	✓	—
		Vitamin D	—	—	✓	✓	—
		Vitamin E	—	—	✓	✓	—
		Vitamin K	—	—	✓	—	—
	Water-soluble vitamins	Vitamin B_1	✓	✓	—	—	—
		Vitamin B_2	✓	✓	—	—	—
		Niacin	✓	✓	—	✓	—
		Vitamin B_6	✓	✓	—	✓	—
		Vitamin B_{12}	✓	✓	—	—	—
		Folic acid	✓	✓	—	✓[2]	—
		Pantothenic acid	—	—	✓	—	—
		Biotin	—	—	✓	—	—
		Vitamin C	✓	✓	—	—	—
Mineral	Macrominerals	Sodium	✓	—	—	—	✓
		Potassium	—	—	✓	—	✓
		Calcium	✓	✓	—	✓	—
		Magnesium	✓	✓	—	✓[2]	—
		Phosphorus	—	—	✓	✓	—
	Microminerals	Iron	✓	✓	—	✓	—
		Zinc	✓	✓	—	✓	—
		Copper	✓	✓	—	✓	—
		Manganese	—	—	✓	✓	—
		Iodine	✓	✓	—	✓	—
		Selenium	✓	✓	—	✓	—
		Chromium	✓	✓	—	—	—
		Molybdenum	✓	✓	—	✓	—

EAR, estimated average requirement; RDA, recommended dietary allowance; AI, adequate intake; UL, tolerable upper intake level; DG, tentative dietary goal for preventing lifestyle-related diseases.
[1] Included when DRIs were defined only for certain age groups.
[2] Defined as intake other than that from typical foods.

Table 3. Coefficient of variation used to estimate the recommended dietary allowance from the estimated average requirement.

Coefficient of variation	Coefficient used for calculating recommended dietary allowance	Nutrients
10%	1.2	Vitamin B_1, vitamin B_2, niacin, vitamin B_6, vitamin B_{12}, folic acid, vitamin C, calcium, magnesium, iron for adolescents aged 15 to 17 y, zinc, selenium, chromium, molybdenum
12.5%	1.25	Protein
15%	1.3	Copper
20%	1.4	Vitamin A, iron for children aged 6 mo to 14 y, iodine

2-4. AI. The AI is defined as the intake sufficient to maintain the health of and prevent the nutrient deficiency of almost all members of a population. The AI is used only when both the EAR and RDA are unavailable. Determination of the AI is mainly based on epidemiologic observations of the nutritional intake of a healthy population and the following 3 concepts:

1) For nutrients for which insufficient intake is unlikely, the AI is estimated from the results of simultaneous assessment of health status by the presence of biomarkers and other factors and nutrient intake. When almost no insufficiency is observed, the median intake value is used as the AI.

2) For nutrients for which biomarker and others are unavailable but the representative nutrient distribution of the Japanese population is available, the median intake value is used as the AI.

3) For infants, the AI is determined by multiplying the volume of typical milk intake and the typical nutrient content of breast milk.

2-5. UL. The UL is defined as the upper limit of habitual intake that is considered to pose no risk of health problems. Theoretically, the UL is the no observed adverse effect level (NOAEL), the maximum intake determined to result in no adverse effects in human studies. Due to limited data regarding the NOAEL in humans and the fact that the studies upon which it is based were of isolated groups, the UL is given as the NOAEL divided by an uncertainty factor (UF) varying from 1 to 5 according to conditions. When the lowest observed adverse effect level (LOAEL), the minimum intake known to cause adverse effects based on studies of particular groups with excessive intake or use of supplements, is known, the NOAEL is determined by dividing the LOAEL by 10.

Adverse effects due to excessive intake in humans are rarely reported, and ethical considerations prohibit conducting human studies into determination of the NOAEL and LOAEL. Therefore, both the NOAEL and LOAEL are estimated based on data collected from animal or, in some cases, in-vitro studies. When only the LOAEL is available, the NOAEL is estimated by dividing the LOAEL by a UF of 10, estimated based on animal studies. When neither the scientific basis nor a consensus of professionals is sufficient for determining the UF, an appropriate UF is selected within a range of 1 to 5 when human data are available and a UF of 10 when only animal data are available. The UFs used in the DRIs are shown in Table 4. It should be noted that determination of the UL slightly differs among nutrients.

Table 4. Uncertainty factor used for calculation of tolerable upper intake level.

UF	Nutrients
1	Vitamin E, copper, manganese, iodine (infants)
1.2	Vitamin D (adults), calcium, phosphorus
1.5	Vitamin A (pregnant women), zinc, iodine (adults)
1.8	Vitamin D (infants)
2	Molybdenum
3	Folic acid, selenium
5	Vitamin A (adults), niacin, vitamin B_6
10	Vitamin A (infants)
30	Iron

2-6. DG. A DG is given as preferable intake for primary prevention of lifestyle-related diseases by reducing the risk of their development and that of their biological markers. A DG is determined based on epidemiologic studies and reference to the results of experimental studies. However, the relationship between nutritional intake and risk of developing lifestyle-related diseases is continuous in nature. No remarkable threshold exists, making it difficult to propose an optimum intake range or threshold.

In the DRIs-J 2010, the diseases for which DGs were established were limited to cardiovascular diseases (e.g., hypertension, dyslipidemia, stroke, and myocardial infarction) and cancer (especially stomach cancer). As such, the DGs pertain to intake of fats (fatty acids), cholesterol, carbohydrates, dietary fiber, sodium (salt), and potassium. The major strategy for prevention of osteoporosis and bone fracture, a strongly desirable goal, is maintenance of bone mass. Of the nutrients related to bone health, among which calcium and vitamin D appear in the DRIs-J 2010, a DG was not given for calcium because the EAR and RDA were determined using bone mass as a marker of deficiency of calcium intake, nor was a DG given for vitamin D because of insufficient consensus regarding the determination of the AI of vitamin D, specifically the use of plasma 25-hydroxyvi-

Table 5. Basic and specific dietary goals for selected nutrients.

Basic goal	Specific goal	Nutrients
Modify intake to approximate DG	Increase intake Decrease intake	Dietary fiber, *n*-3 fatty acids, potassium Cholesterol, sodium
DG is given as a range and goal is modifying to come within range		Total fat, saturated fatty acids, carbohydrates
EAR, RDA, or AI is given and only a UL is given for DG		*n*-6 fatty acids

EAR, estimated average requirement; RDA, recommended dietary allowance; AI, adequate intake; DG, tentative dietary goal for preventing lifestyle-related diseases.

tamin D level. The EAR and RDA of vitamin C were determined with some consideration of the prevention of cardiovascular disease. Since the vitamin C requirement has the character of a DG, a DG for vitamin C was not given considering the calculation process. DGs for saturated fatty acids, *n*-6 fatty acids, and carbohydrates were determined using percentage of energy rather than weight of intake per day (e.g., grams per day) as a unit in consideration of the importance of the energy balance of these nutrients. The goal in determining several DGs was bringing habitual intake toward an upper or lower intake level, while the goal in determining other DGs was to bring or keep habitual intake within a certain intake range. The relationships among the types of DGs and nutrients are shown in Table 5.

Basic Parameters Used in Designing the DRIs

1. Age group

Table 6 shows the manner in which segments of a population were classified into different age groups for determination of the DRIs. As in the DRIs-J 2005, infants were generally divided into 2 groups—aged 0 to 5 and 6 to 11 mo—and further divided into 3 groups for determination of energy and protein intake—aged 0 to 5, 6 to 8, and 9 to 11 mo. Children and adolescents were defined as those aged from 1 to 17 y and adults as those aged 18 y and above. For nutrients for which special consideration of the intake of the elderly was necessary, those aged 70 y and above were defined as elderly.

2. Reference body size

The DRIs are expressed only as single representative values of intake for each sex and age group without consideration of body size (body height and weight) within each group. In other words, all the values were determined based on assumption of a typical body size for each sex and age group. For all age groups of individuals aged 1 y and above, typical body size is based on the median height and weight of each sex and age group as reported by the 2005 and 2006 National Health and Nutrition Survey (NHNS) in Japan (*3*, *4*). For infants aged 0 to 11 mo, typical body size is based on the median values of each sex and age group reported by the 2000 National Growth Survey in Infancy and Childhood (*5*). Table 6 lists the values obtained.

3. Nutrient intakes used to establish AIs and DGs

In certain instances, the nutrient intake of a population must be measured to establish AIs and DGs. In the DRIs-J 2010, the median and percentile of sex- and age-group-specific intake reported in the 2005 and 2006 NHNS (*3*, *4*) were used as reference values. The age group classification of children aged 6 to 11 y differed between the DRIs-J 2010 and the National Health and Dietary Assessment such that the former included 3 groups (6 to 7, 8 to 9, and 10 to 11 y) and the latter 2 groups (6 to 8 and 9 to 11 y). Hence, the mean value of children aged 6 to 8 y, the average of the mean values of children aged 6 to 8 y and aged 9 to 11 y, and the mean value of children aged 9 to 11 y as reported in the 2005 and 2006 NHNS were to determine the DRIs for the age groups 6 to 7 y, 8 to 9 y, and 10 to 11 y, respectively.

It is well known that the accuracy of almost all

Table 6. Reference values of body size based on body height and body weight.[1]

Sex	Males		Females[2]	
Age	Height (cm)	Weight (kg)	Height (cm)	Weight (kg)
0–5 mo	61.5	6.4	60.0	5.9
6–11 mo	71.5	8.8	69.9	8.2
6–8 mo	69.7	8.5	68.1	7.8
9–11 mo	73.2	9.1	71.6	8.5
1–2 y	85.0	11.7	84.0	11.0
3–5 y	103.4	16.2	103.2	16.2
6–7 y	120.0	22.0	118.6	22.0
8–9 y	130.0	27.5	130.2	27.2
10–11 y	142.9	35.5	141.4	34.5
12–14 y	159.6	48.0	155.0	46.0
15–17 y	170.0	58.4	157.0	50.6
18–29 y	171.4	63.0	158.0	50.6
30–49 y	170.5	68.5	158.0	53.0
50–69 y	165.7	65.0	153.0	53.6
≥70 y	161.0	59.7	147.5	49.0

[1] Median of each age group as reported in the 2005 and 2006 National Health and Nutrition Survey in Japan was used for all age groups of individuals aged 1 y old and over. Median height and weight as shown in the growth percentile curve for each month in the 2000 National Growth Survey in Infancy and Childhood was used for infants aged under 1 y.
[2] Excluding pregnant women.

dietary assessments, including those conducted using the dietary record method, suffer from under-reporting (*6*). One Japanese study reported an average under-reporting rate of 16% in men and 20% in women (*7*). However, the extent of under-reporting in the 2005 and 2006 NHNS (*3, 4*). upon whose data the DRIs-J 2010 were largely based, is unknown. A theory and practical means of resolving this problem have not been proposed in either Western countries or Japan. Therefore, the data obtained from the surveys (*3, 4*) were used without any adjustment for possible under-reporting. Table 7 lists the nutrients for which intake data were used to determine the AIs or DGs.

4. Integration of research results

Determination of the DRIs was performed in accordance with reference to systematic reviews and the results of high-quality studies to the greatest extent possible. Because a value must have been determined using results from more than one study, the guidelines shown in Table 8 were used for integration of research results.

5. Consideration of intervention studies using supplements

Supplementation of several nutrients at extremely high doses that cannot be obtained from typically ingested foods is thought to prevent lifestyle-related diseases. Any intervention studies using supplements to examine this claim were consulted in determining the DRIs and included as references. However, as there have also been reports of unfavorable health effects (*8*) after certain favorable results have been reported, a conservative standpoint was used when considering the suitability of additional intake from non-usual sources, such as supplements. The results of studies that examined intake levels unachievable by consumption of typical foods were not considered in the determination of the DGs.

6. Extrapolation methods

6-1. Basic concepts. The data used to establish 5 DRIs (EAR, RDA, AI, UL, and DG) were obtained for a limited range of sex and age groups. Therefore, establishing the DRIs for each sex and age group required extrapolation of available data from one group to other groups. As the reference values for the EAR and AI are often based on the daily intake (weight/day) while the reference values for the UL are given per kg of body weight, different extrapolation methods were used. The EAR for each sex and age group was established by extrapolating from the EAR reference values. The RDA for each sex and age group was established by multiplying the EAR by the coefficient shown in Table 3. The sex- and age-group-specific AI was calculated by extrapolation from the reference AI value.

6-2. EAR and AI. It is difficult to develop a method of extrapolation that accounts for the characteristics of each nutrient. Because the efficiency of energy metabolism highly correlates with body surface area, a formula estimating body surface area from body height and/or body weight has been widely used to determine energy metabolism. Among the formulae developed to estimate body surface area from body height and/or weight (*9*), a formula developed in 1947 using the weight ratio to the 0.75 power was used in determining the DRIs (*10*). Recent studies have reported that this method is useful for estimating the organ weights of various animals, including the cardiovascular and respiratory organ weights of mammals (*11*). Based on these reports, extrapolation is performed as follows when EAR and AI reference values per day (weight/day) and a representa-

Table 7. Nutrients for which intake data were available to compute adequate intakes and dietary goals.

Index	Nutrients
AI	*n*-6 fatty acid, *n*-3 fatty acid, vitamin D, vitamin E, pantothenic acid, biotin[1], phosphorus, manganese[1]
DG	Total fat, saturated fatty acid, *n*-3 fatty acid, sodium, potassium

AI, adequate intake; DG, tentative dietary goal for preventing lifestyle-related diseases.
[1]Data obtained from sources other than the 2005 and 2006 National Health and Nutrition Survey in Japan were used as references.

Table 8. Methods used to integrate study results.

Extent of similarity or difference among study results	Availability or lack of studies using Japanese subjects	Integration concept of study results
Relatively similar	Relative availability	Use of studies with priority
	Relative lack	Use of all studies with equal priority and the mean of the values reported
Relatively different	Availability of relatively high-quality studies	Use of studies with priority
	Availability of relatively low-quality studies	Use of selected high-quality studies and the mean of the values reported
	Lack of studies	

Table 9. Growth factors used in determination of EAR and AI for children and adolescents aged 1 y and over.

Age group	Growth factor
Males and females 1–2 y	0.30
Males and females 3–14 y	0.15
Males 15–17 y	0.15
Females 15–17 y	0
Males and females 18 y and over	0

EAR, estimated average requirement; AI, adequate intake.

Table 10. Methods used for rounding values.

Approximate median value	Method of rounding
0.5	Nearest 0.1
1	Nearest 0.1
5	Nearest 0.5
10	Nearest whole number
50	Nearest 5
100	Nearest 10
500	Nearest 50
1,000	Nearest 100
5,000	Nearest 500

When reference value of UL was given as a quantity per day, the extrapolation equation used was the following: $X=X_0\times(W/W_0)$, where X=UL (intake per day) of a specific age group, X_0=reference value of UL (intake per day), W=reference body weight of the specific age group, W_0=median or mean of body weight of group that provided reference value of UL.

tive value (median or mean) of body weight of a given group are available:

$$X=X_0\times(W/W_0)^{0.75}\times(1+G),$$

where X=EAR or AI (intake per day) of a specific age group, X_0=reference value of EAR or AI (intake per day), W=reference body weight of the specific age group, W_0=median or mean of body weight of group that provided EAR or AI reference value, and G=growth factor (see Table 9).

In several studies, the EAR or AI reference value is given per kg of body weight. In such cases, extrapolation is performed as follows:

$$X=X_0\times W\times(1+G),$$

where X=EAR or AI (intake per day) of a specific age group, X_0=reference value of EAR or AI (intake per day), W=reference body weight of age group, and G=growth factor (see Table 9).

For children, the following growth factor values must also be taken into account: (*1*) the additional intake of a nutrient required for growth and (*2*) the quantity of the nutrient accumulated in the body during growth. To obtain these values, the values used by the FAO, WHO, and UNU (*12*) and the United States and Canada in their DRIs (*9*) were modified for each age group of the Japanese population (Table 9). For infants aged 6 to 11 mo, the following 2 methods were considered: (*1*) extrapolation based on the value for infants aged 0 to 5 mo and (*2*) use of the median value of infants aged 0 to 5 mo and children aged 1 to 2 y. For extrapolation of the DRI values to infants aged 0 to 5 mo, the following formula has been proposed (*9*):

DRI for infants aged 0 to 5 mo
=reference weight of infants aged 6 to 11 mo/(reference weight of infants aged 0 to 5 mo)$^{0.75}$

As infants aged 0 to 5 mo are in the growth stage, determination of their DRIs must consider allowances for growth factors, which the formula given above fails to do. When the value of the reference weight is substituted in the formula, the expressions for boys and girls are $(8.8/6.4)^{0.75}$ and $(8.2/5.9)^{0.75}$, yielding values of 1.27 and 1.28, respectively. As use of these formulae produces extrapolated values that are slightly different for boys and girls, the mean of these values is used to determine the AI for both sexes.

6-3. UL. As is the case for the EARs and AIs, none of methods used to extrapolate the ULs produce values that are sufficiently reliable. For age groups for which data are insufficient, 1 of 2 methods is generally used to establish the value. When the UL reference value is given as a quantity in terms of kg of body weight, the UL is extrapolated as follows:

$$X=X_0\times W,$$

where X=UL (intake per day) of a specific age group, X_0=UL reference value (intake per day), and W=reference body weight of the specific age group.

When the UL reference value is given as a quantity per day, the UL is extrapolated as follows:

$$X=X_0\times(W/W_0),$$

where X=UL (intake per day) of a specific age group, X_0=UL reference value (intake per day), W=reference body weight of the specific age group, W_0=median or mean of body weight of group that provided UL reference value.

7. Methods of rounding values

For the sake of convenience and reliability, EAR, RDA, AI, UL, and DG values are routinely rounded off according to the rules shown in Table 10. For all age groups of children and adults, a single rule was applied for each nutrient. Values for infant and additional values for pregnant and lactating women were rounded to the same number of digits as those used for other sex and age classes. After rounding values, they were smoothed when necessary to remove an excessive difference from neighboring age groups.

Discussion

This review briefly described the theory used in determining the DRIs-J 2010, whose understanding is indispensable in the appropriate use of the values contained in this report. The theory is similar to those used in determining the DRIs in the United States and Canada. However, the DRIs-J 2010 adopted the concept of prevention of chronic diseases using DGs. This is unique and seems to be important because control and prevention of major chronic diseases, i.e., lifestyle-related diseases, is the most important issue in most of developed countries. However, the scientific basis behind this concept is insufficient, requiring its modification based on scientific evidence accumulated in the future. Continued effort to establish the most appropriate DRIs for the Japanese population should be strongly encouraged with an eye toward future revision of the DRIs.

REFERENCES

1) Trumbo PR. 2008. Challenges with using chronic disease endpoints in setting dietary reference intakes. *Nutr Rev* **66**: 459–464.
2) Sasaki S. 2005. Chapter 8 Understanding the DRIs with epidemiologic concepts, p 217–240. *In*: Easy-to-understand Evidence-based Nutrition and Nutritional Epidemiology, Dobunshoin, Tokyo (in Japanese).
3) Ministry of Health, Labour and Welfare, Japan. 2007. National Health and Nutrition Survey Japan (2005).
4) Ministry of Health, Labour and Welfare, Japan. 2009. National Health and Nutrition Survey Japan (2006).
5) Kato N, Okuno A, Takaishi M. 2001. Results on 2000 national growth survey in infancy and childhood. *Shoni Hoken Kenkyu (J Child Health)* **60**: 707–720 (in Japanese).
6) Livingstone MB, Black AE. 2003. Markers of the validity of reported energy intake. *J Nutr* **133** (Suppl 3): S895–920.
7) Okubo H, Sasaki S, Hirota N, Notsu A, Todoriki H, Miura A, Fukui M, Date C. 2006. The influence of age and body mass index on relative accuracy of energy intake among Japanese adults. *Public Health Nutr* **9**: 651–657.
8) Miller ER 3rd, Pastor-Barriuso R, Dalal D, Riemersma RA, Appel LJ, Guallar E. 2005. Meta-analysis: high-dosage vitamin E supplementation may increase all-cause mortality. *Ann Intern Med* **142**: 37–46.
9) Food and Nutrition Board, Institute of Medicine. 1998. The B vitamins and choline: overview and methods. *In*: Dietary Reference Intakes: For Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline (Institute of Medicine, ed.), p 27–40. National Academy Press, Washington DC.
10) Kleiber M. 1947. Body size and metabolic rate. *Physiol Rev* **27**: 511–541.
11) West GB, Brown JH, Enquist BJ. 1997. A general model for the origin of algometric scaling laws in biology. *Science* **276**: 122–126.
12) FAO/WHO/UNU. 1985. Energy and protein requirements. Report of a joint FAO/WHO/UNU expert consultation. Technical Report Series, No. 724. WHO, Geneva.

Dietary Reference Intakes for Japanese 2010: Basic Concepts for Application

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Summary The Dietary Reference Intakes for Japanese (DRIs-J) 2010 is not merely as scientific report describing the intake of energy and nutrients necessary for prevention of deficiency/insufficiency and excess but also a source of practical guidelines in planning for dietary improvement in general and in food services by dietitians and other health professionals. This review briefly describes the basic concepts in the application of the DRIs-J 2010. It consists of two sections considering the purposes of use in the Dietary Reference Intakes (DRIs) in Japan: (1) the basic concepts in their application and related issues and (2) the methods of their application. The latter is further divided into 3 sections each describing a goal in the application of the DRIs: (1) improvement of diet for an individual, (2) improvement of diet for a group, and (3) management of food services. A major challenge in the application of the DRIs is that compared to research into determination of the intake of energy and nutrients for development of the DRIs, research into application of the DRIs has been extremely scarce in Japan. Due to lack of evidence, current application of the DRIs is conceptual rather than scientific and practical. Highly scientific research into application of the DRIs is thus urgently needed.

Key Words dietary reference intakes, application, Japan

Introduction

This review briefly describes the basic concepts in the application of the Dietary Reference Intakes for Japanese (DRIs-J) 2010. Although the use of standardized concepts for DRIs has been proposed in the United States and Europe, universal concepts have not yet been established (*1–3*). As body size, major health problems, and nutritional intake all differ between Japanese and Western populations, country-specific conceptualization of the DRIs is needed.

Basic Concepts in DRI Application and Related Issues

1. Target individuals and groups

The targets of the DRIs are healthy individuals and groups mainly composed of healthy individuals, as well as individuals not receiving dietary education or undergoing dietary therapy or restriction and individuals with low levels of risk factors, such as high blood pressure, dyslipidemia, or hyperglycemia. In cases in which dietary education, therapy, or restriction is recommended to an individual or a group for treatment or prevention of a disease, disease-specific guidelines should be referred to and the DRIs-J 2010 should be used as a supplemental reference. Several studies have reported differences between the estimated average requirements (EARs) and the nutritional requirements of healthy individuals and certain groups, including the elderly (i.e., those needing nursing care) and the disabled (*4–6*). However, as evidence regarding these differences has not yet sufficiently accumulated, it is still unclear whether the values developed for healthy subjects are applicable to these groups.

2. Sources of intake

With some exceptions, the primary sources of energy and nutrients are foods eaten as meals, including fortified foods, and dietary supplements taken for health improvement and not for treatment of disease.

3. Duration of intake

The DRIs are standards for "habitual" intake expressed as "intake per day." Thus, they apply to long-term rather than short-term (e.g., single-day) intake. This is due to the fact that health problems addressed by the DRIs are caused by habitual inadequate intake. The period needed to develop health problems due to inadequate intake depends on the nutrient(s) involved and the type of health problems. For example, serum vitamin B_1 level decreases greatly 2 wk after eliminating vitamin B_1 from the diet, and various symptoms caused by its deficiency emerge within 4 wk (*7*). This illustrates the necessity of dietary management of vitamin B_1 within a period shorter than 1 mo. On the other hand, excessive intake of sodium (salt) is correlated with hypertension due to aging (*8*), indicating the importance of the dietary management of sodium over several decades.

Due to the characteristics of nutrient intake, in particular its day-to-day variability, it is difficult to define the habitual intake of a particular nutrient. According to previous observations (*9–12*), the period required for

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Table 1. Priority of application of DRIs-J 2010 energy and nutrient intake values.

Energy/nutrient	Nutrients (examples)	Notes
1. Energy	—	Including alcohol
2. Protein	Protein	—
3. Fat	Fat	% energy (%E)
4. Nutrients listed in food composition table[1] (nutrients for which both EAR and RDA or AI has been established)	Vitamin A, vitamin B_1, vitamin B_2, vitamin C, calcium, iron	Nutrients for which critical deficiency has been observed and for which prevention of deficiency is important. Requires consideration of relatively short-term intake.
5. Nutrients listed in food composition table[1] (nutrients for which a DG has been established)	Saturated fatty acids, dietary fiber, sodium, potassium	Nutrients important in primary prevention of lifestyle-related diseases. Requires consideration of relatively long-term intake.
6. Nutrients not listed in food composition table[1]	—	Usually low priority except for particular groups or groups with particular food habits.

[1] Table appears in *Standard Tables of Food Composition in Japan*, 5th Revised and Enlarged Edition.
DRIs-J, Dietary Reference Intakes for Japanese; EAR, estimated average requirement; RDA, recommended dietary allowance; AI, adequate intake; DG, tentative dietary goal for preventing lifestyle-related diseases.

assessing or managing habitual intake is approximately 1 mo, with some exceptions for nutrients with great day-to-day variability in intake.

4. *Priority of goals and nutrients in nutritional management* (Table 1)

Reliability and priority in application are not same among energy and nutrients. Maintaining adequate energy balance between intake and expenditure is fundamental in nutritional management. Nutrients are categorized into 2 types depending on the purpose of intake: avoidance of both insufficient and excessive intake (while considering natural growth in infants and children) and primary prevention of lifestyle-related diseases. As the former should be given priority, EARs, recommended daily allowances (RDAs), adequate intakes (AIs), and tolerable upper intake level (ULs) should be determined prior to determining tentative dietary goals for preventing lifestyle-related diseases (DGs). DGs should only be considered when maintenance of health status is assured. Priority is also low for nutritional management of nutrients without confirmed deficiency in humans and for nutrients for which intake cannot be measured or estimated. However, the order of priority is not fixed and may need to be changed, depending on the characteristics of the individuals or groups that are being assessed and the goals of the DRIs.

5. *Points for application based on each of the DRIs*

5-1. Estimated energy requirement. In nutritional management, the estimated energy requirement (EER) of an individual must be considered to determine the energy per serving. The EER is determined by measurement of energy expenditure using the doubly labeled water method. Physical activity level (PAL) is estimated using the following formula, which is based on measurement of energy expenditure and basal metabolic rate (BMR):

$$PAL=EER/BMR$$

However, as the EER is immeasurable from an application point of view, it is estimated from BMR and PAL with consideration of sex and age class using the following formula:

$$EER=BMR\times PAL$$

Nevertheless, the BMR is not always easy to measure, and the estimation error of PAL tends to be large. It is therefore not always practical to estimate energy requirements using the BMR and PAL.

Several formulae have been proposed to estimate the BMR based on individual characteristics, including sex, age, height, and weight, such as the Harris-Benedict equation (*13*); an equation developed by the Food and Agricultural Organization (FAO), the World Health Organization (WHO), and the United Nations University (UNU) (*14*); and the NIHN equation for the Japanese population (*15*). However, equations developed for Western populations have been found to overestimate the EER for the Japanese population (*16, 17*). Thus, when using these equations for estimating an individual's energy requirement, their reliability and applicability must be fully considered, in addition to the estimation error of PAL.

The true energy requirement has been found to have a standard deviation of 200 kcal/d among male adults and 160 kcal/d among female adults (*18*). Because of this wide variation in true energy requirement at an individual level and several other factors, determination of energy balance (i.e., balance between energy intake and expenditure) should be based on evaluation of body weight and body mass index (BMI), both of which are relatively easy to measure accurately, instead of comparison of EER with energy intake as evaluated by

Table 2. Differences between nutrient definitions in DRIs-J 2010 and *Standard Tables of Food Composition in Japan*, 5th Revised and Enlarged Edition.

Nutrient	Difference		Notes when intake or serving size is estimated from food composition table[1] for use in DRIs-J 2010
	DRIs-J 2010	Food composition table[1]	
Vitamin E	Only α-tocopherol is reported.	α-, β-, γ-, and δ-tocopherol are reported individually.	Only α-tocopherol should be used.
Niacin	Niacin equivalents (=niacin [mg]+1/60 tryptophan [mg]) is used.	Nicotinic acid equivalent is used (niacin synthesized in the body from tryptophan is not included).	Niacin (mg) + 1/60 tryptophan (mg) should be used. Since tryptophan concentration in food is roughly 1/100 that of protein, its value approaches the value of niacin (mg)+1/6,000 protein (mg), and can be rewritten as niacin (mg)+1/6 protein (g).

[1] Reference *27*).

dietary assessment.

5-2. *EAR and RDA.* Since use of the EAR poses a 50% probability of insufficient intake, dietary intervention is needed when the intake of several or many members in a group is below the EAR. The RDA is the intake level that poses a nearly 0% of deficiency in an individual or the individuals in a group. Therefore, if the intake of individuals or a group approaches or is above the RDA, it can be assumed that they face nearly no risk of deficiency. However, users of the DRIs-J 2010 should understand the purpose and definition of each DRI and the characteristics of each nutrient because the application method differs according to the purpose.

5-3. *AI.* The AI is determined when the EAR is not available. Although there is very low risk of deficiency when the intake of a nutrient is above the AI, it is not possible to identify the existence of deficiency or its risk when intake is below the AI.

5-4. *UL.* The UL indicates a threshold intake above which a risk of health problems exists. Since UL values are theoretically and empirically difficult to establish, most are based on a few reports of accidental overdose, indicating the insufficiency of scientific evidence for determining ULs. Therefore, individuals should use ULs as values to avoid approaching rather than to avoid exceeding, and not use them in primary prevention of lifestyle-related diseases.

5-5. *DG.* A DG is established for primary prevention of lifestyle-related diseases. As diet is one of many causes of lifestyle-related diseases, it is not correct to strictly maintain DG simply for their primary prevention. For example, excessive intake of sodium (salt) is just one of several factors increasing the risk of hypertension (*19*). Compared to health problems due to insufficient or excessive intake, lifestyle-related diseases are considered outcomes of lifestyle factors, including dietary habits, sustained over very long periods. In view of this consideration, long-term (lifetime) management is more important than strict short-term management.

6. *Dietary assessment*

6-1. *Relationship to application.* Evaluation of energy and nutrient intake is performed for comparison of an intake value with its corresponding DRI value. However, due to the various problems discussed below, especially measurement errors in dietary assessment, users of the DRIs-J 2010 must pay careful attention to the means of standardization and endeavor to maintain accuracy in both assessment and interpretation of the values.

6-2. *Under- and over-reporting.* Of the several methods used for dietary assessment, most are based on self-reporting by subjects, inevitably leading to reporting errors. Of under- and over-reporting, the most significant reporting errors, under-reporting occurs more frequently. Under-reporting of energy in particular requires careful attention. In research, the level of measurement error differs, depending on the assessment method used and subject characteristics. Among Japanese adults, males under-report their energy intake by 11% on average and females by 15% (*20*).

Under-reporting may have a highly negative effect on the interpretation of a dietary assessment. For example, the excessive energy intake of a man who gains 5 kg in a year is 96 kcal/d (i.e., 7,000×5/365), assuming that 1 kg of body weight is equal to approximately 7,000 kcal (*21, 22*). The measurement error due to under-reporting by 13% would be 260 kcal/d for a man whose total energy intake is 2,000 kcal/d, a value much larger than the 96 kcal/d. This example shows that under-reporting makes it almost impossible to compare a value obtained by dietary assessment with the EER. Furthermore, under- and over-reporting are strongly affected by the degree of obesity (*23*). Comparing intake estimated from analysis of 24-h urinary excretion of nitrogen (a biomarker of protein intake), potassium, and sodium and the corresponding self-reported intake of Japanese subjects, one study found a clear relationship between the degree of reporting error and the degree of obesity in terms of BMI (*24*).

6-3. *Day-to-day variation.* It is widely known that day-to-day variations exist in energy and nutritional intakes (*8*). Nevertheless, determination of intake dis-

Table 3. Basic concepts in applying DRIs-J 2010 for dietary improvement of individuals.

Purpose	Indices	Dietary assessment	Planning for and application of dietary improvement
Assessment of energy balance	Change in BMI and/ or body weight	Balance is negative when BMI is below 18.5 and positive when BMI is over 25.0.	Planning should aim to maintain BMI within normal range.
		Evaluation of change by measurement of body weight change.	Note: Measurement should be performed at least twice within a certain period and plans reviewed and revised based on the results.
Assessment of insufficient nutrient intake	EAR, AI	Determination of percentage of individuals with intake below EAR.	Planning should aim to minimize the number of individuals with intake below EAR.
		When using AI, compare AI and measured intake to ensure that intake is not below AI.	When intake is approximate to or above RDA or AI, planning should aim to maintain intake. Note: Measurement of intake below AI does not indicate the probability of inadequacy.
Assessment of excessive nutrient intake	UL	Estimation of possibility of excessive intake by comparing measured intake and UL.	When intake is above UL, planning should aim to reduce intake below UL. Note: Intake above UL should be avoided. When excessive intake is reported, plans should be reviewed, revised, and implemented promptly.
Assessment of risk of primary prevention of lifestyle-related disease	DG	Comparison of measured intake and DG. However, assessment should be done with comprehensive consideration of existence and degree of other nutrition-related and non-nutrition-related factors of target lifestyle-related disease.	Planning should aim to maintain intake within a range of DG. Note: Assessment of target nutrient should be conducted with comprehensive consideration of (1) the existence and degree of other nutrition-related and non-nutrition-related factors contributing to the target lifestyle-related disease and (2) the sustainability of a plan over the long term, as lifestyle-related diseases develop over the course of the lifespan.

DRIs-J, Dietary Reference Intakes for Japanese; BMI, body mass index; EAR, estimated average requirement; RDA, recommended dietary allowance; AI, adequate intake; UL, tolerable upper intake level; DG, tentative dietary goal for preventing lifestyle-related diseases.

tributions without consideration of day-to-day variations is required, as the DRIs do not consider variations despite the fact that the degree of day-to-day variation in energy and nutrient intake differs among individuals and groups (*9–12*). A further challenge is that due to difficulties in study methodology, actual day-to-day variation in the Japanese remains poorly investigated.

Day-to-day variation also poses difficulty in assessing the intake distribution of a group. Because of day-to-day variation, a distribution curve obtained from assessment of a nutrient over a limited number of days is narrower than that obtained from assessment of habitual intake. Therefore, the observed percentage of individuals with deficient/insufficient or excessive intake depends on the number of days examined in a dietary assessment (*25*). Moreover, seasonal variation as a component of day-to-day variation must be considered. The intake of several nutrients, including vitamin C, has been found to have clear seasonal variation in Japanese populations (*7, 11, 24–26*).

6-4. Food composition table. A food composition table is used to calculate nutrient intakes in a dietary assessment and those of the menu of a food service. However, the definitions of the nutrients slightly differ between the DRIs and the food composition table (*27*) (Table 2).

7. Assessment of body size, clinical symptoms, and results of clinical examinations

Body weight and BMI are the most important and practical indices used in planning and evaluating dietary interventions. When evaluating the results of dietary interventions, change in body weight is a more practical index than change in BMI. In an intervention for weight decrease or increase, body weight should be measured and recorded every 4 wk and be followed up for more than 16 wk (*28*). Besides body size, abdominal girth, body fat percentage, and other indices may be used, depending on the purpose of the intervention.

Clinical symptoms and the results of clinical examinations may also be used as indices of insufficient or excessive intake of nutrients. For iron, hemoglobin concentration in blood and menstrual blood loss may be

Table 4. Basic concepts in applying DRIs-J 2010 for dietary improvement of groups.

Purpose	Indices	Dietary assessment	Planning for and application of dietary improvement
Assessment of energy balance	Change in BMI and/ or body weight	Balance is negative when BMI is below 18.5 and positive when BMI is over 25.0.	Planning should aim to maintain BMI within normal range.
		Evaluation of change by measurement of body weight change.	Note: Measurement should be performed at least twice within a certain period and plans reviewed and revised based on results.
Assessment of insufficient nutrient intake	EAR, AI	Determination of percentage of individuals with intake below EAR.	Planning should aim to minimize number of individuals with intake below EAR.
		When using AI, compare AI and measured intake to ensure that intake is not below AI using distribution of measured intake.	When using AI, planning should aim to increase mean group intake to approximate AI. Note: It is difficult to compare percentage of individuals with intake below EAR and the percentage with intake below AI because the percentages have different meanings.
Assessment of excessive nutrient intake	UL	Calculation of percentage of individuals at risk of excessive intake using distribution of measured intake and UL.	Planning should aim to reduce intake of all individuals below UL. Note: Intake above UL should be avoided. When excessive intake is reported, plans should be reviewed, revised, and implemented promptly.
Assessment of risk of primary prevention of lifestyle-related disease	DG	Calculation of percentage of individuals with intake outside range of DG using measured intake and DG.	Planning should aim to increase number of individuals with intake within or approximates the range of DG. Note: Assessment of target nutrient should be conducted with comprehensive consideration of (*1*) the existence and degree of other nutrition-related and non-nutrition-related factors contributing to the target lifestyle-related disease and (*2*) the sustainability of a plan over the long term, as lifestyle-related diseases develop over the course of the lifespan.

used as markers (*29, 30*). However, their careful interpretation is required because clinical symptoms and the results of clinical examinations are affected by other factors besides the levels of a target nutrient.

Methods of Application

The DRIs are used for many purposes but mainly for *dietary improvement* and *management of food services.* Theories of application of dietary improvement, which consists of assessment of dietary intake, preparation based on assessment, and practice, differ between individuals and groups, and should therefore be described separately. The term *management of food service* refers to dietary planning for a particular group and an on-going meal service. The DRIs, which are the fundamental data sources used to establish dietary guidelines and recommendations, do not necessarily need to be achieved immediately for any purpose.

1. Dietary improvement of individuals

1-1. Basic concepts. Table 3 shows the basic concept in application of the DRIs to the dietary improvement of individuals. This concept is based on the concepts proposed in the DRIs of the United States and Canada (*1, 2, 31*) and the application patterns of the DRIs in Japan.

1-2. Dietary assessment (Table 3). For assessment of insufficient or excessive intake of energy, BMI or body weight change should be used. The Japan Society for the Study of Obesity defines a normal BMI as a value between 18.5 and 25.0 (*32*). However, even if an individual is within this range, increase or decrease in body weight suggests a positive or negative energy balance, respectively, and thus requires careful assessment.

When evaluating sufficiency of nutrient intake, either the EAR and RDA is used or, if both are unavailable, the AI. Probability of inadequacy is estimated using measured intake, the EAR, and the RDA. There is nearly no risk of inadequacy when intake is close to or above the RDA. When intake is above the EAR but below the RDA, increasing intake up to the RDA is recommended. However, decisions regarding the intake of a particular nutrient should be made with consideration of the intake of other nutrients. When intake is below the EAR, increasing intake is strongly recommended. Assessment of intake using the AI should consider that intake equal to or above the AI poses nearly 0% risk of inadequacy. Even if intake is below AI, risk of inadequacy cannot, by its nature, be quantitatively judged. As the UL is used for preventing excessive intake, an intake above the UL is evaluated as excessive. DGs are used for primary prevention of lifestyle-related diseases. However, as lifestyle-related diseases have many causes, dietary improvement by adherence to DGs should not be overly emphasized.

1-3. Development and use of dietary improvement plans (Table 3). Planning for dietary improvement consists of evaluation of nutrient intake by dietary assessment and implementation of dietary changes based on the results. However, because conducting these procedures is often difficult, several compromises may be taken into consideration according to the situation. For assessment of insufficient or excessive intake of energy, BMI or body weight change should be used, planning should be focused on maintaining a normal range of BMI, and measurement should be performed at least twice within several months (at least twice a year) and reviewed using changes in body weight as indices. For assessment of nutrient intake, the RDA should be used. If intake is close to or above the RDA, planning should aim to maintain this intake, and if intake is below the RDA, it should aim to approach the RDA. The AI should be used for assessment of nutrients for which the AI has been established. If intake is close to or above the AI, it should be maintained, and if below the AI, it should be increased to approach the AI. As intake above the UL should strictly be avoided, a plan for the reduction of the intake of any nutrient whose intake is above the UL should be promptly developed and implemented. If intake is out of a range of a DG, the goal of planning should be to come within the range.

While conducting such planning, comprehensive consideration of other nutrition- and non-nutrition-related factors associated with lifestyle-related diseases, as well as the sustainably of a particular plan over many years, as prevention of lifestyle-related diseases is a life-long endeavor, is recommended.

2. Dietary improvement of groups

2-1. Basic concepts. The basic concepts in applying the DRIs for dietary improvement of a group are shown in Table 4. These concepts are based on DRIs of the United States and Canada (*1*, *2*, *33*) and the application patterns of the DRIs in Japan. The following 3 procedures are important in these concepts: assessment of dietary intake, development of a plan for dietary improvement based on the results of the assessment, and implementation of the plan for dietary improvement.

2-2. Dietary assessment (Table 4). For assessment of insufficient or excessive intake of energy, the BMI should be used. Energy is calculated from the distribution of the percentage of individuals within and outside the range of normal BMI, defined by the Japan Society for the Study of Obesity as BMI between 18.5 and 25.0 (*32*). For determination of nutrient intake, the distribution of nutrient intake as obtained from dietary assessment is used. Such assessment should be performed with full understanding of measurement errors, especially those due to under- and over-reporting and day-to-day variation.

For nutrients for which the EAR has been established, the percentage of individuals for whom intake is below the EAR should be calculated. Theoretically, the probability method should be used to obtain the correct percentage. However, as it is rarely applicable because it can be used only under strict conditions (*1*), the cut-point method is usually used instead (*13*). In cases in which the distribution curve of requirement is very different from the normal distribution, the value calculated using the cut-point method differs from the true value, as does the value for iron (*1*). Moreover, when mean intake and its distribution differ from the EAR, the value obtained using the cut-point method may differ from the true percentage. When, in using the AI, the percentage of individuals whose intake is below the AI is calculated, it does not theoretically match the true percentage of those with inadequate intake. However, because no other indices exist, the AI must be used for practical reasons. In using the UL, the percentage of those at risk of excessive intake should be calculated from the intake distribution and the UL. In using a DG, the percentage of those whose intake is out of range of the DG should be calculated from the intake distribution and the DG.

2-3. Development and use of plans for dietary improvement (Table 4). For assessment of insufficient or excessive intake of energy, the BMI or change in body weight is used as an index. Planning should focus on increasing the percentage of individuals with a BMI within the normal range, measurement should be performed at least twice within a period of several months (at least twice a year), and change in body weight should be used for making and revising plans.

For assessment of sufficiency of nutrient intake, the EAR or AI is used. When the EAR is used, planning should aim to decrease the percentage of individuals with an intake below the EAR. When the AI is used, planning should aim to increase the mean intake of the group to approach the AI. For prevention of excessive nutrient intake, the UL is used. Planning should aim to reduce individual intake below the UL, as intake above the UL should strictly be avoided. For evaluation of nutrients related to lifestyle-related diseases, the DG is used. Planning should aim to increase the percentage of individuals whose intake is within or close to the DG while considering other nutrition- and non-nutrition-related factors related to lifestyle-related diseases and the sustainability of a particular plan over a long period.

3. Management of food services

3-1. Basic concept. The term *management of food service* refers here to planning for the provision of a continuous food supply with appropriate quality control based on evaluation of intake of a specific group of individuals. Maintenance and improvement of health, healthy growth of children, and primary prevention of lifestyle-related diseases are the key goals of management of food service. Therefore, it is necessary to plan for the serving of foods based on the DRIs.

3-2. Characteristics of target groups. Management of food services for a target group requires determination of the distribution of sex, age, body height and weight, and PAL and the percentage of individuals with a BMI outside the normal range of 18.5 to 25.0 (*34*). Using reference data, such as those contained in student health records, rather than conducting an independent assessment is recommended. When such reference data are not available, those obtained from similar groups can be used. It is desirable to repeat assessment of individual characteristics periodically for revision of the food service plan.

3-3. Dietary assessment. Not only are the meals provided by food services but all meals subject to assessment. It is preferable to use data regarding total intake to determine the extent of nutrient contribution by food services. If such data are difficult to obtain, data obtained by assessment of a single meal or a sample of individuals may be used. To prevent insufficient intake of nutrients, the percentage of individuals with an intake below the EAR is estimated from the measured intake distribution. When the AI is used, the percentage of individuals with intake below the AI is estimated. To prevent excessive intake, the percentage of individuals with an intake above the UL is estimated from the measured intake distribution. For primary prevention of lifestyle-related diseases, the percentage of individuals with an intake outside of a range of a DG is calculated from measured intake distribution.

3-4. Dietary planning. Dietary planning should be conducted using the DRIs, be based on individual characteristics and intakes, and consider whether every meal or a single daily meal is served. Determination of energy provided per serving should be based on sex, age group, and PAL distribution and on standard indices, such as the BMI. Changes in the BMI and body weight should also be used when useful.

Not all individuals in a group must meet the EAR or AI, which may increase the percentage of individuals with excessive intake. Menus should be planned to avoid the risk of approaching the UL. For primary prevention of lifestyle-related diseases, menus should be planned such that nearly no individual's intake falls outside of a range of a DG where possible. It is also important to consider the existence and degree of other nutrition- and non-nutrition-related factors in lifestyle-related diseases; the sustainability of a menu plan over a long period, as prevention of lifestyle-related diseases is a life-long endeavor; and the fact that a DRI is not a standard of nutrient provision but rather of nutrient intake, which requires flexibility in its use.

3-5. Supplementary note regarding dietary planning. As required energy and nutrient intakes differ among groups when individuals are classified into more than one group according to sex, age group, and PAL, preparation of a specific menu for each group is desirable. If doing so is difficult, the method described here may be used as a practical alternative. The EER is calculated based on sex, age group, and PAL. When there is more than one EER for a number of groups, they are grouped together such that one EER may be used as a representative value for these groups, such as when the difference in energy requirement among several groups is within a range of 200 kcal/d. When doing so, the energy intake of each individual should preferably be within ±10% of the EER.

In order of increasing priority, dietary planning of should be conducted as follows: planning for (1) energy; (2) protein, with attention to prevention of deficiency; (3) fat; (4) vitamins A, B_1, B_2, and C; calcium; and iron; (5) saturated fatty acid, dietary fiber, sodium (salt), and potassium; and (*6*) other nutrients considered important for a particular group.

Closing Comments

The DRIs-J 2010 is not merely a scientific report describing the intake of energy and nutrients necessary for prevention of deficiency/insufficiency and excess but also a source of practical guidelines in planning for dietary improvement in general and in food services by dietitians and other health professionals. Reliable and comprehensive data regarding energy and nutrient intakes obtained by evaluation of representative samples of the Japanese population have been indispensable in both determining DRI values and establishing methods for their application. Nevertheless, compared to research into determination of the intake of energy and nutrients in the DRIs, research into application of the DRIs has been extremely scarce in Japan, limiting the availability of data and raising questions concerning its quality (*35*). Due to lack of evidence, current application of the DRIs is conceptual rather than scientific and practical. Highly scientific research into application of the DRIs is thus urgently needed.

REFERENCES

1) Food and Nutrition Board, Institute of Medicine. 2001. Dietary Reference Intakes: Applications in Dietary Assessment (Dietary Reference Intakes). National Academies Press, Washington DC.

2) Barr SI. 2006. Applications of Dietary Reference Intakes in dietary assessment and planning. *Appl Physiol Nutr Metab* **31**: 66–73.

3) Beaton GH. 2006. When is an individual versus a member of a group? An issue in the application of the dietary reference intakes. *Nutr Rev* **64**: 211–225.

4) Ozeki O, Ebisawa L, Ichikawa M, Nagasawa N, Sato F, Fujita Y. 2000. Physical activities and energy expenditures of institutionalized Japanese elderly women. *J Nutr Sci Vitaminol* **46**: 188–192.

5) Gaillard C, Alix E, Sallé A, Berrut G, Ritz P. 2007. Energy requirements in frail elderly people: a review of the literature. *Clin Nutr* **26**: 16–24.

6) Bertoli S, Battezzati A, Merati G, Margonato V, Maggioni M, Testolin G, Veicsteinas A. 2006. Nutritional status and dietary patterns in disabled people. *Nutr Metab Cardiovasc Dis* **16**: 100–112.

7) Katsura E. 1954. Clinical presentation of experiment of vitamin B_1 deficiency in human. *Vitamin* **7**: 708–713 (in Japanese).

8) Intersalt Cooperative Research Group. 1988. Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion. *BMJ* **297**: 319–328.

9) Tokudome Y, Imaeda N, Nagaya T, Ikeda M, Fujiwara N, Sato J, Kuriki K, Kikuchi S, Maki S, Tokudome S. 2002. Daily, weekly, seasonal, within- and between-individual variation in nutrient intake according to four season consecutive 7 day weighed diet records in Japanese female dietitians. *J Epidemiol* **12**: 85–92.

10) Nelson M, Black AE, Morris JA, Cole TJ. 1989. Between- and within-subject variation in nutrient intake from infancy to old age: estimating the number of days required to rank dietary intakes with desired precision. *Am J Clin Nutr* **50**: 155–167.

11) Ogawa K, Tsubono Y, Nishino Y, Watanabe Y, Ohkubo T, Watanabe T, Nakatsuka H, Takahashi N, Kawamura M, Tsuji I, Hisamichi S. 1999. Inter- and intra-individual variation of food and nutrient consumption in a rural Japanese population. *Eur J Clin Nutr* **52**: 781–785.

12) Egami I, Wakai K, Kaitoh K, Kawamura T, Tamakoshi A, Lin Y, Nakayama T, Sugimoto K, Ohno Y. 1999. Intra- and inter-individual variations in diets of the middle-aged and the elderly. *Nippon Koshu Eisei Zasshi* **46**: 828–837 (in Japanese with English summary).

13) Harris JA, Benedict FG. 1919. A Biometric Study of Basal Metabolism in Man. Publication No. 279. Carneric Institute of Washington, Washington DC.

14) FAO/WHO/UNU. 1985. Energy and protein requirements. Report of a joint FAO/WHO/UNU expert consultation. Technical Report Series, No. 724. WHO, Geneva.

15) Ganpule AA, Tanaka S, Ishikawa-Takata K, Tabata I. 2007. Interindividual variability in sleeping metabolic rate in Japanese subjects. *Eur J Clin Nutr* **61**: 1256–1261.

16) Case KO, Brahler CJ, Heiss C. 1997. Resting energy expenditures in Asian women measured by indirect calorimetry are lower than expenditures calculated from prediction equations. *J Am Diet Assoc* **97**: 1288–1292.

17) Yamamura C, Kashiwazaki H. 2002. Factors affecting the post-absorptive resting metabolic rate of Japanese subjects: reanalysis based on published data. *Eiyogaku Zasshi (Jpn J Nutr Diet)* **60**: 75–83 (in Japanese).

18) Brooks GA, Butte NF, Rand WM, Flatt JP, Caballero B. 2004. Chronicle of the Institute of Medicine physical activity recommendation: how a physical activity recommendation came to be among dietary recommendations. *Am J Clin Nutr* **79** (Suppl): 921S–930S.

19) Japanese Society of Hypertension. 2006. Japanese Society of Hypertension guidelines for the management of hypertension (JSH 2004). *Hypertens Res* **29** (Suppl): S1–105.

20) Okubo H, Sasaki S, Hirota N, Notsu A, Todoriki H, Miura A, Fukui M, Date C. 2006. The influence of age and body mass index on relative accuracy of energy intake among Japanese adults. *Public Health Nutr* **9**: 651–657.

21) Livesey G, Elia M. 1988. Estimation of energy expenditure, net carbohydrate utilization, and net fat oxidation and synthesis by indirect calorimetry: evaluation of errors with special reference to the detailed composition of fuels. *Am J Clin Nutr* **47**: 608–628.

22) Forbes GB. 1987. Influence of nutrition. *In*: Human Body Composition. Growth, Aging, Nutrition, and Activity, p 209–247. Springer-Verlag, New York.

23) Zhang J, Temme EH, Sasaki S, Kesteloot H. 2000. Under -and overreporting of energy intake using urinary cations as biomarkers: relation to body mass index. *Am J Epidemiol* **152**: 453–462.

24) Murakami K, Sasaki S, Takahashi Y, Uenishi K, Yamasaki M, Hayabuchi H, Goda T, Oka J, Baba K, Ohki K, Kohri T, Watanabe R, Sugiyama Y. 2008. Misreporting of dietary energy, protein, otassium and sodium in relation to body mass index in young Japanese women. *Eur J Clin Nutr* **62**: 111–118.

25) Ishiwaki A, Yokoyama T, Fujii H, Saito K, Nozue M, Yoshita K, Yoshiike N. 2007. A statistical approach for estimating the distribution of usual dietary intake to assess nutritionally at-risk populations based on the new Japanese Dietary Reference Intakes (DRIs). *J Nutr Sci Vitaminol* **53**: 337–344.

26) Sasaki S, Takahashi T, Iitoi Y, Iwase Y, Kobayashi M, Ishihara J, Akabane M, Tsugane S; JPHC. 2003. Food and nutrient intakes assessed with dietary records for the validation study of a self-administered food frequency questionnaire in JPHC Study Cohort I. *J Epidemiol* **13** (Suppl 1): S23–50.

27) Ministry of Education, Culture, Sports, Science and Technology, Japan. 2005. Report of the Subdivision on Resources. The Council for Science and Technology: Standard Tables of Food Composition in Japan, 5th revised and enlarged ed. Tokyo (in Japanese).

28) Miller WC, Koceja DM, Hamilton EJ. 1997. A meta-analysis of the past 25 years of weight loss research using diet, exercise of diet plus exercise intervention. *Int J Obes* **21**: 941–947.

29) Food and Nutrition Board, Institute of Medicine. 2001. Iron. *In*: Dietary Reference Intakes: For Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc (Institute of Medicine, ed), p 290–393. National Academies Press, Washington DC.

30) Asakura K, Sasaki S, Murakami K, Takahashi Y, Uenishi K, Yamakawa M, Nishiwaki Y, Kikuchi Y, Takebayashi T; Japan Dietetic Students' Study for Nutrition and Biomarkers Group. 2009. Iron intake does not significantly correlate with iron deficiency among young Japanese women: a cross-sectional study. *Public Health Nutr* **12**: 1373–1383.

31) Barr SI, Murphy SP, Agurs-Collins TD, Poos MI. 2003. Planning diets for individuals using the dietary reference intakes. *Nutr Rev* **61**: 352–360.

32) Japan Society for the Study of Obesity. 2006. Guidelines for the Treatment of Obesity 2006. *Journal of Japan Society for the Study of Obesity* **12**: 1–91 (in Japanese).

33) Murphy SP, Barr SI. 2005. Challenges in using the dietary reference intakes to plan diets for groups. *Nutr Rev* **63**: 267–271.

34) Buzzard M. 1998. 24-hour dietary recall and food record methods. *In*: Nutritional Epidemiology (Willett W, ed), 2nd ed, p 50–73. Oxford University Press, New York.

35) Sasaki S. 2011. The value of the National Health and Nutrition Survey in Japan. *Lancet* **378** (9798): 1205–1206.

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Dietary Reference Intakes for Japanese 2010: Energy

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Summary For energy of Dietary Reference Intakes for Japanese (DRIs-J), the concept of Estimated Energy Requirement (EER) is applied. The EER has been established as an index for individuals and groups. The definition of EER for individuals is "habitual energy intake in a day which is predicted to have the highest probability that energy balance (energy intake−energy expenditure, in adults) becomes zero in an individual of a given age, gender, height, body weight, and level of physical activity in good health." In contrast, the definition of EER for a group is "habitual energy intake in a day which is predicted to have the highest probability that energy balance (energy intake−energy expenditure, in adults) becomes zero in a group." The EER is calculated as follows: EER (kcal/d)=basal metabolic rate (BMR) (kcal/d)×physical activity level (PAL). Representative values for BMR per kg body weight are determined based on a number of reports for Japanese. This is called the reference value of BMR (reference BMR). Total energy expenditure measured by the doubly labeled water (DLW) method is utilized to determine PAL for each sex and age group. For adults, physical activity levels are determined based on data for Japanese adults. For children, energy deposition is added to the total energy expenditure. For pregnant and lactating women, additional values compared to EER before pregnancy for each stage of pregnancy and during lactation are calculated. Excess post-exercise oxygen consumption is not added to calculate EER in addition to energy expenditure during physical activity.

Key Words estimated energy expenditure (EER), total energy expenditure, basal metabolic rate (BMR), physical activity level (PAL), doubly labeled water method

Background Information

Daily energy expenditure (total energy expenditure) consists of basal metabolic rate (BMR), physical activity energy expenditure, and thermic effect of food (diet-induced thermogenesis). In children and infants, the need for additional energy for growth also requires determination of not only the energy necessary for meeting daily needs but also the energy necessary for increased tissue for growth (energy deposition) and the energy necessary for tissue formation. Of the two forms of energy required for growth, only energy for tissue formation is currently included in determination of total energy expenditure for children and infants. Therefore, to determine energy requirement, energy deposition needs to be added to total energy expenditure. Determining the energy requirement for pregnant women requires determination of the energy expenditure of the fetus and the energy necessary for the growth of fetal tissues. Determining the energy requirement for lactating women requires determination of the energy required to produce breast milk and consideration of weight loss corresponding to breast milk production. Therefore, increased or decreased energy requirements corresponding to an increase or decrease in tissue growth must be considered in addition to total energy expenditure, as reflected in the formula used to calculate energy requirements:

Energy requirement
=total energy expenditure+energy for the increased or decreased tissue.

For adults undergoing no body weight change, no

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Table 1. Basal metabolic rate of the Japanese population.

Sex	Males			Females		
Age	Reference BMR (kcal/kg weight/d)	Reference weight (kg)	BMR (kcal/d)	Reference BMR (kcal/kg weight/d)	Reference weight (kg)	BMR (kcal/d)
1–2 y	61.0	11.7	710	59.7	11.0	660
3–5 y	54.8	16.2	890	52.2	16.2	850
6–7 y	44.3	22.0	980	41.9	22.0	920
8–9 y	40.8	27.5	1,120	38.3	27.2	1,040
10–11 y	37.4	35.5	1,330	34.8	34.5	1,200
12–14 y	31.0	48.0	1,490	29.6	46.0	1,360
15–17 y	27.0	58.4	1,580	25.3	50.6	1,280
18–29 y	24.0	63.0	1,510	22.1	50.6	1,120
30–49 y	22.3	68.5	1,530	21.7	53.0	1,150
50–69 y	21.5	65.0	1,400	20.7	53.6	1,110
≥70 y	21.5	59.7	1,280	20.7	49.0	1,010

BMR, basal metabolic rate.

additional energy is required above that for meeting daily needs. Therefore, when energy intake exceeds energy requirements, the unutilized energy substrate is accumulated mainly in adipose tissue as triglycerides. An increase in adipose tissue may increase body weight and body fat in the short term and lead to obesity, a risk factor for many lifestyle-related diseases and increased total mortality, in the long term. In contrast, an energy intake less than that of energy expenditure may cause a decrease in the amount of accumulated fat in adipose tissues and in the amount of body protein, such as that contained in muscle tissue; a decrease in bodily functioning and quality of life; and an increase in morbidity due to infectious disease and certain cancers as well as in total mortality. Therefore, the optimal energy intake of adults—their true energy requirement—is that equal to the amount of energy expended when they are at an appropriate body weight.

Determining DRI

Estimated energy requirement

1. Definition of estimated energy requirement

In the determination of the Dietary Reference Intakes for Japanese (DRIs-J) for energy, the concept of estimated energy requirement (EER) was applied in the same way as it had been in determining the DRIs for the United States and Canada (*1, 2*). The EER is established for individuals and groups; the EER for individuals is defined as "habitual energy intake in a day which is predicted to have the highest probability that energy balance (energy intake−energy expenditure, in adults) becomes zero in an individual of a given age, sex, height, body weight, and level of physical activity in good health."

When the energy intake of an individual is the same as the EER, the probability of inadequate intake—that the individual's energy intake is below his/her true energy requirement—is 50% and the probability of excessive intake is 50%. For many nutrients, the probability of adequate energy intake decreases as energy intake decreases, and the probability of adequate energy intake increases as intake increases while remaining sufficiently below the UL. However, the probability of inadequate energy balance increases equally whether intake is below or above the EER. That is, the probability of weight gain increases when an individual's energy intake is above the EER and the probability of weight loss increases when the individual's energy intake is below the EER. For this reason, the DRI concepts used for determination of other nutrients cannot be applied to determination of energy requirements.

In contrast to that for individuals, the EER for a group is defined as "habitual energy intake in a day which is predicted to have the highest probability that energy balance (energy intake−energy expenditure, in adults) becomes zero in a group." When the energy intake of a defined group is the same as the EER, the probability that the energy intake is below a group member's true energy requirement is 50% and probability that the energy intake is above the requirement is 50%. The components with great impact on total energy expenditure are BMR and energy expenditure for physical activities. Therefore, determination of an accurate EER requires determination of the defined individuals' or groups' BMR and the amount of physical activity.

2. Basal metabolic rate

As shown in Table 1, BMR in kcal/d is calculated as follows:

BMR (kcal/d)
=Reference BMR (kcal/kg body weight/d)×reference body weight (kg).

BMR is measured early in the morning while resting in the supine position in a comfortable indoor environment at a comfortable room temperature. The reference BMR is based on the reference BMR reported in the 2005 DRIs-J as well as the BMR values that have been reported by several studies conducted since 1980 (*3–15*).

3. Physical activity level

Physical activity level (PAL) is an index of level of physical activity that considers diet-induced thermogenesis, also. PAL is calculated as total energy expenditure divided by BMR (*16–18*), as shown in the following

Table 2. BMI and PAL at each physical activity level (mean±SD).

PAL (range)	n	Sex ratio (% male)	Age (y)	BMI (kg/m^2)	PAL
Level I (<1.6)	38	55	40±11	23.9±2.5	1.50±0.08
Level II (≥1.6, ≤1.9)	65	52	39±11	22.8±3.1	1.74±0.08
Level III (>1.9)	36	39	40±9	21.3±2.6	2.03±0.13
Total	139	50	39±10	22.7±2.9	1.75±0.22

n, number of subjects; BMI, body mass index; PAL, physical activity level.

formula:

PAL=total energy expenditure (kcal/d)/BMR(kcal/d).

The doubly labeled water (DLW) method, the most accurate method for measuring total energy expenditure that was employed in determining the DRIs of the United States and Canada, was utilized to determine the PAL for each sex and age group. Considering the range of inter-individual variability in energy expenditure based on individual characteristics and evidence, a number of PALs were established to calculate a more accurate EER.

4. Calculation of EER

Using PALs obtained from daily total energy expenditure of Japanese measured using the DLW method (*19*), the EER is calculated as follows:

EER (kcal/d)=BMR (kcal/d)×PAL.

For children, pregnant women, and lactating women, energy deposition is added to the EER to account for increased tissue due to growth, the products of conception and accretion of maternal tissues, and the energy costs corresponding to postpartum lactation and weight change, respectively.

5. Adults

In a study aimed at determining the PAL of Japanese adults (*n*=139, aged 20 to 59 y) (*19*), the subjects were divided into 3 groups using the 25th and 75th percentile values (1.60 and 1.90, respectively; Table 2). Based on the results of the stratification, the groups were labeled according to activity level as Level I (low activity level, representative value=1.50), Level II (moderate activity level, representative value=1.75), and Level III (high activity level, representative value=2.00). According to this classification, the ratio of individuals allocated to each level could be roughly expressed as 1 : 2 : 1. As shown in Table 2, the mean±standard deviation (SD) for the PAL of all subjects was 1.75±0.22. The representative value (or mean) for Level I generally corresponds to the value (mean−1×SD) for the entire group and the representative value (or mean) for Level III to the value of (mean+1×SD).

According to the results of studies of total energy expenditure and PAL of the Japanese using the DLW method (*19–33*), the use of these 3 levels appears appropriate.

6. The elderly

Among the many studies that have attempted to determine the PAL of healthy, independently living elderly subjects (*33–42*), the mean value was 1.69, leading the reference PAL for elderly subjects to be set as 1.70. However, the subjects' mean age in most of these reports (11 out of 13) ranged from 70 to 75 y, and many examined only relatively healthy independently living elderly subjects. These facts, as well as the fact that few studies have examined the average PAL of subjects in their 90 s, makes it difficult to identify reference PALs for the elderly over 70 y. One report (*43*) found that the PAL of subjects in their 90 s tends to be low.

7. Children

Children in the growth stage require energy not only for physical activity but also for tissue formation and increased tissue (energy deposition). As the energy used for tissue formation is included in the calculation of total energy expenditure, the EER (kcal/d) was calculated as follows:

EER (kcal/d)=BMR (kcal/d)×PAL+energy deposition (kcal/d).

As PALs differ by age group, a systematic review was conducted of reports of children's PALs using the DLW method. Values of PAL were determined based on reports with measured BMR data (*44–66*). For children younger than 5 for whom such data were unavailable, PAL values were also based on estimated BMR (*31, 67–74*). The mean PAL was found to be 1.36, 1.47, 1.57, 1.59, 1.63, 1.66, and 1.76 for ages 1 to 2 y, 3 to 5 y, 6 to 7 y, 8 to 9 y, 10 to 11 y, 12 to 14 y, and 15 to 17 y, respectively, showing a tendency to increase with age (Fig. 1). The Grouping of PALs at each age group is shown in Table 3. The similar tendency was observed in a systematic review (*75*).

Although individual variability was observed for ages 1 to 2 y and ages 3 to 5 y, the PALs for these groups were not categorized into levels due to the lack of data for categorizing PAL for individuals or groups. In contrast, the PALs for those aged 6 and over were categorized into 3 levels to consider individual variability. The means of the standard deviation of selected references weighted by the number of subjects based on age group differed in the range 0.17 to 0.25, with a mean value of 0.21. Therefore, the PAL in each age group of children was increased or decreased by 0.20 from the corresponding group's "moderate" value. As there were no data regarding PAL for these age groups in Japan, Level I (low) was established for school-age children for the first time, with consideration of the wide variations in PAL reported in previous studies conducted in foreign countries. In the future, the status and determinants of the PALs of Japanese school-age children need to be studied.

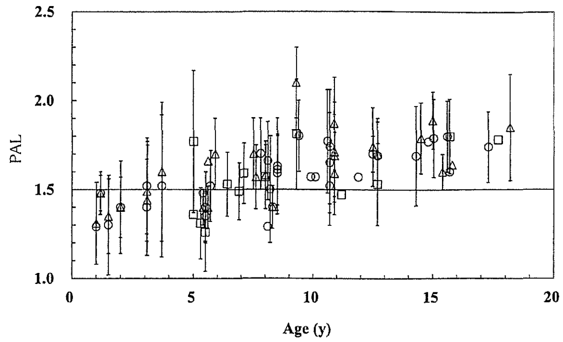

Fig. 1. PAL of children. The data presented for all age groups were taken only from studies that measured basal metabolic rate except for those for children aged 3 to 5 y, for whom data were also taken from studies that estimated basal metabolic rate, and children aged 1 to 2 y, for whom data were also taken from studies that measured sleeping metabolic rate and estimated basal metabolic rate, due to the lack of studies for these age groups. △, boys; ○, girls; □, boys and girls; mean±SD. PAL: physical activity level.

Energy for increased tissue was determined as the product of increased weight per day calculated from the reference weight and the energy density of increased tissue (*1*) (refer to Table 4 for details).

8. Infants

For infants, as for older children, energy is required for not only physical activity but also tissue formation and energy deposition. As the energy required for tissue formation is included in total energy expenditure, the EER was calculated as follows:

EER (kcal/d)

=total energy expenditure (kcal/d)+energy deposition (kcal/d).

For determining the total energy expenditure of infants, the Food and Agricultural Organization (FAO), World Health Organization (WHO), and United Nations University (UNU) have reported that total energy expenditure of breast-fed infants can be modeled by the following regression equation, which uses body weight as an independent variable and considering the relationships among sex, age (months), body weight, body height, and total energy that were identified in previous studies (*76, 77*):

Total energy expenditure (kcal/d)

=92.8×reference weight (kg)−152.0.

As no study has determined Japanese infants' total energy expenditure using the DLW method, total energy expenditure was determined by substituting the reference weights of the Japanese into the regression equation. As with children, energy deposition is calculated as the product of increased weight per day as calculated using the reference weight and energy density of increased tissue for infants (*67*) (Table 4).

The EER is determined for infants at 3 different ages: 0 to 5 mo, 6 to 8 mo, and 9 to 11 mo. For infants aged 0 to 5 mo who undergo large weight changes, attention must be placed on the large difference in the EER between the first and second half of this period. As formula-fed infants typically have greater total energy expenditure than breast-fed infants (*76*), the FAO, WHO, and UNU have reported that the EER of formula-fed infants should be determined using the following regression equation (*76, 77*).

Total energy expenditure (kcal/d)

=82.6×body weight (kg)−29.0.

9. Additional values for pregnant women

The EER of pregnant women is calculated as follows:

EER (kcal/d)

=EER before pregnancy (kcal/d)+additional energy required by pregnant women (kcal/d).

Considering that the female reproductive period encompasses several age groups, it is necessary to determine the additional amounts of energy needed to maintain good health during pregnancy and for normal delivery for each stage of pregnancy. Longitudinal studies using the DLW method found that although PAL decreases during the early and late stage of pregnancy, increased rates of total energy expenditure during the early, mid, and late stage of pregnancy correspond to increased rates of weight gain, as does an increase in BMR during the late stage of pregnancy (*76–82*). Therefore, differences between pre-pregnancy EER and total energy expenditure during each stage (*76, 77*) adjusted by an average total weight gain of 11 kg during pregnancy (*83*) are as follows: +19 kcal/d during the early stage, +77 kcal/d during the mid-stage, and +285 kcal/d during the late stage. Total energy deposition is calculated as the sum of energy deposition of protein and fat that yields a final weight gain of 11 kg, based on protein deposition and body fat deposition on a per-stage basis (*76, 77*). Thus, energy deposition is 44 kcal/d during the early stage, 167 kcal/d during the mid-stage, and 170 kcal/d during the late stage.

As a result, total additional energy for each stage is calculated as follows:

Additional energy for pregnant women (kcal/d)

Table 3. PAL by physical activity level of each age group of both males and females.

PAL	Level I (low)	Level II (moderate)	Level III (high)
1–2 y	—	1.35	—
3–5 y	—	1.45	—
6–7 y	1.35	1.55	1.75
8–9 y	1.40	1.60	1.80
10–11 y	1.45	1.65	1.85
12–14 y	1.45	1.65	1.85
15–17 y	1.55	1.75	1.95
18–29 y	1.50	1.75	2.00
30–49 y	1.50	1.75	2.00
50–69 y	1.50	1.75	2.00
≥70 y	1.45	1.70	1.95

PAL: physical activity level.