Physical Activities and Energy Expenditures of Institutionalized Japanese Elderly Women

Tomoko OZEKI,^{1,*} Hidemichi EBISAWA,¹ Mineko ICHIKAWA,¹ Nobue NAGASAWA,²
Fumiyo SATO³ and Yoshiaki FUJITA^{1,4}

¹ Department of Nutrition, Tokyo Metropolitan Institute of Gerontology,
Itabashi-ku, Tokyo 173-0015, Japan

² Division of Food and Nutrition, Nagoya Women's College,
Nagoya 467-0003, Japan

³ Division of Nutrition, Jumonji Women's College,
Niiza, Saitama 352-0017, Japan

⁴ Department of Clinical Nutrition, Kawasaki University of Medical Welfare,
Kurashiki, Okayama 701-0193, Japan

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Summary The daily energy expenditure and physical activity index of institutionalized Japanese elderly women were measured. One hundred and thirteen Japanese elderly women (aged 79.5 ± 7.0 y) who live in institutions for the elderly and receive meal services participated voluntarily. A dietary survey, energy metabolic study, and time study were carried out over three consecutive days, and the basal metabolic rate (BMR) and energy expenditure by physical activity were measured. The intensity of daily physical activity was based on the physical activity index (PAI: total/basal energy expenditure). The mean BMR was 881 ± 145 kcal/d (20.9 ± 3.8 kcal/kg BW). The PAI in individuals ranged from 1.01 to 1.57, the mean value was 1.26 ± 0.14 , and 64% of the subjects examined showed a lower value than 1.3 of PAI. From these values, the mean total energy expenditure was calculated as $1,112 \pm 231$ kcal/d (26.2 ± 5.2 kcal/kg BW).

Key Words energy expenditure, institutionalized elderly women, basal metabolic rate, physical activity index

According to the Japanese abridged life tables for 1998 of the Ministry of Health and Welfare, the life expectancy at birth is 77.16 y for males and 84.01 y for females, and the percentage of the elderly population in Japanese society has been rapidly increasing. Among the aged population, elderly individuals who take an active part in their communities or households usually have good nutritional status (1). In contrast, most inactive elderly persons, especially those who live in institutions for the elderly, suffer from malnutrition (2, 3).

In general, the meals in facilities for the elderly are based on the Recommended Dietary Allowances (RDA). In the current RDAs in Japan (4), energy requirements have been expressed as functions of the basal metabolism and physical activity. Moreover, since the RDAs are basically established for healthy and self-supporting people, they include uncertain tables for the energy requirements of inactive and/or frail elderly persons who habitually spend many hours a day either sitting or lying in nursing homes or hospitals. Therefore if meals for very sedentary and frail elderly persons were prepared to provide the same amount of energy as for healthy persons, the meals must include more energy than required for actual energy expenditure in their daily living. Specifically, an increase in remaining foods

results not only in wasted expenses incurred for meal services, but also in the insufficient intake of essential nutrients besides energy. Therefore it is important for adequate meal services in institutions to clarify daily physical activity and energy expenditure of their residents, as well as those of healthy and self-supporting elderly persons. But unfortunately few reports are available on the actual circumstances of the daily lives and the energy expenditures of institutionalized Japanese elderly besides two reports that measured small groups (5, 6). The purpose of this study is therefore to clarify the actual situation of daily physical activities and the energy expenditure of institutionalized Japanese elderly people.

SUBJECTS AND METHODS

Subjects. From among elderly female volunteers living in institutions for the elderly with meal services who had no abnormalities in preliminary urinary tests for sugar, protein, ketone body and urobilinogen and who have not been taking any special dietary therapy, 113 persons (27 living in nursing homes, 51 living in homes for the elderly, and 35 living in homes for the elderly with moderate fees) were randomly selected as subjects for this study. Most subjects living in nursing homes needed some support for their daily living, though all could ingest foods orally. Before the test, we provided a full explanation to the subjects of the aims,

* To whom correspondence should be addressed.
E-mail: ozeki@tmig.or.jp

design, and procedures of this examination. Throughout the examination, all subjects went about their usual daily lives. This study was carried out under the approval of the ethical committee of our institute.

Dietary survey and metabolic study. All foods given were weighed beforehand, and the food remaining after each meal was also weighed for three consecutive days, excluding holidays. Simultaneously, the amount of snack foods ingested privately during the test period was also recorded in detail through an interview. On the basis of the net weights of foods eaten by subjects, nutrient intake was calculated based on the most recent standard food tables for Japan (7, 8).

To roughly estimate skeletal muscle mass, we measured 24-h urinary creatinine excretions in parallel with the dietary survey.

The basal metabolic rate (BMR) was measured with a portable metabolic monitoring system (Datax, Deltatrac MBM-100 metabolic monitor, Finland) (9, 10) in the early morning after an overnight fast. The subjects were placed under a canopy while resting in bed for the entire measurement period of 30 min. Subjects were able to breathe more naturally under the canopy than when using a mask or mouthpiece (11). The measurements of their oxygen consumption and carbon dioxide production were made at 1-min intervals during spontaneous breathing by sucking air through a canopy at a constant rate. When these reached a stable plateau (usually, 10 min after covering above the neck with a canopy), the subject's state was regarded as steady and the average of the last 20 min values was calculated as available data. Before measuring each subject, the equipment was calibrated by using standard gases consisting of 95% oxygen and 5% carbon dioxide; the precision was then reconfirmed by analyzing the fresh air in the room.

Time study. To determine the "physical activity index (PAI)" and the energy expenditure by physical activity in daily living, in parallel with the dietary survey, the subjects were monitored by an investigator from the time they arose in the morning until the time they retired at night, and behavior and activities for 24 h were recorded in detail. Activities such as urination at night were recorded through an interview the next morning.

The following equation was used to obtain the total daily energy expenditure (4).

Total energy expenditure=BMR×PAI

PAI=∑(Af×T/1,440)

Af: activity factor for individual activities
T: time for individual activities (min)

Statistics. Results are given as mean±SD. Relations between variables were analyzed by calculating Pearson correlation coefficients, with statistical significance level at $p<0.05$.

RESULTS

Physical characteristics

The mean age, height, body weight, body mass index (BMI), and creatinine excretion of the subjects are shown in Table 1. Compared to mean values for the sex and age groups of reference persons in the year 2000 in Japan (4), the mean height and weight of our subjects were slightly lower. However, it seems that our subjects were representative of elderly Japanese.

Basal metabolic rate (BMR), daily physical activity, and energy balance

The results are summarized in Table 2. The mean BMR was 881 ± 145 kcal/d (20.9 ± 3.8 kcal/kg BW).

When daily living activities examined by the time

Table 1. Mean age, height, body weight, BMI, and urinary creatinine excretion of subjects.

	RDA ¹	Subjects
<i>n</i>		113
Age (y)	≥70	79.5±7.0 ² (62–94)
Height (cm)	145.6	144.0±6.5 (127.0–161.0)
Body weight (kg)	48.7	43.1±8.5 (28.0–63.0)
BMI ³	23.0	20.8±3.7 (12.0–29.6)
Cr ⁴ (mg/d)		509±116 (225–729)

¹ Reference values by sex and age group in the current RDAs for Japan (4).
² Mean±SD. Values in parentheses indicate ranges.
³ Body mass index: body weight (kg)/height (m)².
⁴ Urinary creatinine excretion.

Table 2. Mean intake, expenditure, and balance of energy in Japanese institutionalized elderly women.

	<i>n</i>	Dietary intake ¹	Basal metabolism	Total expenditures	Balance
kcal/d					
RDA ²			1,010	1,300	
Subjects	113	1,412±310 ³ (717–2,322)	881±145 (568–1,360)	1,112±231 (578–1,755)	+300±254 (–369–+1,082)
kcal/kg BW					
RDA			20.7		
Subjects	113	33.4±7.6 (17.9–55.6)	20.9±3.8 (14.8–34.7)	26.2±5.2 (15.1–46.7)	+7.2±6.0 (–7.5–+26.1)

¹ Total amounts from institutional meals and snack foods ingested privately.
² Reference values by sex and age group in the current RDAs for Japan (4).
³ Mean±SD. Values in parentheses indicate ranges.

Fig. 1. Mean time distribution for representative daily living activities in the 113 elderly females examined. Daily living behavior was classified into four categories: resting, standing, walking, and walking fast. The RDA model shows an example given as a model for "low level" in the current RDAs in Japan (4).

Fig. 2. Frequency distribution of daily activity factors for residents living in nursing homes or homes for the elderly. The physical activity index for individuals was calculated on the basis of the results of the time study.

study were broadly classified into four categories according to the current RDAs (4) in individuals—resting, standing, walking, and walking fast—the mean times were 1,078 min (74.9% of 24 h), 224 min (15.5%), 80 min (5.6%), and 58 min (4.0%), respectively (Fig. 1). The calculated PAI distributed in the range of 1.01 to 1.57 (Fig. 2) and the mean value was 1.26 ± 0.14 . From these values, the mean total energy expenditure was calculated as $1,112 \pm 231$ kcal/d (26.2 ± 5.2 kcal/kg BW), and the mean energy expenditure by physical activity was calculated as 231 ± 131 kcal/d (5.3 ± 2.9 kcal/kg BW).

Subjects ingested $1,149 \pm 270$ kcal/d from meals served, and 263 ± 235 kcal/d from snack foods ingested privately, resulting in $1,412 \pm 310$ kcal/d for the mean total energy intake. From these values, the mean energy balance was calculated to be $+300 \pm 254$ kcal/d ($+7.2 \pm 6.0$ kcal/kg BW), with 8% of subjects having a slightly negative energy balance.

As shown in Fig. 3, there was a significantly positive correlation between PAI and total daily energy expenditure (y : kcal/kg of the ideal body weight [IBW]), and the

Fig. 3. Correlation between total daily energy expenditure (y : kcal/kg IBW) and PAI (x) in institutionalized elderly women. The regression equation was calculated as follows: $\hat{y} = 19.083x + 0.323$ (n : 113, r : $+0.591$, $p < 0.001$), where $\hat{y}$ is the expected energy expenditure. The standard deviation of y from $\hat{y}$ (SD) was calculated as 3.673.

regression equation was calculated as follows: $\hat{y} = 19.083x + 0.323$ (n : 113, r : $+0.591$, $p < 0.001$). Standard deviation (SD) of total daily energy expenditure from the expected values based on the regression equation was calculated as 3.673. Based on the regression equation and the obtained SD, the total energy expenditures (expected mean $\pm$ SD) of inactive elderly persons with 1.00 and 1.30 PAI were estimated as 19.4 ± 3.7 and 25.1 ± 3.7 kcal/kg IBW, respectively.

DISCUSSION

With the development of automation and motorization in our daily lives and changes in living environments, the BMR of the Japanese people, including elderly persons, has gradually decreased (12). Moreover, age-related changes in body composition, especially increased body fat and/or decreased lean body mass, are related to decreased BMR in later life (13, 14). Furthermore, the resting metabolic rate per unit of fat-free mass was lower in the old than the young (15–18). The BMR by body weight in the present study concurred with the corresponding values by sex and age groups in the current RDAs in Japan (4), with the values for institutionalized Japanese elderly women reported (5, 6), and with the estimated values by the Harris-Benedict formula. When the BMR was expressed as the basis of urinary creatinine, however, which roughly indicates skeletal muscle mass, it was 1.4 times higher than the value for American elderly women (19). One possible explanation for this difference may be that urinary creatinine excretion in our subjects was only 11.8 mg/kg BW, and this value was much less than that of American elderly people (19). This causes speculation that age-related decrease in skeletal muscle mass is remarkable in our subjects, as compared with elderly American people.

In general, energy requirements have been expressed as the functions of the basal metabolism and physical activity. The report of a joint FAO/WHO/UNU Expert Consultation (20) has recommended that the average

daily energy requirement for healthy elderly persons might be approximated at 1.55 to 1.75 times the BMR. Young (21) also indicated the energy requirement to be 1.75 times the BMR for healthy elderly men. The lowest PAI (“very light”) in the current RDAs in the United States (22) is 1.56. On the other hand, in the current RDAs in Japan the PAI is classified into four graded levels: Low (1.3), slightly low (1.5), adequate (1.7), and high (1.9). The division of PAI in the current RDAs in Japan is a lower range than in other reports (20–22). Nevertheless, the mean PAI of all 113 elderly subjects in this study was calculated to be 1.26 ± 0.14 . This mean value was almost the same as the “low level” in the current RDAs in Japan. It was noticed, however, that about 64% of our subjects, including almost all the nursing home residents, showed a lower PAI than 1.3, that is, the lowest activity level in the current RDAs in Japan. This is because total resting time (18 h) in daily living activities of our subjects was much longer than that given as a model in the current RDAs in Japan (12 h) (4). The current RDAs have recommended that energy expenditure should be increased to an adequate level by changing lifestyles and/or by exercising and participating in sports in leisure time (4). But these recommendations seem to be impractical for frail elderly persons who are almost bedridden in nursing homes. A strong need exists for physical activity programs for such frail elderly persons.

The expected mean energy expenditure corresponding to 1.3 PAI, estimated by regression analysis in this study, was 25.1 kcal/kg IBW, and the standard error of the mean (SE: $SD/\sqrt{n}$) was calculated as 0.35 kcal/kg IBW. The 95% upper confidence limit (mean + 2SE) was 25.8 kcal/kg IBW, and this was slightly lower than what it was (26.9 kcal/kg BW) for the corresponding PAI value in the current RDAs in Japan (4). This equation is not sufficient to conclude individual expectations, however, because SD (3.7) is much larger than the difference between RDA and the expected mean energy expenditure ($1.8 = 26.9 - 25.1$).

Moreover, the mean energy balance of our subjects was calculated to be +300 kcal/d. If this large positive energy balance continued, their body weight could increase progressively, but weight gains were not observed during the test period. In this study, total energy expenditure was calculated by the factorial method, using *Af* for respective activities, which was measured not in elderly persons, but also in healthy adults. Voorrips et al. (23) reported that energy expenditure at rest condition did not differ between elderly and middle-aged groups, but energy expenditure in walking was significantly higher in elderly women than in middle-aged women. Moreover, subjects with neuromuscular disease, who have progressive weakness and wasting of skeletal muscle as the frail elderly in this study, showed a higher energy cost for physical activity (24). This suggests that elderly persons need more energy for the same physical behavior compared with healthy adults.

Energy requirements in the current RDAs in Japan (4) have been expressed as the functions of basal metab-

Fig. 4. Correlation between PAI and cumulative hours in four living activities, respectively, in institutionalized elderly women. Regression lines for the subjects are as follows: (a) $PAI = -0.050x + 2.15$ ($n: 113$, $r: 0.844$, $p < 0.001$) (SD: 0.076); (b) $PAI = 0.040x + 1.11$ ($n: 113$, $r: 0.509$, $p < 0.001$) (SD: 0.122); (c) $PAI = 0.046x + 1.20$ ($n: 113$, $r: 0.263$, $p < 0.01$) (SD: 0.136); (d) $PAI = 0.131x + 1.13$ ($n: 113$, $r: 0.912$, $p < 0.001$) (SD: 0.058). SD: see legend of Fig. 3.

Table 3. The number of subjects by classified median PAI and each living activity.

a. Resting hours (n=113)		
	>18 h/d	≤18 h/d
PAI≤1.23	47 (41.6%)	8 (7.1%)
>1.23	12 (10.6%)	46 (40.7%)
Rate of concordance: 41.6 + 40.7 = 82.3 (%).		
b. Standing hours (n=113)		
	≤3 h/d	>3 h/d
PAI≤1.23	33 (29.2%)	22 (19.5%)
>1.23	17 (15.0%)	41 (36.3%)
Rate of concordance: 29.2 + 36.3 = 65.5 (%).		
c. Walking hours (n=113)		
	≤1 h/d	>1 h/d
PAI≤1.23	24 (21.2%)	31 (27.4%)
>1.23	13 (11.5%)	45 (39.8%)
Rate of concordance: 21.2 + 39.8 = 61.0 (%).		
d. Walking-fast hours (n=113)		
	≤0.5 h/d	>0.5 h/d
PAI≤1.23	44 (38.9%)	11 (9.7%)
>1.23	6 (5.3%)	52 (46.0%)
Rate of concordance: 38.9 + 46.0 = 84.9 (%).		

olism and physical activity. Therefore it is essential to estimate the levels of daily physical activity in inactive elderly persons. In this study, when the PAI was plotted against the respective total hours of resting, standing, walking, or walking-fast in daily living activities in individual subjects, there were significant correlations between the PAI and respective hours (Fig. 4). As shown in Table 3a, when the subjects were divided into four groups, the number of subjects low in PAI and long in resting hours was 46 (40.7% among total subjects of 113); those high in PAI and short in resting hours was 47 (41.6%). The rate of concordance was 82.3%. Similarly, the rate of concordance between the PAI and total walking-fast hours was calculated as 84.9% (Table 3d). The correlations of PAI and total resting hours or total walking-fast hours were much higher than those of the PAI and total standing or walking hours. They suggested that the total resting and/or total walking-fast hours were available for the estimation of PAI of inactive elderly persons.

CONCLUSION

The present study showed that 64% of institutionalized Japanese elderly women, almost all residents in the nursing home, have a lower PAI than the "low level" in the current RDAs in Japan. This is important to consider for adequate meal services in institutions for the elderly from the viewpoint of preventing malnutrition caused by an increase in remaining foods through an excess supply in dietary energy.

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