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Energy Expenditure in Normal-Weight and Overweight Korean Middle-Aged Women

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ABSTRACT

The purpose of this study was to compare the energy expenditure of normal-weight and overweight Korean middle-aged women (40 – 60 yr). Middle-aged overweight (BMI ≥ 25, n = 20) and normal-weight women (BMI ≤ 23, n = 20) were recruited in Seoul. Anthropometric measurements, body composition, energy intake, daily activity time, and energy costs of some daily activities were measured. Energy expenditure at rest and while reading the newspaper, washing dishes, mopping the floor, and walking on a treadmill at 1.0, 2.0, 3.5mph were measured by indirect calorimeter and total daily energy expenditure was estimated by summation of energy costs of different activities. The overweight group had significantly higher values of body weight, triceps skinfold thickness, thigh circumference, waist circumference, hip circumference, BMI, WTR, WHR, body surface area, percentage body fat, fat mass, fat free mass (FFM), and muscle mass compared to normal-weight group. The energy intakes of both groups were close to RDA and other nutrient intake status was also satisfactory. There were no significant differences in intakes of energy and nutrients between the two groups. Overweight subjects showed lower energy expenditure per kg body weight for reading the newspaper, washing dishes and mopping the floor, and walking on a treadmill at 2.0 and 3.5 mph, however, energy expenditure per kg FFM did not differ between the two groups. Daily energy expenditure for all activities was significantly higher in the overweight compared to the normal-weight group due to higher body weight. Both overweight and normal-weight groups showed negative energy balance between energy intake and energy expenditure, and there was no significant difference in energy balance between the two groups. Total daily energy expenditure correlated highly with FFM and body surface area. The result of present study does not offer an explanation on the energy imbalance and weight gain of overweight women.

KEY WORDS: overweight, energy expenditure, energy intake, body composition, energy balance.

INTRODUCTION

The overall prevalence of obesity in Korea is rapidly increasing and health risks associated with obesity are also growing.[1-3] Obesity is defined as an excess of body fat and is often expressed in terms of body weight in relation to height (the body mass index, BMI). The '98 National Health and Nutrition survey report[2] showed that 22.8% of Koreans had a BMI over 25. This was an increase of over 2% compared to the '95 National Nutrition Survey result of 20.5%.[1]

The balance between energy intake and energy expenditure is expressed as body weight. Excess energy intake has been thought to be the primary cause of obesity. Even though the prevalence of obesity in Korea has increased in recent years, the average energy intake of adult Koreans has steadily decreased from 2150 kcal in 1970 to 2052 kcal in 1980 and 1868 kcal in 1990.[3] The average energy intake in the '98 survey was 1985 kcal, however, an individual 24 hr-recall method instead of a household survey was employed for this survey, making it hard to directly compare with the previous data. To explain this discrepancy, it seems reasonable to study energy expenditure of overweight people to understand the cause of weight gain. There are several lines of evidence that low energy expenditure may contributes to obesity.

Studies of total energy expenditure (TEE) between obese and lean subjects have shown inconsistent results.[4-6] A low relative RMR has been reported in some studies of obese people and suggested that low RMR may be a contributing factor in obesity.[7] It has also been suggested that obese people may have lower energy expenditure for physical activities, however, the energy expended during physical activities by obese people is largely unknown.[8,9] A study on the difference in energy expenditure at rest and during several activities between obese and normal weight subjects will help us understand why individuals require different amounts of energy to maintain body weight and why some individuals are more susceptible to weight gain than others.

The purpose of the present study is to document the underlying causes for the imbalance between energy intake and energy expenditure in overweight adult females.

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Energy expenditure during several activities was measured by indirect calorimeter and energy intake was assessed to evaluate energy balance of overweight and normal-weight Korean middle-aged women. The values of over-weight females were compared with normal weight subjects to explain the cause of obesity.

MATERIAL AND METHODS

1. Subjects

Subjects were 40 middle-aged women (40−60 yrs) living in Seoul; 20 women with a BMI $\leq$ 23 (18.1−22.9 kg/m^2) were classified as normal-weight group and 20 subjects with a BMI $\geq$ 25 (25.2−34.1 kg/m^2) were classified as overweight. All were apparently healthy, not suffering from any known disease, and used no drugs known to influence energy metabolism. Women suffering from muscular problems were excluded since this study requires the measurement of energy expenditure during walking. Subjects were fully informed about the purpose, significance and protocol of the study and gave verbal consent to participate.

2. Diet and activity records

Subjects completed a one-day diet record and a one-day activity record on same day. For diet record, subjects were instructed how to measure and to record food intake with the aid of a dietary scale. The diet records were checked for completeness at time of their return and were analyzed by computer using NUTASS program. For the activity record, the subjects were asked to write activities for the whole day on a five-minute interval scale sheet.

3. Anthropometry measurements

Body weight, fat mass, muscle mass, and percentage body fat were measured with INBODY 2.0 (Biospace, Korea) employing bioelectrical impediment analysis method. Height was measured with stadiometer, and waist, hip, and thigh circumferences were measured with anthropometric tape (Preston 5293). BMI (body mass index), WHR (waist to hip circumference ratio), and WTR (waist to thigh circumference ratio) were calculated. Triceps skinfold thickness measurement was done with Lange skinfold caliper, and body surface area was obtained by use of a nomogram. All measurements were taken by the same investigator to minimize measurement error.

4. Energy expenditure measurements

Energy expenditure at rest and during some daily activities was measured using indirect calorimeter (KB1-C, Aerosport, USA) in the nutrition laboratory at Ewha Womans University. Oxygen consumption during activities was measured and energy expenditure was estimated by using a value of 4.82 kcal per liter of oxygen consumed.[10] Subjects acclimated to mouthpiece and nose clip before energy cost measurement of selected activities.

For measuring energy expenditure at rest, subjects were at least 2 hr postprandial and rested quietly in a supine position, awake but motionless, in a bed for 15 minutes before measurement. The measurements were done for 15 minutes and the value for the last 10 minutes was used to determine energy cost. The measurement for the first five minutes was thrown away for adaptation.

To measure energy expenditure for physical activities, daily activities were grouped into seven categories by intensity[11-13] (Table 1), and one representative activity for each category was chosen for measurement of energy cost. Energy expenditure for reading newspaper, washing dishes, mopping floor, and walking on a treadmill at 1.0, 2.0, 3.5 mph (miles per hour) was measured. Oxygen consumption for reading newspaper, washing dishes and mopping floor was measured for five minutes, and the energy cost was estimated using the value for the last three minutes. Three minutes measurement was done for walking on a treadmill at 1.0, 2.0, 3.5 mph, and the value of the last two minutes was used for the energy expenditure estimation. Energy cost for sleeping was calculated at 90% of energy cost at rest.[11]

From the one-day activity record, activities of each subject were grouped into seven categories and time spent for each category was summed. TEE (total energy expenditure) was estimated by summation of energy cost (kcal/min) multiplied by time spent (min) for each category of

Table 1. Classifying physical activities by intensity and examples of activities

Intensity of activities	Examples of activities
Sleeping	sleeping
Very light	lying, sitting quietly, watching TV, listening music
Light	standing quietly, talking, eating, card playing, sewing, reading newspaper
Moderate	driving automobile, washing dishes, cooking, music playing, folding cloth, ironing, shopping, dressing, making bed, cleaning (light), putting on make-up, washing, laundry (washing machine)
More active	mopping floors, child caring, showering, cleaning (moderate)
More severe	cleaning (heavy), bathing, laundry (hand), gymnastics
Very severe	bicycling, health club exercising (general), jogging, walking (up stairs)

activity.

5. Statistical analysis

Data were analyzed by using the SAS institute program.[14] The results are expressed as MEAN ± SE. Independent two-sample t-test was used to compare mean values of overweight and normal-weight groups. Pearson's correlation coefficients were used to assess the relationship between energy expenditure and body size.

RESULTS & DISCUSSION

1. Anthropometry and body composition

Table 2 shows age and the anthropometric characteristics of the subjects entering the study. There were no significant differences in mean age and height between the two groups. The overweight group showed significantly higher values of body weight, triceps skinfold thickness, thigh circumference, waist circumference, hip circumference, BMI, WTR, WHR, and body surface area (BSA) compared with the normal-weight group.

The overweight subjects also showed significantly higher values of percentage body fat, fat mass, muscle mass, and fat free mass than normal group. The ratio of overweight to normal-weight groups were higher in percentage body fat (136.3%) and fat mass (175.5%) than in muscle mass (113.7%) and fat free mass (114.0%), which means that body fat contributes more in body weight difference between overweight and normal-weight subjects than muscle mass.

Table 2. Age and Anthropometric characteristics of subjects[1)]

	Overweight (N = 20)	Normal (N = 20)
Age (yr)	48.1 ± 1.0	48.8 ± 1.3
Height (cm)	155.3 ± 0.9	156.1 ± 0.9
Weight (kg)	68.9 ± 2.0***[3)]	52.2 ± 0.9
TST (mm)[2)]	30.7 ± 1.4***	22.4 ± 1.2
TC (cm)	60.0 ± 0.6***	52.5 ± 0.7
WC (cm)	88.3 ± 1.8***	71.1 ± 1.2
HC (cm)	100.3 ± 1.5***	89.7 ± 0.8
BMI	28.5 ± 2.8***	21.4 ± 1.3
WHR	0.88 ± 0.06***	0.79 ± 0.06
WTR	1.47 ± 0.1*	1.36 ± 0.12
BSA (m^2)	1.68 ± 0.11***	1.50 ± 0.06
Percent body fat (%)	36.6 ± 1.1***	26.9 ± 0.8
Fat mass (kg)	24.7 ± 1.21***	14.1 ± 0.54
Muscle mass (kg)	40.9 ± 0.7**	38.1 ± 0.7
Fat free mass (kg)	43.3 ± 0.8***	35.9 ± 0.7

1) MEAN ± SE
2) TST: Triceps skinfold thickness, TC: Thigh circumference
WC: Waist circumference, HC: Hip circumference
BSA: Body surface area
3) Significantly different between two groups by independent 2 sample t-test (*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$)

2. Energy and nutrient intakes

Energy and nutrient intakes of overweight and normal-weight subjects were satisfactory and no significant differences in nutrient intakes were found (Table 3). Mean energy intakes of the overweight and normal-weight groups were 2080 kcal and 2153 kcal, respectively. There was no significant difference in calorie distribution: 63.9% of energy from carbohydrate, 16.1% from protein, and 19.9% from fat for overweight group and 61.7% from carbohydrate, 16.2% from protein, and 22.1% from fat for normal group.

These results are similar with other studies.[15-17] In a study by Choi *et al.*,[15] energy intake of women with a BMI < 25 was 2147 kcal/day and women with a BMI > 25 was 2089 kcal/day. In these studies, energy intake did not differ between overweight and normal weight subjects.

3. Energy expenditure

Energy expenditure for selected activities and for walking on a treadmill are presented in Table 4. Overweight group showed lower energy expenditure expressed per kg body weight for activities such as reading newspaper, washing dishes, mopping floors, and walking on a treadmill at 2.0, and at 3.5 mph. When energy expenditure was expressed per kg FFM, no significant differences were found between the two groups. However energy expenditure for the activities per min showed significantly higher in overweight subjects due to the higher body weight.

Geissler *et al.*[18] reported that the post-obese subjects

Table 3. Daily average nutrient intakes[1)]

	Overweight (N = 20)	Normal (N = 20)
Energy (kcal)	2080.0 ± 173.5	2152.7 ±159.9
Protein (g)	80.9 ± 7.4	84.6 ± 8.0
Fat (g)	45.2 ± 7.5	53.3 ± 6.7
Carbohydrate (g)	316.0 ± 30.5	311.8 ± 21.4
Ca (mg)	628.2 ± 59.6	683.8 ± 68.9
P (mg)	1122.6 ± 102.0	1239.4 ± 97.0
Fe (mg)	15.9 ± 1.7	18.1 ± 1.5
Vitamin A (μgR.E.)	671.4 ± 93.2	568.6 ± 86.3
Vitamin B_1 (mg)	1.5 ± 0.3	1.3 ± 0.2
Vitamin B_2 (mg)	1.3 ± 0.1	1.5 ± 0.1
Niacin (mg)	15.8 ± 1.5	19.0 ± 2.5
Vitamin C (mg)	140.0 ± 23.9	160.4 ± 31.1
Energy distribution		
%Carbohydrate	63.9 ± 2.5	61.7 ± 2.3
%Protein	16.1 ± 0.8	16.2 ± 0.9
%Fat	19.9 ± 2.2	22.1 ± 1.8

1) MEAN ± SE

had metabolic rates 15% lower than lean controls at any level of activities. Obese and postobese individuals may have lower metabolic rates than their counterparts.[18][19] The lower metabolic rate would result in lower maintenance energy requirements and an apparent increase in the efficiency of energy use. This would contribute to an ease of weight gain or resistance to weight loss.

As shown in Table 5, daily activity time (AT) and energy expenditure (EE) on various activities were not significantly different between overweight and normal-weight groups. The 24-hr energy expenditure (total energy expenditure) was significantly higher in the overweight compared to the normal-weight group ($p < 0.05$). Other investigators have repeatedly reported that RMR and mean 24-hr energy expenditure of obese subjects were higher than those of lean control subjects.[4][20]

Both overweight and normal-weight groups showed negative energy balance (Table 6). Even though the difference was not statistically significant, the overweight group showed greater negative balance than normal-weight group because the overweight group had higher total daily energy expenditure while energy intake was similar. This is hard to explain because overweight people seem to maintain their high body weight with greater negative energy balance. Many other investigators also reported that obese people had (−) energy balance.[15][20][21] However, part of the reason could be explained by the possibility of underreporting energy intake in self-reported dietary intake. It has been shown that overweight people have a tendency to underreport energy intake.[22][23] It could be speculated that the social pressure placed on women to be slim induced alterations in their recording of food, which made them appear to be modest eaters.

To document the relationship between energy expenditure and body size, Pearson's correlation coefficients were calculated. As shown in Table 7, TEE was significantly

Table 4. Energy cost of selected activities[1]

		Overweight	Normal-wt[4]
Sleeping[3]	kcal/kg BW/hr	0.52 ± 0.02	0.58 ± 0.04
	kcal/kg FFM/hr	0.82 ± 0.04	0.79 ± 0.05
	kcal/min	0.59 ± 0.03	0.51 ± 0.03
Lying	kcal/kg BW/hr	0.58 ± 0.03	0.65 ± 0.04
	kcal/kg FFM/hr	0.91 ± 0.04	0.88 ± 0.05
	kcal/min	0.66 ± 0.03	0.56 ± 0.04
Reading newspaper	kcal/kg BW/hr	1.96 ± 0.08*[2]	2.16 ± 0.06
	kcal/kg FFM/hr	3.12 ± 0.15	2.96 ± 0.09
	kcal/min	2.25 ± 0.11**	1.88 ± 0.07
Washing dishes	kcal/kg BW/hr	3.22 ± 0.11**	3.60 ± 0.12
	kcal/kg FFM/hr	5.10 ± 0.17	4.92 ± 0.13
	kcal/min	3.68 ± 0.13**	3.13 ± 0.11
Mopping floors	kcal/kg BW/hr	5.19 ± 0.26**	5.96 ± 0.21
	kcal/kg FFM/hr	8.20 ± 0.40	8.15 ± 0.27
	kcal/min	5.91 ± 0.28**	5.15 ± 0.16
Treadmill exercise 1.0 mph	kcal/kg BW/hr	5.48 ± 0.33	6.18 ± 0.26
	kcal/kg FFM/hr	8.65 ± 0.53	8.45 ± 0.34
	kcal/min	6.19 ± 0.35	5.37 ± 0.24
Treadmill exercise 2.0 mph	kcal/kg BW/hr	7.27 ± 0.38**	8.48 ± 0.30
	kcal/kg FFM/hr	11.49 ± 0.60	11.63 ± 0.43
	kcal/min	8.29 ± 0.44*	7.38 ± 0.30
Treadmill exercise 3.5 mph	kcal/kg BW/hr	10.39 ± 0.54**	11.95 ± 0.42
	kcal/kg FFM/hr	16.34 ± 0.84	16.39 ± 0.63
	kcal/min	11.70 ± 0.61*	10.39 ± 0.41

1) MEAN ± SE
2) Significantly different between two groups by independent 2 sample t-test (*: $p < 0.1$, **: $p < 0.05$, ***: $p < 0.01$)
3) Energy cost for sleeping was calculated at 90% of resting energy cost.
4) Number of subjects was 20 for each group, except one subject of overweight group dropped for treadmill at 2.0 mph (N = 19) and 2 subjects dropped out at 3.5 mph (N = 18).

Table 6. Energy balance[1]

	Overweight (N = 20)	Normal (N = 20)
TEI (kcal)	2080.2 ± 173.5	2152.7 ± 159.9
TEE (kcal)	3256.8 ± 217.9*[2]	2674.0 ± 129.6
Energy balance (kcal)[3]	−1176.6 ± 279.6	−521.4 ± 199.3

1) MEAN ± SE
2) Significantly different between two groups by independent 2 sample t-test (*: $p < 0.05$)
3) Energy balance = Total energy intake - Total energy expenditure

Table 5. Daily activity time (AT) and energy expenditure (EE) of various activities[1]

	Overweight (N = 20)		Normal (N = 20)	
	AT (min)	EE (kcal)[2]	AT (min)	EE (kcal)
Sleeping	398.5 ± 16.2	234.2 ± 12.6	406.0 ± 15.1	206.1 ± 15.6
Very light	242.5 ± 27.8	163.2 ± 22.2	240.5 ± 19.5	129.9 ± 12.3
Light	229.0 ± 38.6	500.4 ± 82.2	227.0 ± 23.9	432.2 ± 47.9
Moderate	539.5 ± 32.2	1975.2 ± 136.8	517.5 ± 38.3	1635.5 ± 145.1
More active	30.5 ± 7.0	181.7 ± 42.2	36.0 ± 7.5	191.7 ± 42.0
More severe	7.5 ± 4.7	54.8 ± 33.6	18.0 ± 6.1	128.7 ± 45.6
Very severe	0	0	0	0
24-hr energy expenditure	3256.8 ± 217.9*[3]		2674.0 ± 129.6	

1) MEAN ± SE
2) Energy expenditure per min (kcal/min) × activity time of each activity (min)
3) Significantly different between two groups by independent 2 sample t-test (*: $p < 0.05$)

Table 7. Correlation coefficients between energy expenditure and anthropometric measurements

	TEE (kcal/day)
Height (cm)	0.244
Weight (kg)	0.372*
FFM (kg)	0.402*
Percent fat (%)	0.218
BMI	0.328*
BSA (m^2)	0.399*
TST (mm)	−0.012

1): Correlation coefficients (*: $p < 0.05$)

correlated with body weight, FFM, BMI, and BSA. Among indices of body size, FFM is the most highly correlated with TEE, and body weight and body surface area also show relatively high correlations. Coefficient correlations of percentage body fat and triceps skinfold thickness were low. Therefore it seems that active tissue (FFM) and BSA determine daily energy expenditure and body fat mass has minimal effect. Webb[24] reported that total daily energy expenditure correlated highly with fat-free mass and body surface area, independent of age and sex.

In conclusion, overweight subjects showed lower energy expenditure per kg body weight for several activities than normal-weight individuals, however, energy expenditure per kg FFM did not differ between the two groups. Daily energy expenditure for all activities was a little higher in obese compared to normal group due to higher body weight, however, total daily energy expenditure was significantly higher in overweight subjects. The total daily energy expenditure was correlated highly with FFM and body surface area.

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