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Prevalence of Masked Obesity Associated with Lifestyle-Related Habits, Dietary Habits, and Energy Metabolism in Japanese Young Women

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ABSTRACT

We investigated the prevalence of Masked Obesity (MO) and the correlations between MO and lifestyle-related habits (e.g., exercise habits, dieting habits), dietary habits, energy metabolism, and seasons. The subjects were 131 young Japanese college students. Body composition was measured by bioelectrical impedance method and Resting Metabolic Rate (RMR) was measured by an indirect calorimeter. Subjects with a BMI in the normal range (n=110) were divided into the MO (percentage of body fat to Body Weight [BF] ≥30%) and control (C) (BF<30%) groups. Dietary energy and nutrient intakes were calculated from weighed dietary records. A questionnaire on lifestyle habits was obtained individually from the subjects. The percentage of MO was 32% of subjects within normal BMI. The prevalence of MO was the highest in winter, probably due to accumulation of body fat as an adaptation to cold. The MO group had low Fat-Free Mass (FFM) and high BF. RMR of the MO group was significantly lower than that of the C group. The MO group tended to have poor exercise habits, more dieting (restricting calorie intake) experiences and consumed a diet with less vegetables and beans. We concluded that the prevalence of MO was 32%; it was the highest in winter for subjects who had high fat and low FFM. This fact may be due to poor exercise, more dieting experiences and insufficient intake of vegetables and beans. Furthermore, this accumulation of body fat may be partly due to low RMR.

Keywords: body mass index, energy metabolism, life-related habits, masked obesity, seasonal variation

INTRODUCTION

Body Mass Index (BMI: expressed as body weight in kilograms divided by height in meters squared, kg/m^2) is a useful tool for defining anthropometric characteristics and determining obesity. However, a disadvantage of BMI is that it does not reflect the precise levels of body fat. Recently, obesity has been found in young Japanese women whose BMI is in the normal range (18.5≤BMI<25 kg/m^2), but have a relatively high percentage of body fat based on Japanese standards. This phenomenon called "masked obesity" has been detected often (Takahashi *et al.* 2002), and its prevalence is growing. It has been suggested that masked obesity is associated with a higher risk of developing serum lipid abnormalities, arteriosclerosis, and obesity. Additionally, obesity at a young age is associated with high morbidity and mortality due to arteriosclerotic disease, even if obesity is improved in adulthood (Must *et al.* 1992). Masked

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obesity is not easily detected on the basis of BMI alone; thus, body composition measurements are necessary for early detection of this condition (Oguri *et al.* 2006).

It has been speculated that masked obesity may be caused by young women consuming inappropriate diets and maintaining sedentary lives (Yoshiike *et al.* 2002). Yoshiike *et al.* found that the mean BMI of women aged 20 to 39 years in the National Health and Nutrition Examination Survey decreased between 1976 and 1995. In addition, the percentage of women in their twenties who were underweight (BMI<18.5 kg/m^2) was 13.4% in 1981; however, since then it increased continuously to 21.7% in 2016, with one in five young women being underweight (2017 National Health and Nutrition Examination Survey). Reports have suggested that increased thinness may be influenced by inappropriate dieting behaviors associated with young people's desire to be thin (Mase *et al.* 2012) and that these dieting habits may make small Fat-Free Mass (FFM) more likely to accumulate as body fat and influence the formation of masked obesity. This is because, in the case of normal body weight with low or normal body fat, energy restriction such as dieting will induce a greater loss of lean mass than body fat (Dulloo & Jacquet 1999).

Body composition and nutritional status (McKinney *et al.* 2008) change seasonally, and body weight, fat mass, and fat percentage are known to increase during the winter and decrease during the summer in young Japanese women (Yumigeta *et al.* 2015). Subcutaneous fat gain in winter (Ishigure *et al.* 1980) is an important adaptation to the cold environment (Glaser & Shephard 1963). It is unclear, however, whether seasonal changes in body fat are associated with the prevalence and development or improvement of masked obesity.

This study aimed to examine the prevalence of masked obesity and to comprehensively assess whether masked obesity is associated with lifestyle-related habits, eating habits, energy metabolism, and seasons.

METHODS

Design, location, and time

Participants were 131 female students in the fourth year who belong to the Faculty of Home Economics at a university in Kobe and live in the Kansai area (south-western half of Japan including Kobe or Osaka city). The study was conducted in the spring of 2015 and 2016. Twenty five subjects participated in a one year study investigating seasonal changes in body fat percentage in winter, spring, summer, and autumn of 2015–2016. Seasonal variation in the prevalence of masked obesity was examined from the body fat percentage. Informed consent was obtained in advance by explaining the aim and method of the study. This study was approved by the Human Ethics Research Committee of Kobe Women's University.

Sampling

Of the total participants, 14 students (10.7%) had a BMI<18.5 kg/m^2, and 7 students (5.3%) had a BMI≥25 kg/m^2. Data from these students (n=21) were excluded, thus data from the subjects with a BMI in normal range (n=110) were extracted for the study.

Definition of masked obesity and the categories

Masked obesity was defined as BMI (18.5≤BMI<25 kg/m^2) with percentage of body fat of ≥30% (Fukuoka *et al.* 2012). Subjects with a BMI in the normal range were divided into two groups: the masked obesity (MO: body fat ≥30%) group and the control (C: body fat <30%) group.

Data collection

Body composition was measured by Inbody 720 (Biospace, Tokyo, Japan) using the bioelectrical impedance method. The measurements by the instrument are highly correlated with the underwater weighing method and Dual-energy X-ray absorptiometry (DEXA) methods (Utter & Lambeth 2010; Cha *et al.* 1995; Malavolti *et al.* 2003). Therefore, the body composition analyzer was used for these measurements.

Body weight and body composition were measured for three consecutive days during the low basal body temperature period, immediately after the end of menstruation for each subject, and the mean value was used for the data. Measurements were performed under the following conditions: 3 hours after breakfast, after urinary and fecal excretion, and with changing into an examination suit.

Resting metabolic rate was measured at the same time as body composition, during the low basal body temperature phase, to avoid the effect of sex hormones. Measurements were performed using a metabolic analyzer (MedGem+, MP Japan Co. Ltd.) while subjects were sitting in chairs and resting for about 10 min.

Dietary surveys were conducted on three consecutive days during the low basal temperature period (along with body composition measurements), using the self-weighing records method. Subjects were asked to use their dietary record forms and leaflets to document all of the ingredients and seasonings used as well as their weights. For the marketed products, the trade name, brand name, and amount of energy and nutrients displayed were recorded. Nutrition calculations were performed using Excel Eiyou-kun Ver.6.0 (Kenpakusha, Tokyo, Japan), and energy/nutrient intake per day was calculated.

A questionnaire survey was conducted to investigate lifestyle and dietary habits associated with masked obesity. Questionnaire items were related to dieting experience, and past and current exercise habits. Questionnaires were distributed at the time of body composition measurement; they were self-completed and collected on the same day.

Data analysis

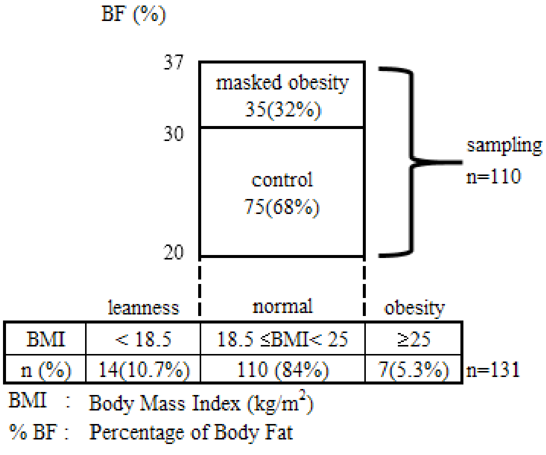
IBM SPSS, Ver. 21 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. An unpaired t-test was used for testing between the two groups, a chi-square test was used for cross-tabulation, and a Pearson test for correlation. The level of significance was less than 5%.

RESULTS AND DISCUSSION

Physique of the subjects and prevalence of masked obesity

The subjects with a BMI in normal range (n=110) were extracted from the participants (n=131). Their height, weight, BMI, body fat, and fat-free mass are shown in Table 1. The height and weight of the subjects were within the range of body sizes in the results of the National Health and Nutrition Examination Survey in Japan (MoHWL 2017) aged 20–29 years (Table 1). Thus, the BMI of the subjects was 21.1±1.5 kg/m^2, which was similar to the BMI (20.6±3.3 kg/m^2) of the National Survey data in Japan (MoHWL 2017).

Among the subjects with a normal BMI, the prevalence of masked obesity (% body fat ≥30%) was about 32% in the spring where the experiment started (Figure 1). The prevalence of MO in our study was higher than that of MO reported in 2012 (17.8%) (Fukuoka *et al.* 2012) but is almost equivalent to that reported in 2017 (Takeda *et al.* 2017). The frequency of masked obesity seems to increase year by year. As masked



Leanness (BMI<18.5), normal (18.5≤ BMI<25) and obesity (BMI≥25) were classifed according to Japanese standards. The subjects with a BMI in normal range were extracted and divided into masked obesity (%BF≥30%) and control (%BF<30%) by % body fat.

Figure 1. BMI distribution in participants(n=131) and classification of the subjects with a normal range of BMI by % body fat

Table 1. Physical characteristics of subjects

Anthropometric parameters	Subjects	Value	
		Minimum	Maximum
Height (cm)	158.1±5.0	146	169.4
Weight (kg)	52.8±5.1	42.3	66.3
BMI (kg/m^2)	21.1±1.5	18.5	24.7
Muscle mass (kg)	35.38±3.24	28.8	44
Skeletal muscle mass (kg)	20.43±2.08	16.1	25.8
Fat-free mass (kg)	37.81±3.45	30.7	47
Body fat mass (kg)	14.96±3.00	9.7	24.1
Body fat percentage (%)	28.21±3.93	19.57	37.1
Body water content (l)	27.72±2.55	22.5	34.3
Intra cellular water content (l)	17.20±1.59	13.9	21.4
Extra cellular water content (l)	10.49±0.93	8.6	12.9
Protein weight (kg)	7.44±0.69	6.0	9.2
Mineral amount (kg)	2.69±0.25	2.26	3.48
Waist hip ratio	0.81±0.29	0.75	0.88
RMR (kcal/day)	1,039±120	780	1,330

Values are means±Standard deviation (SD) (n=110); RMR: Resting Metabolic Rate; BMI: Body Mass Index
The subject with a normal range of BMI ($18.5 \leq BMI < 25$) were extracted in the study

obesity cannot be detected without measuring body composition, some people with MO may remain unaware that their health is at risk. Hence, obesity awareness is important for preventing the development of obesity (Akil & Top 2019).

Comparison of body composition between masked obesity and normal individuals

Body compositions and resting metabolic rate of the MO group were compared with those of the C group (Table 2).

There was no significant difference between the MO and C groups in height, but body weight was significantly greater by 3.1 kg in the MO group than in the control. The BMI (=22 kg/m^2) in the MO group was also significantly greater than that (=20 kg/m^2) in the C group (Table 2); thus, the BMI in the MO group might be an indicator of masked obesity. In other words, a BMI of 22 in young Japanese women might imply a health risk instead of an appropriate BMI based on the World Health Organization standards (WHO expert consultation 2004). Thus, these results supported a WHO report that Asian populations might have risk factors for diabetes mellitus and cardiovascular disease even below a BMI of 25 kg/m^2 because Asian people generally have a higher body fat than white people of the same BMI(WHO expert consultation 2004).

Comparison of body composition showed that FFM was lower in the MO group by 1.4 kg than in the C group (p=0.056), and the body fat mass was significantly higher by 4.5 kg in the MO than in the control group ($p<0.001$). Thus,

Table 2. Comparison of body composition and resting metabolic rate between masked obesity group and control group

Body composition	MO (n=35)	C (n=75)	p value
Height (cm)	157.0±4.9	158.5±5.0	0.144
Weight (kg)	54.9±5.0	51.8±4.9	0.002
BMI (kg/m^2)	22.24±1.26	20.57±1.34	<0.001
Muscle mass (kg)	34.70±2.82	35.98±3.36	0.054
Skeletal muscle mass (kg)	19.85±1.76	20.69±2.17	0.049
FFM (kg)	36.89±3.00	38.24±3.59	0.056
Body fat mass (kg)	18.03±2.31	13.53±2.06	<0.001
Body fat percentage (%)	32.74±1.84	26.09±2.63	<0.001
Right arm muscle mass (kg)	1.65±0.21	1.70±0.24	0.351
Left arm muscle mass (kg)	1.62±0.20	1.65±0.25	0.562
Trunk muscle mass (kg)	16.15±1.38	16.33±1.59	0.556
Right leg muscle mass (kg)	5.75±0.64	5.96±0.69	0.133
Left leg muscle mass (kg)	5.76±0.63	5.96±0.68	0.131
Right arm fat mass (kg)	1.22±0.18	0.87±0.14	<0.001
Left arm fat mass (kg)	1.24±0.19	0.90±0.14	<0.001
Trunk fat mass (kg)	8.60±1.23	6.22±1.16	<0.001
Right leg fat mass (kg)	2.99±0.36	2.31±0.31	<0.001
Left leg fat mass(kg)	2.98±0.36	2.30±0.30	<0.001
Waist hip ration	0.83±0.03	0.81±0.03	<0.001
BMR (kcal)	1,166±65	1,196±77	0.056
RMR (kcal/kg body weight)	18.93±1.95	20.19±2.43	0.008

Values are means±SD (n=110); Unpaired t test; MO: Masked Obesity group; C: Control group
FFM: Fat-Free Mass; BMR: Basal Metabolic Rate; RMR: Resting Metabolic Rate

we found that the weight gain of masked obesity was due to an increase in body fat that greatly exceeded the decline in fat-free mass.

When comparing body parts, muscle mass in the trunk, and upper and lower limbs, the MO group was almost the same as that of the C group. On the other hand, body fat mass was significantly greater ($p<0.001$) in the MO group than in the C group in all body parts, including the trunk, upper limbs, and lower limbs. Approximately 30%–40% of fat in the trunk and the upper and lower limbs accumulated more than in the C group.

Resting metabolic rate was significantly lower in the MO group than in the C group. Lower energy metabolism in MO might easily promote fat accumulation.

Energy and nutrient intakes

Energy intake of the MO group was similar to that of C group (Table 3). Intakes of protein, fat, and carbohydrates in the MO group were also similar to those in C group. Similarly, the energy composition ratio of fat to total energy in the MO group was not different from that in the

Table 3. Composition of total energy intake (per day) and nutrient intakes (per day) of between masked obesity group and control group

Energy and nutrient intakes	MO (n=35)	C (n=75)	p value
Energy (kcal)	1,434±320	1,471±298	0.55
Protein (g)	53.41±13.60	55.87±14.66	0.40
Fat (g)	50.27±15.62	49.85±15.45	0.90
Carbohydrate (g)	191.61±52.81	191.04±45.49	0.95
Protein (%E)	14.93±2.09	15.13±2.41	0.67
Fat (%E)	31.42±6.42	30.35±6.63	0.43
Carbohydrate (%E)	53.50±10.00	52.18±7.79	0.45
Dietary fiber (g)	7.38±2.94	9.01±4.71	0.06
Sodium (mg)	2384.6±668.3	2495.9±776.8	0.47
Potassium (mg)	1689.1±662.2	1737.0±710.2	0.74
Calcium (mg)	292.8±128.4	347.8±153.8	0.07
Magnesium (mg)	145.5±42.7	175.3±72.9	0.01
Phosphorus (mg)	666.2±216.7	718.4±241.1	0.28
Iron (mg)	4.21±1.65	5.16±2.63	0.05
Zinc (mg)	5.51±2.08	5.97±1.92	0.26
Copper (mg)	0.66±0.21	0.76±0.26	0.07
Vitamin A (µg)	325.9±216.6	367.4±254.1	0.41
Vitamin D(µg)	4.12±3.09	3.63±3.38	0.47
Vitamin E (mg)	4.28±1.94	4.64±2.24	0.41
Vitamin K (µg)	123.6±73.67	168.4±251.2	0.31
Vitamin B1 (mg)	0.67±0.31	0.67±0.26	0.99
Vitamin B2 (mg)	0.82±0.29	0.86±0.33	0.52
Niacin (mg)	19.07±6.62	21.61±8.15	0.11
Vitamin B6 (mg)	0.81±0.30	0.89±0.35	0.22
Vitamin B12 (µg)	3.27±1.93	3.62±3.42	0.58
Pantothenic acid (mg)	4.06±1.46	4.28±1.52	0.48
Biotin (µg)	21.64±8.09	26.59±12.85	0.02
Vitamin C (mg)	90.27±113.5	71.12±44.37	0.34
Salt (g)	6.10±1.79	6.32±2.03	0.58

Values are means±SD (n=110); Unpaired *t* test; MO:Masked Obesity group
C:Control group; Protein (%E): The energy composition ratio of protein to total energy; Fat (%E): The energy composition ration of fat to total energy; Carbohydrate (%E): The energy composition of carbohydrate to total energy

C group. The energy intake in our data was lower by 200 kcal than the results presented by the National Health and Nutrition Survey in Japan, although it was not strictly comparable because of the different methods used (MoHWL 2017).

On the other hand, the intake of dietary fiber was lower in the MO group than in the C group by 18%, although there was insignificance (p=0.06) between them. Low dietary fiber intake might cause accumulation of fat in the MO group with the same energy intake as the control group (Table 3).

There were no differences between the two groups in sodium and potassium intakes; however, calcium, iron, and copper intakes tended to be lower in the MO group than in the control, and magnesium intakes were significantly higher in the MO group than in the control. With respect to vitamins, the MO group tended to have less vitamins, especially significantly less biotin.

Relationship between body fat percentage and food intake

The correlation between the percentage of body fat and intakes of food groups such as vegetables or beans (Table 4) were examined in all subjects. There were significant and negative correlations between body fat percentage and intakes of vegetables and beans, respectively; a higher body fat percentage was associated with lower intakes of vegetables and beans.

There are many research studies on the correlation between the intakes of vegetables and fruits and the percentage of body fat. In Japan, the subjects with masked obesity consumed a smaller daily intake of green and yellow vegetables and light-colored vegetables, and they consumed fried foods more frequently than those with standard proportions (Takeda *et al.* 2017). In Canada, surveys of Atlantic areas where obesity frequently emerged suggested that lower consumption of vegetables and fruits was inversely associated with visceral fat, and higher consumption of vegetables and fruits was associated with lower body fat mass (Yu *et al.* 2017). In a systematic review, increased vegetable consumption caused weight loss and was associated with reduced risks of becoming overweight and obese (Nour *et al.* 2018).

There was also a significant negative correlation between soy intake and body fat percentage, indicating that higher soy intake was associated with lower body fat percentage (Table 4). This suggests that soy protein contains peptides that reduce body fat. Experimentally, it has been shown that consumption of soy protein reduces body weight and body fat mass in addition to lowering plasma cholesterol and triglycerides in humans and rats (Velasquez *et al.* 2007). Thus, the lower body fat percentage may be due to the body fat-lowering effect of soybean protein when bean intake was high.

Table 4. Correlation between body fat percentage and intake of vegetables and beans

Food group	Body fat percentage		
	n	r	p
Vegetables	131	-0.17	0.049
Beans*	131	-0.22	0.012

*Tofu, natto, atsuage, etc
Pearson

Therefore, the results suggest that unhealthy dietary habits such as the low intake of vegetables and soybeans might accelerate body fat accumulation and then lead to formation of masked obesity.

Comparison of exercising habits and dieting experiences between the MO and C groups

In lifestyle habits, 31.4% and 56% of the MO and C groups, respectively, reported having present exercise habit (Table 5). However, there was no difference between the MO and C groups in their past exercise habit. Accumulation of body fat may be attributable to excessive energy

Table 5. The percentage of the subjects with dieting experiences, present exercise habit and past exercise habit in masked obesity groups and control groups

Dieting experiences and exercise habit	MO n(%)	C n(%)	Total n(%)	p value
Dieting experiences				
Yes	27(77.1%)	34(45.3%)	61(55.5%)	<0.01
No	8(22.9%)	41(54.7%)	49(44.5%)	
Present exercise habit				
Yes	11(31.4%)	42(56.0%)	53(48.2%)	0.02
No	24(68.6%)	33(44.0%)	57(51.8%)	
Past exercise habit				
Yes	31(88.6%)	62(82.7%)	93 (84.5%)	0.43
No	4(11.4%)	13(17.3%)	17(15.5%)	

MO: Masked Obesity group; C: Control group intake or physical inactivity (Weinsier *et al.* 2002). As energy intake of the MO group was almost the same as that of the C group (Table 3), less physical activity may easily lead to masked obesity (Table 5).

Dieting behaviors for thinness are thought to contribute to masked obesity (Mase *et al.* 2012). In the present study, 77% of the subjects in the MO group had dieting experiences, which was much higher than the 45% in the C group. Therefore, inappropriate dieting behaviors would be a risk factor for masked obesity in young persons with normal BMI because dieting in people with a normal physique might induce a greater loss of fat-free mass rather than fat (Dulloo & Jacquet 1999).

Physical inactivity was also strongly associated with FFM. FFM of the MO group was somewhat lower compared with that of the C group. Since muscle, the main part of the fat-free mass, is the largest tissue for burning fat, the decline in fat-free mass results in a substantial tissue reduction that burns fat (Dulloo&Jacquet 1999).

Seasonal changes in the prevalence of masked obesity

The prevalence of masked obesity was 48% in winter, 36% in spring and summer, and 40% in autumn (Figure 2). There were seasonal changes in the prevalence of masked obesity with the highest frequency in winter and the lowest frequency in spring and summer.

High body fat in winter is in accordance with the physiological mechanisms that adapt to cold by increasing the amount of subcutaneous fat in winter (Ishigure *et al.* 1980) (Glaser & Shephard 1963), suggesting that seasonal changes need to be considered and investigated in studies of masked obesity.

Strengths and limitations

Seasonal changes in the prevalence of MO have never been examined in previous studies; we addressed this gap and found the highest prevalence of MO in winter, with most subjects likely to be associated with poor exercise, inappropriate dieting experiences, and unhealthy dietary habits. Exercise and healthy food intake reduce accumulation of body fat, thus preventing MO. Therefore, measurement of body fat mass in body composition is essential for enhancing awareness about MO among those with normal body weight.

This study, however, has some limitations as well. First, the subjects do not include men. Second, the subjects were all in the narrow age range of 21 to 22 years. Third, the participants

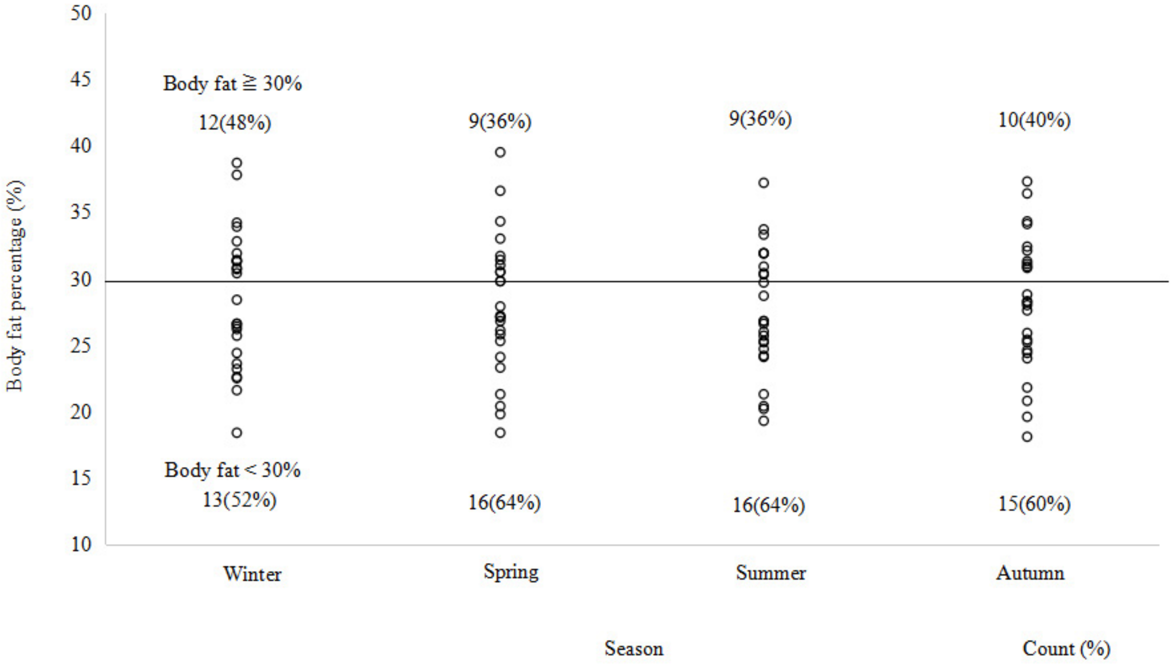


Figure 2. Seasonal changes in prevalence of masked obesity

were all (a) educated, (b) versed in the field of home economics, (c) women in a university, and (d) lived in urban areas. Thus, the results on a single population may not necessarily reflect physical condition of young women in general.

CONCLUSION

Masked obesity was found in about 32% of young women with normal BMI values in our spring study. There were seasonal changes in the prevalence of masked obesity with the highest frequency in winter and the lowest frequency in spring and summer. It was shown that the body composition of subjects with masked obesity consisted of low levels of fat-free mass and high levels of body fat, accumulated widely in the trunk, upper limbs, and lower limbs. Dietary habits with low vegetable and soy protein intake may accelerate body fat accumulation. Additionally, it was also speculated that the low FFM was due to inappropriate dieting and less exercising. Studies of masked obesity need to also consider seasonal changes.

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AUTHOR DISCLOSURES

The authors have no conflict of interest.

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