速　　報

Seasonal effect on Diet-Induced Thermogenesis

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Abstract

Information about seasonality in the measurement of diet-induced thermogenesis (DIT) is important for understanding the intra-individual variability of DIT and the contribution of DIT on weight regulation. In this study, the seasonal change of DIT in autumn and winter were investigated for young women (N = 14, 18 – 24 yrs). The DITs of subjects were measured in autumn and winter. The DIT, body weight, body mass index (BMI) and percent body fat of each subject were measured on four or more occasions in each season for precision, and the mean value was used as the individual's value for a given season. The mean outdoor temperatures at starting measurement in the morning were 22°C in autumn, and 11°C in winter. The means of body weight, BMI and percent body fat did not change between seasons. DIT (%) significantly declined from autumn to winter ($p < 0.05$, Paired t-test). For DIT curve (the increase of postprandial energy expenditure during 300 min after meal), significant main effect of season was observed (ANOVA, $p < 0.05$, autumn > winter).

In conclusion, there is the seasonal effect on DIT measurement; it declines from autumn to winter. The seasonality would be needed to be considered in any future study of DIT.

Key words : Diet-Induced thermogenesis, seasonality, young women

1. Introduction

There has been a lot of interest in excessive energy intake and the decline in physical activity as major causes for human obesity. In addition to those causes, the possibility has recently been pointed out that a decline in thermogenesis function is also a possible cause of obesity. Regarding thermogenesis, studies have been done on obesity such as basal metabolic rate, resting metabolic rate and Diet-Induced Thermogenesis (DIT), which is defined as "the increase of energy expenditure induced by meal ingestion" (Segal, 1989; Tounian, 1993). The DIT focused on in this very study accounts for a minor portion of total energy expenditure in a day, however, its decline is considered to be related to the decline of the energy expenditure that could cause obesity in the long term. There is a recent report indicating that a habitual dieting has a direct effect on DIT (Tobe, 2003).

The relation between body weight change and DIT has been investigated in order to clarify the role of DIT for body weight regulation, however, no consistent result has been observed. Research on the relationship between body weight change of obese people and DIT has shown that DIT increases as body weight decreases (Maffeis et al., 1992), and also that the DIT decreases (Garrow and Webster, 1989; Nichols et al., 1989). Weststrate (1993) points out that there exists a great intra-individual variability in measurement of DIT and it is a major research result discrepancies. Weststrate also states that a research design with a greater power of test is necessary. It is similarly necessary to specify the cause of an intra-individual DIT variation in order to further understand DIT and to aid in the further study of DIT.

Seasonal effects on DIT measurement have not yet been focused upon. The purpose of this study is to clarify the possibilities of any seasonal effects on

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intra-individual variation in measurement of DIT.

2. Subjects and procedure

Subjects for the study were 14 young women between 18 to 24 years old, all in good heath and not on any medication. Prior to the research, each subject was given an oral explanation by the author of the study regarding the research purpose, the advantage and the possible dangers of participating in the research, and all signed a consent agreement.

All 14 subjects had their DIT, height, weights and body fat percentage measured in autumn and winter. Five subjects had also had the same measurements taken in summer (from the end of July to August), prior to the autumn measurements. For all 14 subjects the autumn measurements took place between the end of September and the end of October, and the winter ones were taken from the middle of December to the beginning of February. The mean outdoor temperature at time when measurements were taken in the morning was 22℃ in the autumn, and 11℃ in the winter. It was 31 ℃ in the summer when the 5 subjects had their extra measurement taken. Each subject was measured on more than 4 occasions during each season and their average measurement value was given as their individual value to accurately determine a DIT measurement value for each season. The measurements were taken for a month to a month and half, and the deviation of each individual's menstrual cycle in each season was accounted for.

The subjects were instructed to avoid any hard exercise and to get enough sleep on the day before the measurements, to finish dinner at least 12 hours prior to the time of the measurement, and to not have any food until the measurements began. They arrived at the research facility between 8 and 9 in the morning, and rested lying on their backs for half an hour in the measuring room with the temperature regulated at between 24 to 26℃ . Then in a slightly reclined position, their resting metabolic rate was measured for half an hour. The resting metabolic rate was used later as a baseline when calculating DIT. Exhalation from the subjects was collected into a Douglas bag through a facemask, and oxygen concentration, carbon dioxide concentration, and the volume of expired gas were measured. After measuring the resting metabolic rate, the subjects ate a test meal (toast, milk and cheese) for approximately 20 minutes, which contained 2220kJ of total energy, equivalent to 531kcal, with 15 % protein, 36% fat and 49% carbohydrates. After the test meal, energy expenditure was measured for 20 minutes, and then the subjects rested for 20 minutes. Repeating this cycle of the measurement of energy expenditure and then resting, energy expenditure was measured 8 times in total. That is to say, the variation of energy metabolic rates was tracked at 8 measuring points during 300 minutes after the meal. The subjects were instructed to stay awake and stay as still as possible in a slightly reclined position during the measurements. They were allowed to read, watch TV (and videos) and listen to music. Throughout the research the room temperature was kept the same, and the subjects were allowed to use a blanket if they felt cold.

The oxygen and carbon dioxide concentrations collected from the subjects' expired gas were analyzed by a gas analyzer (NEC Medical Systems, Inc., Tokyo). The device's calibration was set with 100% nitrogen and reference gas (16.2% O_2 , 5.0% CO_2), and the device was checked with nitrogen and reference gas before every gas analysis. Expired gas was vacuumed out from the Douglas bag using a pump at a constant speed and its volume was measured by a gas meter. Energy expenditure was calculated using the Weir's formula (1949). To calculate DIT the energy expenditure increase after the meal was diachronically calculated using the resting metabolic rate before the meal as a baseline. The progress of its change was taken as the DIT curve. DIT (%) was calculated as the percentage of the accumulated value of energy expenditure increase during the 300 minutes after the meal, and the DIT (%) was for the energy load (2220kJ) from the test meal. Together with the DIT measurement; height, body weight and the percentage of body fat were also measured (Bioelectric impedance method, Tanita TBF-511, Tokyo).

Seasonality for each index was analyzed using a paired t-test or analysis of variance. SPSS 12.0 for Windows was used for a statistical analysis.

3. Results

Mean values for weight, BMI and the percentage of body fat are indicated according to each season in Table 1. The subjects for this study have 20kg/ m^2 average BMI and 27% average body fat percentage. These body figures are quite standard for young Japanese women for their age. Regarding seasonal change of weight, there was an average increase of 0.1kg, however, no statistically significant change could be observed. The results were similar for both the BMI and the percentage of body fat; the change in BMI was as insignificant as the change of weight. Therefore, it can be stated that there was no seasonal change in body figure for the test group. Table 1 also lists the resting metabolic rate and the DITs. No significant change was observed in the resting metabolic rate between the seasons, however, the DIT in winter showed significantly lower value than that of autumn ($p < 0.05$; paired t-test).

In Figure 1, increases in energy expenditure (DIT curve) after meal ingestion for each season are indicated. The winter curve is always located at a lower value compared to the autumn one, and it shows the tendency that DIT declines in winter. When a seasonal effect for the DIT curve was investigated using repeated measures 2-way analysis of variation, the main effects of 2 factors, which were the season and the time after meal ingestion showed the significance (both $p<0.05$, $p<0.001$)(Table 2). On the other hand, interaction (the season x time after meal ingestion) was not found to be significant.

The same measurements were taken from the 5 subjects among the 14 who were measured in summer prior to autumn start for the entire group. Due to small number of samples and they being limited, seasonal effects on DIT (%) were analyzed only for reference, using repeated measures analysis of variation (Table 3), and the main effect of "season" was found to be significant ($p<0.05$),

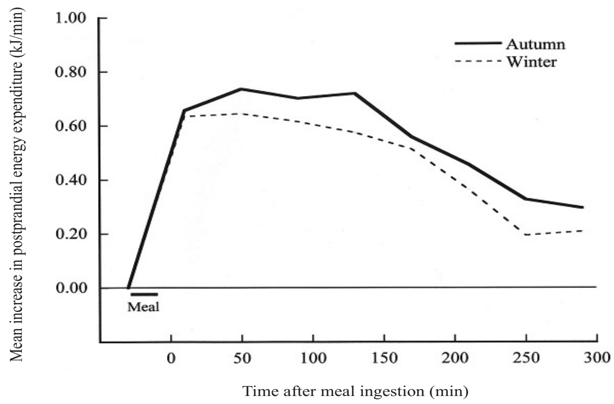

Figure 1 Mean increases in postprandial energy expenditure after test meal ingestion from autumn to winter (N=14). The parallel line is a baseline. Seasonal major effect was significant in ANOVA ($p<0.05$).

and the value was statistically lower in autumn compared to summer in terms of multiple comparison ($p<0.05$). The main effect was not significant between summer and winter, however, p value was close to 5% level ($p=0.06$). Also, in performing repeated measure 2-way analysis of variation for DIT curve, the main effect of season was close to the significance value (Figure 2), though it was slightly off the 5% level of significance ($p=0.06$).

4. Discussion

All measurements were performed in a room with the temperature maintained at 24 to 26℃ at all times for this study. It is well known that the resting metabolic rate will be affected and will change according to the

Table 1 Means and standard deviations for subjects' physical indices and energy metabolic indices in each season

Indices	Autumn	Winter	Differences between seasons
Physical characteristics			(Paired t-test)
Body weight (kg)	50.9 ± 6.4	51.0 ± 6.2	ns
Body mass index: BMI (kg/m^2)	20.1 ± 2.0	20.2 ± 1.9	ns
Percent body fat (%)	26.8 ± 5.4	27.1 ± 5.2	ns
Metabolic indices			
Resting metabolic rate as baseline (kJ/d)	5453 ± 753	5483 ± 687	ns
Diet-induced thermogenesis: DIT (%)	7.5 ± 1.3	6.4 ± 1.6	p < 0.05
Diet-induced thermogenesis: DIT (kJ)	167 ± 29	142 ± 36	p < 0.05

ns: not significant.

Table 2 Result of repeated measures 2-way analysis of variation on mean increase for postprandial energy expenditure (N=14)

Sources	Type Ⅲ Sum of square	d.f.	Mean square	F	p
Season	0.022	1	0.022	7.76	$p < 0.05$
Time after meal ingestion	0.377	7	0.054	37.29	$p < 0.001$
Season × Time after meal ingestion	0.005	7	0.001	0.77	ns
— Error —					
Season	0.037	13	0.003		
Time after meal ingestion	0.132	91	0.001		
Season × Time after meal ingestion	0.083	91	0.001		

ns: not significant.

Table 3 Result of repeated measures analysis of variation on DIT (%) (N=5)

Source	Type Ⅲ Sum of square	d.f.	Mean square	F	p	Multiple comparison 1)
Season	8.697	2	4.348	5.82	$p < 0.05$	S > A ($p < 0.05$)
Error	5.974	8	0.747			

1) S: Summer, A: Autumn

room temperature (Kashiwazaki, 1990). The indication of no seasonal change for resting metabolic rate as a baseline shows that the room temperature was under appropriate control. Also, the subjects' weights and body fat percentages from autumn to winter showed no major change, therefore, it can be inferred that neither their dietary nor physical exercise habits changed between seasons.

By contrast, the significant differences were observed in autumn and winter for DIT and DIT curve. From the fact that interaction of "the season x the time after meal ingestion" for DIT curve was not significant, it can be stated that DIT in winter declines, for the entire curve has a lower value at every point. Even in the analysis for 3 seasons, the main effect of season for DIT (%) was significant, after multiple comparison, though no difference was found in autumn and winter, a meaningful decline from summer to autumn was observed. Taking all of these results into consideration, it is possible to state that a tendency can be observed for DIT to decline from a warmer season to a colder season.

It is necessary to look at these results from a few different perspectives. First, regarding the possibility that a systematic error was included in measurement system, all measurements were performed with the exact same procedure for each season, and the analyzer's sensitivity was thoroughly checked. Even if there was any sort of systematic error when measuring energy expenditure, a

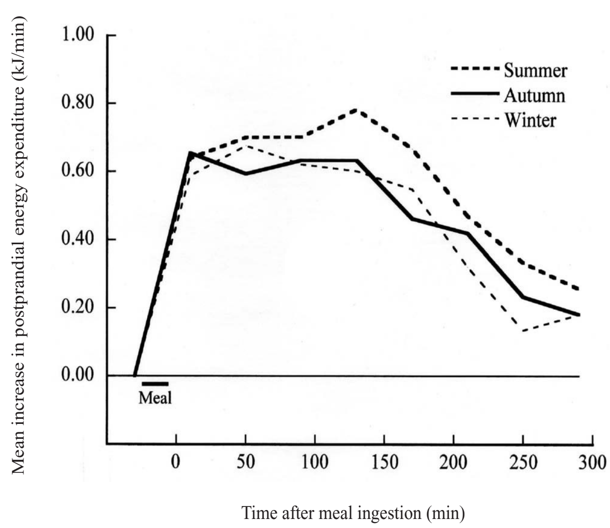

Figure 2 Mean increases in postprandial energy expenditure after test meal ingestion in summer, autumn and winter (N=5).

systematic error would not influence the DIT value easily in the calculation process that calculates DIT by taking the resting metabolic rate of that very day as a baseline. Therefore, it would be quite unlikely that a systematic error in measurement system could be a cause.

Regarding the conditions for the study, a possible seasonal difference is the temperature which the subjects were exposed to until they arrived at the measuring room on the experiment day. There was about a 10 °C difference between the seasons regarding the outdoor temperature, but it is not clear whether the outdoor temperature prior to the DIT measurement affected the DIT measurement, which was done later. In relation to the room temperature, the possibility cannot be denied that subjects might have felt the room temperature, which was maintained at a consistent temperature during the experiment, was rather different from the actual room temperature due to their acclimation to differing outdoor temperatures during each season.

Another possibility is that a reaction of DIT itself shows a biological change according to a season. There is no known study regarding DIT seasonal change at the time of this research. However, if there's seasonality for a reaction of DIT itself, it might relate to seasonality for energy balance or body weight. In order to explain a seasonal change from a biological aspect, it is necessary to identify biological factors that affect DIT, and have seasonal change. There are biological factors that are said to be related to DIT at the current time, such as sympathetic nervous system (Jung, 1979; Acheson, 1983) and insulin resistance (Ravussin and Zawadzki, 1987), and it is not clear if these factors will be influenced by season.

This study could not specify the cause of seasonal effect, however, considering seasonality on DIT measurement is necessary for longitudinal studies on DIT, especially on interventional study. There have been different research results reported on DIT effect in relation to body weight regulation, but there is a possibility that seasonality worked as a confounding variable, and therefore distorting the true findings.

In conclusion, there is a possibility that season affects DIT measurement; DIT in winter declines compared to autumn. It is necessary to consider seasonality in the study of DIT.

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