Hypertension Research (2010) 33, 568–572

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ORIGINAL ARTICLE

Seasonal variation in metabolic syndrome prevalence

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Accumulating evidence has shown that seasonal variations can exist within metabolic syndrome parameters. The aim of this study was to examine the hypothesis that there are seasonal variations in the prevalence of metabolic syndrome in Japanese subjects. We investigated a total of 1202 male workers in our institution (44 ± 10 years) who underwent health checkups in both June (summer) and December (winter) 2008. In this study, metabolic syndrome was defined according to the criteria proposed by the National Cholesterol Education Program (NCEP), the International Diabetes Federation (IDF) and the Japanese Society of Internal Medicine (JSIM). Serum levels of high-density lipoprotein-cholesterol and fasting glucose, as well as blood pressure (BP), were significantly higher in winter than in summer, whereas waist circumference and serum levels of triglyceride exhibited little change. The prevalence rates of NCEP, IDF, and JSIM metabolic syndrome in this study were 3.8, 15.1 and 12.4% in winter and 3.2, 10.7 and 8.4% in summer, respectively. Of all metabolic syndrome components, an elevated BP was most significantly correlated with the seasonal variation of metabolic syndrome prevalence. This study demonstrated seasonal variations in metabolic syndrome prevalence in Japanese male workers. These results indicate that the season of health checkups may affect the clinical diagnosis and management of metabolic syndrome.

Hypertension Research (2010) **33,** 568–572; doi:10.1038/hr.2010.32; published online 19 March 2010

Keywords: blood pressure; metabolic syndrome; seasonal variation; winter

INTRODUCTION

Metabolic syndrome is highly associated with the presence of abdominal obesity and is noted worldwide as a possible cause of atherosclerotic cardiovascular disease.[1–3] This syndrome has also been the focus of much attention in the scientific literature, because major organizations such as the National Cholesterol Education Program (NCEP) and the International Diabetes Federation (IDF) have each released separate diagnostic criteria.[4,5] Such organizations have proposed that metabolic syndrome can be clinically diagnosed using a clustering of simple measurements, including waist circumference (WC), triglyceride (TG), high-density lipoprotein-cholesterol (HDL-C), blood pressure (BP) and fasting glucose. It is important to recognize that there are seasonal variations in these metabolic parameters, which may affect the assessment of this syndrome. Accumulating evidence has shown that seasonal variations exist in the metabolic parameters.[6–10] These variations usually have a tendency to be higher in fall and winter than in spring and summer. It is believed that physical activities and cold acclimatization may affect these variations.[7–9] For example, cold increases BP through increases in sympathetic tone. However, little is known about the relationship between seasonal variations in metabolic parameters and metabolic syndrome prevalence. Therefore, we hypothesized that there is a strong relationship between seasonal variations in metabolic parameters and seasonal variations in metabolic syndrome prevalence. To elucidate this hypothesis, we assessed Japanese male workers in summer and winter.

METHODS

Study subjects

We investigated a total of 1202 male workers (20–69 years) belonging to the Nuclear Science Research Institute, Tokai Research and Development Center, Japan Atomic Energy Agency, who underwent health checkups in both June (summer) and December (winter) 2008. In this study, we excluded female workers owing to a smaller number of possible participants (n=141). In addition, male subjects who were taking medications for hypercholesterolemia, hypertension and diabetes mellitus were also excluded, because the study results might have been influenced by these drugs. All subjects had a negative history of coronary artery disease, stroke or cancer. At each checkup, demographic data and health information were collected by self-administered questionnaires, and all participants were subjected to a physical examination assessing height, weight, WC and BP. Resting BP in a sitting position was measured by trained technicians using a standard mercury sphygmomanometer. Venous blood samples were collected from each subject after 9 h or overnight fasting.

This study was conducted in accordance with the guidelines expressed in the Declaration of Helsinki and approved by the institutional committee.

Definition of metabolic syndrome

In this study, metabolic syndrome was defined according to the criteria proposed by NCEP, IDF and the joint committee of eight Japanese medical societies, including the Japanese Society of Internal Medicine (JSIM).[4,5,11] The NCEP criteria are as follows: Subjects with more than three of the following components are considered to have NCEP metabolic syndrome: (1) abdominal obesity defined as WC $>$102 cm; (2) high TG defined as TG $\geqslant$150 mg per 100 ml; (3) low HDL-C defined as HDL-C $<$40 mg per 100 ml; (4) elevated BP

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Received 17 November 2009; revised 29 January 2010; accepted 1 February 2010; published online 19 March 2010

defined as BP ⩾130/85 mm Hg; and (5) high glucose defined as fasting glucose ⩾110 mg per 100 ml. The sole criterion for IDF diagnosis is abdominal obesity defined as WC ⩾85 cm. In addition, subjects with more than of the resting components of the NCEP criteria receive a diagnosis of IDF metabolic syndrome, for which high glucose is defined as fasting glucose ⩾100 mg per 100 ml. The sole criterion for JSIM diagnosis is identical to that of IDF. In addition, subjects with more than two of the following components are considered to have JSIM metabolic syndrome: (1) high TG defined as TG ⩾150 mg per 100 ml or low HDL-C defined as HDL-C <40 mg per 100 ml; (2) elevated BP defined as BP ⩾130/85 mm Hg; and (3) high glucose defined as fasting glucose ⩾110 mg per 100 ml.

Data analysis

Continuous data are expressed as means ± s.d. Categorical data are presented as absolute values and percentages. Comparison of continuous variables was performed by ANCOVA (analysis of covariance) with age as a covariate. Comparison of categorical variables was evaluated by χ^2 analysis. ANOVA (analysis of variance) was used for multiple comparisons, followed by the Tukey–Kramer *post hoc* test. Values of $P<0.05$ were considered statistically significant. Statistical analysis was performed using the JMP Statistical Discovery Software for Windows version 7 (SAS Institute, Cary, NC, USA).

RESULTS

Characteristics of study subjects

The characteristics of the study subjects in summer are shown in Table 1. The mean levels of low-density lipoprotein-cholesterol, urea nitrogen, creatinine, uric acid, hemoglobin and hematocrit were within the normal range. Current smokers comprised 23.4% of the study population. Serum levels of low-density lipoprotein-cholesterol were markedly higher in winter than in summer (131 ± 31 *vs.* 127 ± 30 mg per 100 ml, $P=0.0033$).

Seasonal variations in metabolic parameters

The metabolic parameters of all subjects were assessed in both summer and winter. The seasonal variations in metabolic parameters are listed in Table 2. Serum levels of HDL-C and fasting glucose were significantly higher in winter than in summer ($P=0.0006$, $P=0.0010$), whereas WC and serum levels of TG did not differ ($P=0.4526$, $P=0.4430$). In particular, systolic and diastolic BP levels were significantly higher in winter than in summer (systolic BP: 129 ± 14 *vs.* 125 ± 14 mm Hg, $P<0.0001$; diastolic BP: 78 ± 10 *vs.* 70 ± 11 mm Hg, $P<0.0001$; respectively). The seasonal amplitudes in systolic and diastolic BP were greater in subjects having WC ⩾85 cm (127 ± 14/72 ± 11 mm Hg in summer and 132 ± 15/81 ± 10 mm Hg in winter) than in subjects with WC <85 cm (123 ± 14/69 ± 10 mm Hg in summer and 127 ± 14/76 ± 10 mm Hg in winter).

Table 1 Characteristics of study subjects

Characteristics	n=*1202*
Age, years	44 ± 10
Body mass index, kg m^{-2}	23.6 ± 3.0
LDL-cholesterol, mg per 100 ml	127 ± 30
Urea nitrogen, mg per 100 ml	14.1 ± 3.2
Creatinine, mg per 100 ml	0.85 ± 0.12
Uric acid, mg per 100 ml	5.9 ± 1.1
Hemoglobin, g per 100 ml	14.9 ± 1.0
Hematocrit, %	44.6 ± 2.8
Current smoker, *n* (%)	281 (23.4)

Abbreviation: LDL, low-density lipoprotein.
Data are expressed as mean ± s.d. or number (%).

Table 2 Seasonal variations in metabolic parameters

	Summer	*Winter*	P-*value*
Waist circumference, cm	83.4 ± 8.2	83.6 ± 8.2	0.4526
Triglyceride, mg per 100 ml	113 ± 75	115 ± 69	0.4430
HDL-C, mg per 100 ml	62 ± 16	65 ± 17	0.0006
Systolic BP, mm Hg	125 ± 14	129 ± 14	<0.0001
Diastolic BP, mm Hg	70 ± 11	78 ± 10	<0.0001
Fasting glucose, mg per 100 ml	89 ± 16	91 ± 16	0.0010

Abbreviations: BP, blood pressure; HDL-C, high-density lipoprotein-cholesterol.
All data are expressed as mean ± s.d.

Seasonal variations in metabolic syndrome prevalence

In this study, we used several criteria to evaluate the consistency of seasonal variations in metabolic syndrome prevalence. Seasonal variations in the prevalence of NCEP, IDF and JSIM metabolic syndrome are shown in Figure 1. The prevalence rates of NCEP, IDF and JSIM metabolic syndrome in this study was 3.8, 15.1 and 12.4% in winter and 3.2, 10.7 and 8.4% in summer, respectively ($P=0.3743$, $P=0.0012$, $P=0.0010$, respectively). The significant differences in prevalence data between NCEP criteria and the other criteria were considered to be dependent on differences in WC measurements because the prevalence of modified NCEP metabolic syndrome was 10.3% in summer and 14.0% in winter when the reference level of WC measurements was changed from >102 to ⩾85 cm. Seasonal frequencies of the metabolic syndrome components are shown in Figure 2. Frequencies of abdominal obesity, high TG or low HDL-C component were comparable in the two seasons and therefore had little impact on seasonal variations of metabolic syndrome prevalence. The frequency of elevated BP component increased from 37.4% ($n=450$) in summer to 49.3% ($n=592$) in winter ($P<0.0001$), which was related to seasonal variations of NCEP, IDF and JSIM metabolic syndrome prevalence. In addition, 93.5, 87.8 and 90.0% of subjects having NCEP, IDF and JSIM metabolic syndrome, respectively, had elevated BP component in winter. Moreover, the seasonal frequency of high glucose component had a greater impact on the seasonal variation of IDF metabolic syndrome prevalence itself. The frequency of high glucose component defined as fasting glucose ⩾100 mg per 100 ml increased from 9.2% ($n=110$) in summer to 13.8% ($n=166$) in winter ($P=0.0003$), although that defined as glucose ⩾110 mg per 100 ml was comparable in both the seasons ($P=0.4674$).

Influence of age and smoking status on metabolic syndrome prevalence

Seasonal variations in metabolic syndrome prevalence could be substantially influenced by age (Figure 3). The frequency of metabolic syndrome occurrence in subjects aged ⩾40 years was significantly higher than that in subjects <40 years of age in either season. Moreover, in subjects aged ⩾40 years, the prevalence of IDF and JSIM metabolic syndrome significantly increased from 13.0 and 10.3% in summer to 19.1 and 15.8% in winter, respectively ($P<0.01$, $P<0.01$), whereas that of NCEP metabolic syndrome did not differ (4.0% in summer and 5.0% in winter). On the other hand, there was no relationship between smoking status and metabolic syndrome prevalence.

DISCUSSION

In this study, we showed that there are seasonal variations in metabolic syndrome prevalence in Japanese male workers, mainly due to a higher proportion of elevated BP component defined as BP ⩾130/85 mm Hg

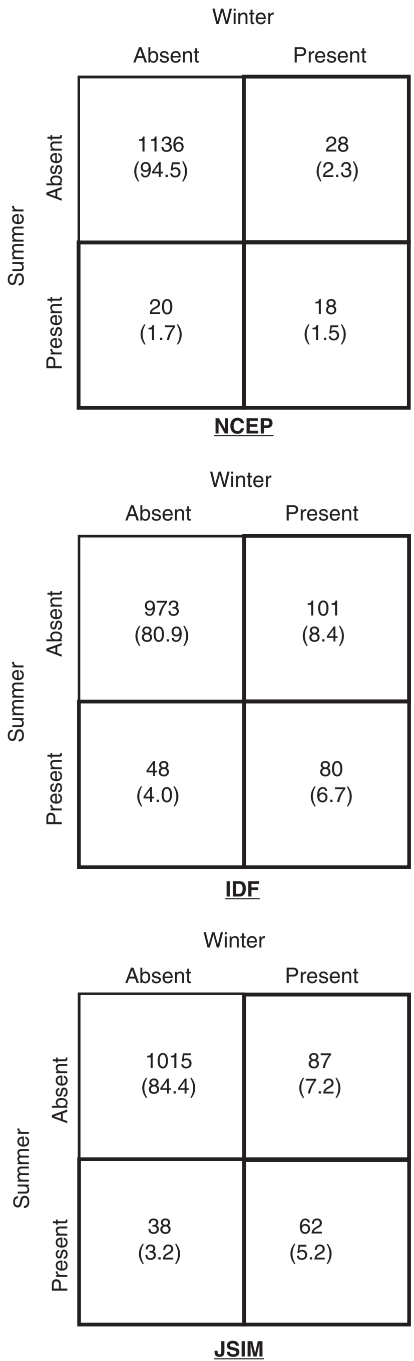

Figure 1 Seasonal prevalence of NCEP, IDF and JSIM metabolic syndrome.

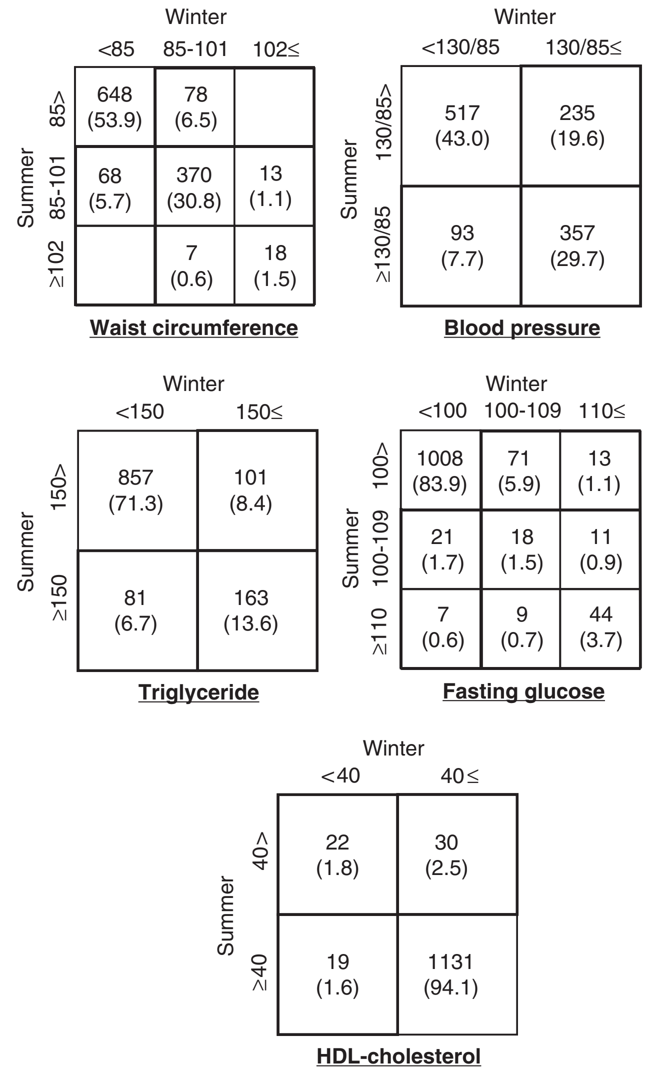

Figure 2 Seasonal frequencies in metabolic syndrome components.

in winter. This result provides direct support to the notion that seasonal variation in metabolic parameters, especially in BP, affects a diagnosis of metabolic syndrome.

Metabolic syndrome is a risk factor for atherosclerotic cardiovascular disease and consists of atherogenic dyslipidemia, elevated BP, increased glucose concentration, as well as prothrombotic and proinflammatory states.[12] The criteria of major organizations such as NCEP and IDF are that metabolic syndrome can be diagnosed clinically using a cluster of simple measurements, including WC, TG, HDL-C, BP and fasting glucose. However, despite accumulating evidence of seasonal variations in these metabolic parameters, these variations are not included, even in the criteria of these international organizations. A large cross-sectional study reported that systolic BP decreases with increasing air temperature, with an 8.0 mm Hg difference between the lowest and the highest air temperature quintile.[8] There are also seasonal variations in serum levels of TG, HDL-C and fasting glucose. Many studies have shown that lipids including TG, HDL-C and low-density lipoprotein-cholesterol have a tendency to be higher in fall and winter than in spring and summer, although this phenomenon is not fully understood. Studies examining the role of body mass index, diet and physical activity have reported that these variables do not fully explain the variation between seasons.[13,14] On the other hand, Ockene *et al.*[7] reported a possible mechanism in which a change of blood volume due to fluctuations in environmental temperature and/or physical activity can contribute to accompanying variations in lipid levels. Thus, these findings suggest that the seasons in which patient health assessments are performed may affect the clinical diagnosis of metabolic syndrome. However, the seasonal variations in metabolic syndrome prevalence are yet to be fully elucidated.

There are several important findings in this study. First, there are seasonal variations in metabolic syndrome prevalence in Japanese male workers regardless of NCEP, IDF or JSIM criteria. This study

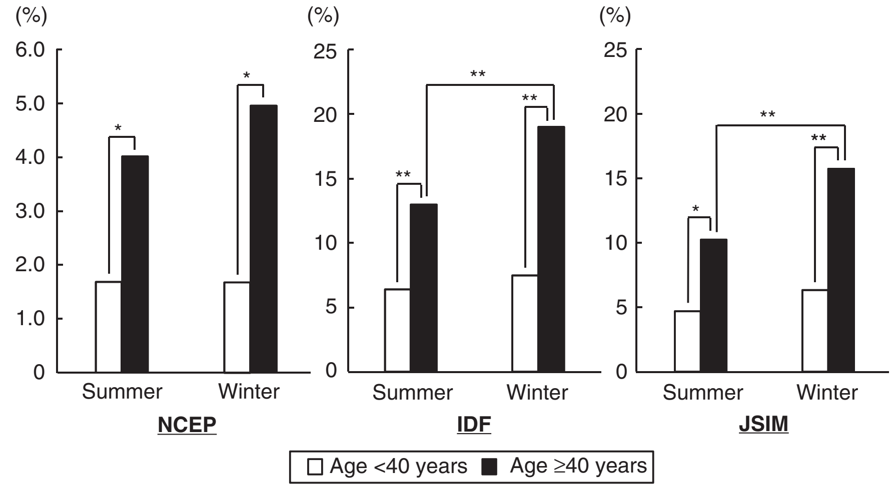

Figure 3 Seasonal prevalence of NCEP, IDF and JSIM metabolic syndrome in subjects aged <40 years (n=423) or $\geqslant 40$ years (n=779). *$P<0.05$, **$P<0.01$ by the Tukey–Kramer *post hoc* test.

showed that 0.6, 4.4 and 4.0% of subjects met the NCEP, IDF and JSIM criteria, respectively, for diagnosis more often in winter than in summer, and that the variations were observed predominantly in subjects aged $\geqslant$40 years. In Japan, the specific guidelines for health checkups and guidance were initiated in 2008 to prevent lifestyle-related diseases, with a focus on metabolic syndrome. The 2006 Japan National Health and Nutrition Examination Survey reported that metabolic syndrome prevalence was presumed to be found in ~25.5% of Japanese males, or 6.55 million subjects who were 40–75 years of age. Therefore, the particular season in which health checkups are conducted may produce misclassification of metabolic syndrome, especially in Japanese males. Second, both systolic and diastolic BP levels were markedly elevated in winter, although cold temperatures increase systolic BP predominantly through increases in sympathetic tone. On the basis of meteorological data obtained from the Mito Local Meteorological Observatory, the mean monthly air temperature in this area was 19.0 °C in June and 1.7 °C in December 2008. Seasonal amplitudes in systolic and diastolic BP were 5 and 9 mm Hg, respectively, in study subjects with abdominal obesity. These values were significantly higher in subjects with a diagnosis of abdominal obesity. This information may be of use to clinicians in deciding how they should approach risk assessment in subjects with abdominal obesity and/or metabolic syndrome, as well as how aggressively to treat a patient based on the season. Many meta-analyses have shown that BP control is very important for cardiovascular outcomes.[15–17] The INTERSALT study reported that decreasing systolic BP by at least 2.2 mm Hg is associated with a 4% lower risk of coronary death and a 6% lower risk of stroke death in middle age.[18] Moreover, many studies have shown that morbidity and mortality of cardiovascular disease are higher in winter than in seasons.[19,20] We propose that strict management of the seasonal BP variability has a key role in the prevention of cardiovascular disease, and health checkups are more useful when they are conducted in the winter season. However, further studies are required to clarify the clinical implications of the relationship between BP variability and the season of health checkups. Finally, many subjects with metabolic syndrome have insufficient control of risk factors, especially BP. In this study, the majority of subjects with metabolic syndrome in winter had BP $\geqslant$130/85 mm Hg. Recent treatment guidelines have incorporated the concept of global risk assessment and management to improve long-term outcomes.[21] On the basis of such recommendations, we may have to aggressively manage medications for subjects with metabolic syndrome, although lifestyle managements (such as weight reduction, smoking cessation, increased physical activity and diet modification) are very important in clinical practice.

Study limitations

There are some limitations to this study. First, our study was conducted in a single year; an extended observation period will be necessary for further research. Second, these study results might not be consistent with those of a similar study intended for Japanese females. For a better understanding of the seasonal variations in metabolic syndrome prevalence, these effects should be confirmed in Japanese females. Third, we could not investigate differences in diet, physical activities and psychotropic medications of the study subjects. The differences between summer and winter results in study subjects may influence metabolic syndrome parameters and prevalence to some extent. Finally, this study could not determine whether the variations have a role in cardiovascular disease. We hope to conduct further studies in the near future to understand the effect of these variations in the clinical arena.

CONCLUSIONS

We showed that there were seasonal variations in metabolic syndrome prevalence in Japanese male workers. These results indicate that the season in which health checkups are conducted may affect the clinical diagnosis and management of metabolic syndrome. We propose that seasonal variations in metabolic components and metabolic syndrome prevalence should be taken into consideration in annual health checkups.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

This work has not been published previously, in whole or in part. In addition, no support was received.

1 Gami AS, Witt BJ, Howard DE, Erwin PJ, Gami LA, Somers VK, Montori VM. Metabolic syndrome and risk of incident cardiovascular events and death: a systematic review and meta-analysis of longitudinal studies. *J Am Coll Cardiol* 2007; **49**: 403–414.

2 Takeuchi H, Saitoh S, Takagi S, Ohnishi H, Ohhata J, Isobe T, Shimamoto K. Metabolic syndrome and cardiac disease in Japanese men: applicability of the concept of metabolic syndrome defined by the National Cholesterol Education Program-Adult Treatment Panel III to Japanese men–The Tanno and Sobetsu Study. *Hypertens Res* 2005; **28**: 203–208.
3 Grundy SM. Metabolic syndrome pandemic. *Arterioscler Thromb Vasc Biol* 2008; **28**: 629–636.
4 Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, Gordon DJ, Krauss RM, Savage PJ, Smith Jr SC, Spertus JA, Costa F, American Heart Association National Heart, Lung, and Blood Institute. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation* 2005; **112**: 2735–2752.
5 Alberti KG, Zimmet P, Shaw J, IDF Epidemiology Task Force Consensus Group. The metabolic syndrome—a new worldwide definition. *Lancet* 2005; **366**: 1059–1062.
6 Yanovski JA, Yanovski SZ, Sovik KN, Nguyen TT, O'Neil PM, Sebring NG. A prospective study of holiday weight gain. *N Engl J Med* 2000; **342**: 861–867.
7 Ockene IS, Chiriboga DE, Stanek 3rd EJ, Harmatz MG, Nicolosi R, Saperia G, Well AD, Freedson P, Merriam PA, Reed G, Ma Y, Matthews CE, Hebert JR. Seasonal variation in serum cholesterol levels: treatment implications and possible mechanisms. *Arch Intern Med* 2004; **164**: 863–870.
8 Alpérovitch A, Lacombe JM, Hanon O, Dartigues JF, Ritchie K, Ducimetière P, Tzourio C. Relationship between blood pressure and outdoor temperature in a large sample of elderly individuals: the Three-City study. *Arch Intern Med* 2009; **169**: 75–80.
9 Hayashi T, Ohshige K, Sawai A, Yamasue K, Tochikubo O. Seasonal influence on blood pressure in elderly normotensive subjects. *Hypertens Res* 2008; **31**: 569–574.
10 Liang WW. Seasonal changes in preprandial glucose, A1C, and blood pressure in diabetic patients. *Diabetes Care* 2007; **30**: 2501–2502.
11 Committee to evaluate diagnostic standards for metabolic syndrome. Definition and, the diagnostic, standard for, metabolic syndrome. *Jpn Soc Intern Med* 2005; **94**: 794–809. (in Japanese).
12 Grundy SM. Metabolic syndrome: a multiplex cardiovascular risk factor. *J Clin Endocrinol Metab* 2007; **92**: 399–404.
13 Rastam L, Hannan PJ, Luepker RV, Mittelmark MB, Murray DM, Slater JS. Seasonal variation in plasma cholesterol distributions: implications for screening and referral. *Am J Prev Med* 1992; **8**: 360–366.
14 Matthews CE, Freedson PS, Hebert JR, Stanek 3rd EJ, Merriam PA, Rosal MC, Ebbeling CB, Ockene IS. Seasonal variation in household, occupational, and leisure time physical activity: longitudinal analyses from the seasonal variation of blood cholesterol study. *Am J Epidemiol* 2001; **153**: 172–183.
15 Miura K, Nakagawa H, Ohashi Y, Harada A, Taguri M, Kushiro T, Takahashi A, Nishinaga M, Soejima H, Ueshima H, Japan Arteriosclerosis Longitudinal Study (JALS) Group. Four blood pressure indexes and the risk of stroke and myocardial infarction in Japanese men and women: a meta-analysis of 16 cohort studies. *Circulation* 2009; **119**: 1892–1898.
16 Shimada K, Fujita T, Ito S, Naritomi H, Ogihara T, Shimamoto K, Tanaka H, Yoshiike N. The importance of home blood pressure measurement for preventing stroke and cardiovascular disease in hypertensive patients: a sub-analysis of the Japan Hypertension Evaluation with Angiotensin II Antagonist Losartan Therapy (J-HEALTH) study, a prospective nationwide observational study. *Hypertens Res* 2008; **31**: 1903–1911.
17 Shimamoto K, Fujita T, Ito S, Naritomi H, Ogihara T, Shimada K, Tanaka H, Yoshiike N, J-HEALTH Study Committees. Impact of blood pressure control on cardiovascular events in 26 512 Japanese hypertensive patients: the Japan Hypertension Evaluation with Angiotensin II Antagonist Losartan Therapy (J-HEALTH) study, a prospective nationwide observational study. *Hypertens Res* 2008; **31**: 469–478.
18 Stamler J, Rose G, Stamler R, Elliott P, Dyer A, Marmot M. INTERSALT study findings. Public health and medical care implications. *Hypertension* 1989; **14**: 570–577.
19 Kloner RA, Poole WK, Perritt RL. When throughout the year is coronary death most likely to occur? A 12-year population-based analysis of more than 220 000 cases. *Circulation* 1999; **100**: 1630–1634.
20 Rumana N, Kita Y, Turin TC, Murakami Y, Sugihara H, Morita Y, Tomioka N, Okayama A, Nakamura Y, Ueshima H. Seasonal pattern of incidence and case fatality of acute myocardial infarction in a Japanese population (from the Takashima AMI Registry, 1988 to 2003). *Am J Cardiol* 2008; **102**: 1307–1311.
21 Ogihara T, Kikuchi K, Matsuoka H, Fujita T, Higaki J, Horiuchi M, Imai Y, Imaizumi T, Ito S, Iwao H, Kario K, Kawano Y, Kim-Mitsuyama S, Kimura G, Matsubara H, Matsuura H, Naruse M, Saito I, Shimada K, Shimamoto K, Suzuki H, Takishita S, Tanahashi N, Tsuchihashi T, Uchiyama M, Ueda S, Ueshima H, Umemura S, Ishimitsu T, Rakugi H, Japanese Society of Hypertension Committee. The Japanese Society of Hypertension Guidelines for the Management of Hypertension (JSH 2009). *Hypertens Res* 2009; **32**: 3–107.