Impact of lifestyle habits and body composition on glucose dysregulation

Chizumi YAMADA^{1, 2, 4} Emiko KIKUCHI^{1, 2} Noriaki KISHIMOTO^{1, 3, 4} Tamae OGATA^{1, 2}
Emiko KURODA^{1, 2} Akira KUBO^{1, 2} Ichiro KUWAHIRA² Yutaka SHIINA^{1, 2}
Naoaki ISHII⁴ Yasuhiro NISHIZAKI^{1, 3, 4}

¹Department of Clinical Health Science, Tokai University School of Medicine

²Tokai University Tokyo Hospital

³Tokai University Hospital

⁴Life Care Center, Graduate School of Medicine, Tokai University

ABSTRACT

Objective Excessive caloric intake and a sedentary lifestyle are well-known risk factors for incident diabetes. The aim of this study was to determine if body composition, nutrient intake and daily energy expenditure values had any impact on glucose regulation.

Methods A total of 81 subjects (49 men and 32 women) who underwent anti-aging health checks at Tokai University Tokyo Hospital were enrolled in this study. Body composition was evaluated using whole-body dual-energy X-ray absorptiometry. A food frequency questionnaire (FFQ) was used to estimate nutrient intake and energy expenditure values.

Results The subjects were not obese on average in BMI. Percentage of body fat showed a significantly positive correlation with fasting glucose in both men and women. The relationship between energy intake and fasting glucose remained inconclusive in this study. There was a significantly negative correlation between fasting glucose and daily energy expenditure in men, and resting energy expenditure in women, but not energy expenditure of exercise in both men and women.

Conclusion The present study shows that subclinical glucose dysregulation was associated with decreased energy expenditure other than exercise and increased percentage of body fat, rather than excessive energy intake and/or decreased physical activity in the anti-aging checkup examinees. We strongly emphasize the importance of evaluating body composition to detect early signs of metabolic changes, because subjects with sarcopenic obesity are at high risk of developing lifestyle-related diseases including type 2 diabetes. (HEP. 2017; 44: 594-599.)

Key words Type 2 diabetes, body composition, sarcopenic obesity, lifestyle habits, anti-aging health checkup system

INTRODUCTION

Excessive caloric intake and a sedentary lifestyle are well-known risk factors for incident diabetes. In addition to the calories themselves, some types of nutrition are associated with the development of diabetes. White rice is rich in carbohydrates and a staple food in Asian countries. A meta-analysis including the Japanese population has shown that higher consumption of white rice is associated with a significantly increased risk of type 2 diabetes, especially in Asian (Chinese and Japanese) populations¹⁾. A dose-response relationship between white rice intake and diabetes risk was observed and the relative risk of type 2 diabetes was 1.11 for each incremental serving (158 g) per day of white rice intake¹⁾. Saturated fat is also known as a risk factor for diabetes²⁾. On the other hand, dietary fiber, for example eating whole grains, has been shown to reduce the risk of type 2 diabetes³⁾.

A sedentary lifestyle, such as prolonged television watching, has been proven to increase the risk of obesity and type 2 diabetes⁴⁾. Conversely, type 2 diabetes can be prevented in high-risk subjects by regular physical exercise⁵⁻⁷⁾. A study of Japanese males showed that mild physical activity (i.e., walking to work ≥ 21 min) reduces the risk of type 2 diabetes⁸⁾. The association between physical activity of moderate intensity and the risk of type 2 diabetes was systematically evaluated, and it was shown that adherence to recommendations to participate in physical activities of moderate intensity (3.0–6.0 METs) such as brisk walking can substantially reduce the risk of type 2 diabetes⁹⁾.

Since its foundation in June 2006, Tokai University Tokyo Hospital has conducted anti-aging checkups^{10, 11)} of over 1,900 examinees. Analysis of the health data from these checkups over a decade revealed some age-related factors, such as sarcopenic obesity, which is defined as a normal body mass index (BMI) with excessive body fat. Our analysis of the anti-aging checkup examinees revealed that those with sarcopenic obesity had an elevated risk for lifestyle-related diseases equal to that of obese people¹²⁾. Thus, not only BMI, but also body composition is important for detecting early signs of metabolic changes.

The aim of this study was to determine if lifestyle habits and body composition had any impact on glucose regulation. Data on

Received: April 28, 2017, Accepted: May 22, 2017

Corresponding author: Prof. Yasuhiro Nishizaki

¹Address: Tokai University Hospital

143 Shimokasuya, Isehara, Kanagawa 259-1193, Japan

TEL: +81-463-93-1121, FAX: +81-463-93-1661

E-mail: y-nishizaki@tokai.ac.jp

whole-body dual-energy X-ray absorptiometry (DXA) measurement, nutrient intake and daily energy expenditure values, as well as clinical parameters of lifestyle-related diseases were compared with or without fasting glucose abnormalities.

SUBJECTS AND METHODS

1. Subjects

A total of 81 subjects (49 men and 32 women) aged between 38 and 84 years who underwent anti-aging health checks at Tokai University Tokyo Hospital were enrolled in the study. The surveillance period was from April to September 2015. All subjects gave written informed consent to the use of their health records for analysis. This study was approved by the Ethics Committee of Tokai University, and was conducted in accordance with the Declaration of Helsinki.

2. Measurements

Anthropometric measurements were performed and blood samples were obtained after overnight fasting. Of the measurements included in the anti-aging health check examinations¹¹⁾, the following parameters were used for analysis: BMI, waist circumference, systolic blood pressure (BP), fasting glucose, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides, and adiponectin. Height and weight were measured in the standing position, and BMI was calculated as weight/height² (kg/m²). Waist circumference was assessed at the end of expiration by measuring the minimum circumference at the level of the umbilicus. Body fat mass, fat-free mass and percentage of body fat (% body fat) were evaluated using whole-body DXA (Prodigy; GE Healthcare Japan, Tokyo, Japan). BP was measured in the sitting position. Serum level of high molecular weight adiponectin was measured using a latex particle-enhanced turbidimetric immunoassay (LTIA)¹³⁾.

3. Evaluation of dietary nutrient intake and energy expenditure

A food frequency questionnaire (FFQ; Kenpakusya, Tokyo, Japan) validated by Takahashi *et al.*¹⁴⁻¹⁶⁾ was used to calculate nutrient intake. The FFQ used in the present study included questions on the consumption of various food items over the previous one or two months. Daily nutrient intake was calculated by multiplying the consumption frequency of each food by the nutrient content of the portion size, and summing the products for all food items. Daily energy expenditure, resting energy expenditure and energy expenditure of exercise were also estimated using the FFQ. Energy expenditure values were estimated by reporting the hours of the following behaviors in a day (sleeping, lying or sitting, sedentary work, slow walking or housework, light activity, moderate physical activity and vigorous physical activity excluding that of daily living). Based on the self-reported data on duration and intensity, the daily energy expenditure (kcal/day), resting energy expenditure (kcal/day) and energy expenditure of exercise (kcal/day) were calculated according to the instructions accompanying the FFQ.

4. Statistical analysis

Data is expressed as mean $\pm$ standard deviation (SD). SPSS Statistics (Version 22.0; SPSS Inc.) was used for the statistical

analyses. Pearson's correlation coefficient was calculated as a measure of association between fasting glucose and clinical parameters. Statistical significance of comparisons between the fasting glucose <110 group and the fasting glucose $\geq$ 110 group was determined by Student's *t*-test. All *p*-values were two-tailed, and *p* < 0.05 was considered significant.

RESULTS

Clinical characteristics, laboratory data, nutrient intake and energy expenditure of the subjects are shown in **Table 1**. The study subjects consisted of 49 men and 32 women, including 7 well-controlled diabetic subjects (6 men and 1 woman). The mean age was 62.8 ± 12.3 for men and 64.3 ± 12.0 for women. The average fasting glucose level was higher in men (102.6 ± 13.8 mg/dL) than in women (93.4 ± 9.6 mg/dL). The subjects were not obese on average (BMI 23.1 ± 2.5 kg/m² for men and 20.4 ± 2.6 kg/m² for women), and the average percent body fat was $24.1 \pm 5.8\%$ for men and $27.8 \pm 7.2\%$ for women. The mean systolic BP, HDL-C, LDL-C, triglycerides and adiponectin values were within the normal ranges. Dietary intake of total calories, carbohydrate, protein, fat, saturated fat, fiber and salt was compatible with that of the National Health and Nutrition Survey in both men and women¹⁷⁾. Daily energy expenditure values were slightly higher than daily caloric intake values in both men and women. Energy expenditure of exercise was 356.0 ± 248.4 kcal/day for men and 327.3 ± 240.5 kcal/day for women.

The correlations between fasting glucose and clinical parameters are shown in **Table 2**. Fasting glucose was significantly positively correlated with body fat mass in men. It was significantly negatively correlated with fat-free mass in women. The percentage of body fat showed a significantly positive correlation with fasting glucose in both men and women. Fasting glucose was significantly negatively correlated with adiponectin in men, and significantly positively correlated with systolic BP in women. The influence of dietary nutrient intake on glucose level was insignificant in men. In women, fasting glucose was significantly positively correlated with intake of protein, fat, saturated fat and salt in women, although daily caloric intake showed no significant correlation with fasting glucose. There was a significantly negative correlation between fasting glucose and daily energy expenditure in men, and resting energy expenditure in women, but not energy expenditure of exercise in both men and women.

Next, we compared clinical characteristics between the fasting glucose <110 group and the fasting glucose $\geq$ 110 group (**Tables 3 and 4**). Compared with the fasting glucose <110 group, the fasting glucose $\geq$ 110 group was significantly lower in fat-free mass, adiponectin, daily energy expenditure and resting energy expenditure, and significantly higher in triglycerides in men (**Table 3**). In women, although the number of subjects with fasting glucose $\geq$ 110 may be too small to achieve statistical significance, intake of calories, protein, fat, saturated fat and salt was higher and resting energy expenditure was lower in the fasting glucose $\geq$ 110 group (**Table 4**). In both men and women, the influence of energy expenditure of exercise was insignificant.

Table 1 Background characteristics of the study subjects

	Men	Women
Number of subjects	49	32
Age (years)	62.8 ± 12.3	64.3 ± 12.0
Fasting glucose (mg/dL)	102.6 ± 13.8	93.4 ± 9.6
BMI (kg/m ²)	23.1 ± 2.5	20.4 ± 2.6
Waist circumference (cm)	87.1 ± 7.3	78.4 ± 7.9
Body fat mass (kg)	16.3 ± 5.2	12.5 ± 4.3
Fat-free mass (kg)	48.0 ± 4.2	34.0 ± 3.9
Percent body fat (%)	24.9 ± 6.2	26.5 ± 7.5
Systolic BP (mmHg)	122.9 ± 14.7	123.3 ± 19.7
LDL-C (mg/dL)	116.4 ± 20.6	126.6 ± 31.7
HDL-C (mg/dL)	59.3 ± 14.0	75.2 ± 14.9
Triglyceride (mg/dL)	95.8 ± 36.8	77.3 ± 38.0
Adiponectin (μg/mL)	8.8 ± 4.2	16.9 ± 10.4
Dietary nutrient intake		
Energy (kcal/day)	1,930.7 ± 489.2	1,742.9 ± 380.2
Carbohydrate (g/day)	245.2 ± 63.8	224.8 ± 49.4
Protein (g/day)	71.1 ± 21.6	64.9 ± 16.4
Fat (g/day)	62.5 ± 22.2	59.2 ± 17.4
Saturated fat (g/day)	19.1 ± 8.2	18.7 ± 6.7
Fiber (g/day)	13.9 ± 4.4	14.3 ± 4.1
Salt (g/day)	10.5 ± 3.3	8.9 ± 2.7
Alcohol (kcal/day)	176.2 ± 160.6	85.7 ± 134.2
Energy expenditure		
Daily energy expenditure (kcal/day)	2,368.2 ± 444.2	1,872.7 ± 395.6
Resting energy expenditure (kcal/day)	1,515.5 ± 300.6	1,135.0 ± 121.9
Energy expenditure of exercise (kcal/day)	356.0 ± 248.4	327.3 ± 240.5

Data is presented as mean ± SD.

BMI, body mass index; BP, blood pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol

Table 2 Correlations between fasting glucose and clinical parameters

	Men		Women	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Age	0.159	0.274	0.061	0.739
BMI	0.254	0.078	0.097	0.596
Body fat mass	0.211	0.146	-0.030	0.872
Fat-free mass	0.331	0.020	0.265	0.143
Percent body fat	-0.143	0.328	-0.390	0.027
Systolic BP	0.353	0.013	0.411	0.019
LDL-C	0.207	0.153	0.398	0.024
HDL-C	0.168	0.250	0.142	0.437
Triglyceride	-0.060	0.684	-0.234	0.197
Adiponectin	0.243	0.092	0.248	0.172
hsCRP	-0.334	0.019	-0.166	0.365
Energy	0.016	0.913	0.312	0.083
Carbohydrate	-0.001	0.992	0.171	0.351
Protein	0.020	0.889	0.416	0.018
Fat	0.011	0.942	0.398	0.024
Saturated fat	-0.012	0.936	0.392	0.026
Fiber	0.129	0.379	0.090	0.625
Salt	0.072	0.622	0.458	0.008
Alcohol	0.090	0.538	-0.150	0.411
Daily energy expenditure	-0.330	0.012	-0.194	0.287
Resting energy expenditure	-0.157	0.280	-0.368	0.038
Energy expenditure of exercise	-0.194	0.182	-0.076	0.679

Table 3 Comparison of clinical parameters between the fasting glucose <110 group and the fasting glucose ≥110 group in men

	Fasting glucose <110	Fasting glucose ≥110	Significance
Number of subjects	38 (77.6%)	11 (22.4%)	
Age (years)	62.3 ± 13.1	66.1 ± 6.6	ns
Fasting glucose (mg/dL)	96.5 ± 5.6	123.6 ± 13.2	**
BMI (kg/m ²)	22.8 ± 2.4	23.9 ± 3.0	ns
Waist circumference (cm)	86.6 ± 7.1	88.8 ± 7.9	ns
Body fat mass (kg)	15.8 ± 4.8	18.0 ± 6.4	ns
Fat-free mass (kg)	48.7 ± 4.0	45.1 ± 4.1	*
Percent body fat (%)	24.1 ± 5.8	27.8 ± 7.2	ns
Systolic BP (mmHg)	121.1 ± 15.0	129.0 ± 12.3	ns
LDL-C (mg/dL)	117.4 ± 20.1	112.9 ± 22.9	ns
HDL-C (mg/dL)	60.0 ± 12.5	57.1 ± 18.7	ns
Triglyceride (mg/dL)	90.0 ± 35.0	115.6 ± 37.4	*
Adiponectin (μg/mL)	9.4 ± 4.5	6.6 ± 1.6	*
Dietary nutrient intake			
Energy (kcal/day)	1,957.2 ± 512.8	1,839.1 ± 404.8	ns
Carbohydrate (g/day)	250.1 ± 64.8	228.5 ± 60.0	ns
Protein (g/day)	71 ± 23.1	71.6 ± 16.1	ns
Fat (g/day)	63.3 ± 22.9	59.7 ± 20.3	ns
Saturated fat (g/day)	19.3 ± 8.4	18.4 ± 7.5	ns
Fiber (g/day)	13.7 ± 4.6	14.6 ± 3.4	ns
Salt (g/day)	10.4 ± 3.6	10.6 ± 2.4	ns
Alcohol (kcal/day)	173.7 ± 163.9	185.1 ± 155.8	ns
Energy expenditure			
Daily energy expenditure (kcal/day)	2,450.5 ± 444.1	2,084.1 ± 320.6	*
Resting energy expenditure (kcal/day)	1,548.5 ± 325.6	1,401.3 ± 151.7	*
Energy expenditure of exercise (kcal/day)	373.2 ± 243.8	296.5 ± 266.7	ns

Data is presented as mean ± SD, unless otherwise stated. *, $p < 0.05$; **, $p < 0.01$

Table 4 Comparison of clinical parameters between the fasting glucose <110 group and the fasting glucose ≥110 group in women

	Fasting glucose <110	Fasting glucose ≥110	Significance
Number of subjects	30 (93.7%)	2 (6.3%)	
Age (years)	64.3 ± 12.3	64.5 ± 7.8	ns
Fasting glucose (mg/dL)	91.7 ± 6.5	120.0 ± 11.3	**
BMI (kg/m ²)	20.5 ± 2.7	18.7 ± 0.9	ns
Waist circumference (cm)	78.8 ± 7.8	72.5 ± 10.6	ns
Body fat mass (kg)	12.5 ± 4.4	10.9 ± 6.2	ns
Fat-free mass (kg)	34.2 ± 3.9	28.9 ± 5.8	ns
Percent body fat (%)	26.5 ± 7.6	27.4 ± 8.4	ns
Systolic BP (mmHg)	122.1 ± 19.2	142.0 ± 24.0	ns
LDL-C (mg/dL)	127.4 ± 32.6	114.0 ± 12.7	ns
HDL-C (mg/dL)	74.7 ± 15.1	82.5 ± 13.4	ns
Triglyceride (mg/dL)	77.9 ± 39.2	68.0 ± 5.7	ns
Adiponectin (μg/mL)	16.9 ± 10.8	15.2 ± 8.3	ns
Dietary nutrient intake			
Energy (kcal/day)	1,702.0 ± 329.8	2,357.0 ± 722.1	*
Carbohydrate (g/day)	221.8 ± 48.5	269.1 ± 55.1	ns
Protein (g/day)	63.3 ± 13.6	89.5 ± 41.1	*
Fat (g/day)	57.1 ± 13.1	91.5 ± 46.5	**
Saturated fat (g/day)	17.8 ± 4.3	30.9 ± 22.9	**
Fiber (g/day)	14.2 ± 4.2	15.6 ± 1.6	ns
Salt (g/day)	8.5 ± 2.5	13.7 ± 2.7	**
Alcohol (kcal/day)	81.4 ± 131.9	150.0 ± 212.1	ns
Energy expenditure			
Daily energy expenditure (kcal/day)	1,890.1 ± 401.8	1,613.0 ± 164.9	ns
Resting energy expenditure (kcal/day)	1,145.8 ± 115.0	972.2 ± 143.2	*
Energy expenditure of exercise (kcal/day)	330.3 ± 248.3	281.6 ± 36.1	ns

Data is presented as mean ± SD, unless otherwise stated. *, $p < 0.05$; **, $p < 0.01$

DISCUSSION

In the present study, the impact of lifestyle habits and body composition on glucose regulation was investigated in the anti-aging checkup examinees. We ascertained that excessive energy intake and/or decreased physical activity had a low impact on fasting glucose level. Rather, glucose dysregulation was found to be associated with decreased energy expenditure other than exercise and increased percentage of body fat.

Excessive caloric intake and a sedentary lifestyle are well-known risk factors for incident diabetes. The lifestyle intervention in clinical trials (Finnish Diabetes Prevention study⁵) and Diabetes Prevention Program in the United States⁶) emphasized lifestyle changes that included moderate weight loss (7% of body weight) and regular physical activity (150 min/week), with dietary strategies to reduce intake of fat and calories². Obesity (BMI ≥ 25 kg/m²) is one of the most important risk factors for type 2 diabetes, and being overweight (BMI 22–25 kg/m²) also increases the risk of diabetes¹⁸. It has been reported that a weight loss of 5–10% can reduce the incidence of diabetes in obese and overweight subjects with impaired glucose tolerance^{5,6}. The subjects in both the fasting glucose <110 group and the fasting glucose ≥ 110 group were not obese on average in BMI, and the women in the fasting glucose ≥ 110 group showed a lower BMI than those in the fasting glucose <110 group. However, the subjects with fasting glucose ≥ 110 showed a higher percentage of body fat ($27.8 \pm 7.2\%$ for men and $27.4 \pm 8.4\%$ for women) compared to those with fasting glucose <110 ($24.1 \pm 5.8\%$ for men and $26.5 \pm 7.6\%$ for women), although not significant. Sarcopenic obesity is defined as a normal BMI with excessive body fat. Our analysis of the anti-aging checkup examinees revealed that those with sarcopenic obesity had an elevated risk for lifestyle-related diseases equal to that of obese people¹². In that study, the percentage of body fat was measured by the bioelectrical impedance method, which is less precise than DXA. In the present study, body composition was evaluated by DXA, the gold standard method. In accordance with the previous report, increased percentage of body fat (increased body fat mass and/or decreased fat-free mass) was associated with glucose dysregulation. Skeletal muscle accounts for more than half ($\sim 55\%$) of the total fat-free mass, and maintenance of skeletal muscle mass is important for its metabolic quality as well as physical strength and functional status. There is a progressive reduction of skeletal muscle mass in weight-stable elderly men and women^{19,20}, suggesting that weight stability in older individuals does not imply body composition stability. Therefore, we strongly emphasize the importance of evaluating body composition to detect early signs of metabolic changes.

Excessive energy intake had a low impact on fasting glucose level in the present study. Dietary intake of nutrients in this study was compatible with that of the National Health and Nutrition Survey in both men and women¹⁷, suggesting that data collection was properly performed. The FFQg is validated against 7-day dietary records and the FFQg-estimated nutrient intake values are 72–121% of those of the 7-day dietary records¹⁴. The reproduc-

ibility of the FFQg at intervals of 1–2 months is 93–119% for each nutrient¹⁴. The influence of dietary nutrient intake on glucose level was insignificant in men. In women, although the number of subjects with fasting glucose ≥ 110 may be too small to achieve statistical significance, energy intake seemed to be positively associated with fasting glucose, but it remains inconclusive in this study.

Regular physical exercise is known to prevent type 2 diabetes^{5–7}. However, decreased physical activity had a low impact on fasting glucose level in our subjects. Rather, decreased energy expenditure other than exercise was found to be associated with glucose dysregulation. Daily energy expenditure consists of three components: resting metabolic rate (60–75%), thermic effects of food (10%) and physical activity (15–30%)²¹. Resting metabolic rate can be measured by the doubly labeled water technique or calorimetry, and voluntary physical activity is often measured by accelerometers, but no method is suitable for every situation and every population¹⁹. Compared to other instruments, questionnaires are easy to distribute and administer, and allow the collection of information on physical activity and other factors from a greater number of study subjects²¹. However, questionnaires are prone to bias, including social desirability and recall bias²². In the present study, daily energy expenditure, resting energy expenditure and energy expenditure of exercise were evaluated by a questionnaire. According to the Dietary Reference Intakes for Japanese (2015)²³, the resting metabolic rate for the age group 50–59 is 1,400 kcal/day for men and 1,100 kcal/day for women. In this study, resting energy expenditure was $1,515.5 \pm 300.6$ kcal/day for men and $1,135.0 \pm 121.9$ kcal/day for women, almost compatible with the reference values²³. Energy expenditure of exercise was 356.0 ± 248.4 kcal/day for men and 327.3 ± 240.5 kcal/day for women, which is roughly equivalent to brisk walking (5.0 METs) for one hour and is considered reasonable as daily physical activity. In the present study, there was a significantly negative correlation between fasting glucose and daily energy expenditure in men, and resting energy expenditure in women, but not energy expenditure of exercise in both men and women. Daily energy expenditure and resting energy expenditure are dependent on fat-free mass, and combined with the relationship between fasting glucose and body composition, this result is considered meaningful.

Our study has some limitations. First, the sample size was not large enough for conclusions regarding marginally insignificant *p*-values. Second, because of the cross-sectional nature of the study, the cause-effect relationship of our findings is unclear and a prospective study is required. Third, our subjects, who undergo anti-aging health checks at Tokai University Tokyo Hospital, are considered to be more affluent and health-conscious than ordinary people, and therefore the results of this study may not be applicable to the general population. However, the present study is meaningful in promoting awareness of the importance of body composition for detecting early signs of metabolic changes.

In conclusion, the present study shows that subclinical glucose dysregulation was associated with decreased energy expenditure other than exercise and increased percentage of body fat, rather

than excessive energy intake and/or decreased physical activity in the anti-aging checkup examinees. We strongly emphasize the importance of evaluating body composition to detect early signs of metabolic changes, because subjects with sarcopenic obesity are at high risk of developing lifestyle-related diseases including type 2 diabetes.

The authors state that they have no Conflict of Interest (COI).

REFERENCES

- 1) Hu EA, Pan A, Malik V, Sun Q. White rice consumption and risk of type 2 diabetes: meta-analysis and systematic review. *BMJ* 2012; 344: e1454.
- 2) American Diabetes Association, Bantle JP, Wylie-Rosett J, Albright AL, Apovian CM, Clark NG, et al. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. *Diabetes Care* 2008; 31: S61-78.
- 3) de Munter JS, Hu FB, Spiegelman D, Franz M, Franz M, van Dam RM. Whole grain, bran, and germ intake and risk of type 2 diabetes: a prospective cohort study and systematic review. *PLoS Med* 2007; 4: e261.
- 4) Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. *JAMA* 2003; 289: 1785-91.
- 5) Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, et al (Diabetes Prevention Program Research Group). Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002; 346: 393-403.
- 6) Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, et al (Finnish Diabetes Prevention Study Group). Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med* 2001; 344: 1343-50.
- 7) Okada K, Hayashi T, Tsumura K, Suematsu C, Endo G, Fujii S. Leisure-time physical activity at weekends and the risk of Type 2 diabetes mellitus in Japanese men: the Osaka Health Survey. *Diabet Med* 2000; 17: 53-8.
- 8) Sato KK, Hayashi T, Kambe H, Nakamura Y, Harita N, Endo G, et al. Walking to work is an independent predictor of incidence of type 2 diabetes in Japanese men: the Kansai Healthcare Study. *Diabetes Care* 2007; 30: 2296-8.
- 9) Jeon CY, Lokken RP, Hu FB, van Dam RM. Physical activity of moderate intensity and risk of type 2 diabetes: a systematic review. *Diabetes Care* 2007; 30: 744-52.
- 10) Nishizaki Y, Kubo A, Kuwahira I, Tanino R, Sueno T, Kuroda E, et al. A proposal research for new health check-up items focusing on the future super-aging society in Japan. *Health Evaluation and Promotion* 2011; 38: 537-46.
- 11) Nishizaki Y, Kubo A, Kuwahira I, Kuroda E, Nigou N, Sueno T, et al. Anti-aging health check-up system: For the prevention of potentially progress aging related disadvantageous changes in elderly. *Health Evaluation and Promotion* 2012; 39: 519-29.
- 12) Yamada C, Kishimoto N, Motegi S, Kikuchi E, Ogata T, Kuroda E, et al. Health screening/Ningen Dock can reduce age-related risks! The results of anti-aging checkups at Tokai University Tokyo Hospital over a decade. *Health Evaluation and Promotion* 2017, in press.
- 13) Nishimura A, Sawai T. Determination of adiponectin in serum using a latex particle-enhanced turbidimetric immunoassay with an automated analyzer. *Clin Chim Acta* 2006; 371: 163-8.
- 14) Takahashi K, Yoshimura Y, Kaimoto T, Kaimoto T, Iimuro S, Ohashi Y, et al. Validation of a food frequency questionnaire based on food groups for estimating individual nutrient intake. *Jpn J Nutr* 2001; 59: 221-32.
- 15) Miyaki K, Tohyama S, Murata M, Kikuchi H, Takei I, Watanabe K, et al. Salt intake affects the relation between hypertension and the T-786C polymorphism in the endothelial nitric oxide synthase gene. *Am J Hypertens* 2005; 18: 1556-62.
- 16) Yamada C, Fujimoto S, Ikeda K, Nomura Y, Matsubara A, Kanno M, et al. Relationship of homocysteine and homocysteine-related vitamins to bone mineral density in Japanese patients with type 2 diabetes. *J Diabetes Investig* 2011; 2: 233-9.
- 17) Ministry of Health, Labour and Welfare, National Health and Nutrition Survey 2015. (Accessed April 25, 2017, at <http://www.mhlw.go.jp/file/04-Houdouhappyou-10904750-Kenkoukyoku-Gantaisakukenkouzoushinka/kekkaigaiyou.pdf>).
- 18) Colditz GA, Willett WC, Rotnitzky A, Manson JE. Weight gain as a risk factor for clinical diabetes mellitus in women. *Ann Intern Med* 1995; 122: 481-6.
- 19) Gallagher D, Ruts E, Visser M, Heshka S, Baumgartner RN, Wang J, et al. Weight stability masks sarcopenia in elderly men and women. *Am J Physiol Endocrinol Metab* 2000; 279: E366-75.
- 20) Hughes VA, Frontera WR, Roubenoff R, Evans WJ, Singh MA. Longitudinal changes in body composition in older men and women: role of body weight change and physical activity. *Am J Clin Nutr* 2002; 76: 473-81.
- 21) Lagerros YT, Lagiou P. Assessment of physical activity and energy expenditure in epidemiological research of chronic diseases. *Eur J Epidemiol* 2007; 22: 353-62.
- 22) Rennie KL, Wareham NJ. The validation of physical activity instruments for measuring energy expenditure: problems and pitfalls. *Public Health Nutr* 1998; 1: 265-71.
- 23) Ministry of Health, Labour and Welfare, Dietary Reference Intakes for Japanese 2015. (Accessed April 25, 2017, at <http://www.mhlw.go.jp/file/06-Seisakujouhou-10900000-Kenkoukyoku/Overview.pdf>).