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Original article

Relationship between weight gain and metabolic syndrome in non-obese Japanese adults

Shiori Toga [a], Yuko Fukkoshi [a,1], Rie Akamatsu [b,*]

[a] Graduate School of Humanities and Sciences, Ochanomizu University, c/o Rie Akamatau, 2-1-1, Otsuka, Bunkyo-ku, Tokyo 112-8610, Japan
[b] Natural Science Division, Faculty of Core Research, Ochanomizu University, 2-1-1, Otsuka, Bunkyo-ku, Tokyo 112-8610, Japan

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ABSTRACT

Aims: To examine the effects of weight gain (in kg) on the parameters of metabolic syndrome (MetS) in non-obese Japanese adults over a period of 1 year.
Method: We analyzed data on 1653 workers in a financial corporation (698 males and 955 females) who may have gained weight during 1 year but nevertheless remained non-obese. Data were collected twice: baseline data were collected between April 2010 and March 2011, and follow-up data were collected the next year. We calculated weight gains over the year and assigned all subjects into one of four groups according to the amount of weight gained: 0–0.99 kg weight gain (reference), 1.00–1.99 kg, 2.00–2.99 kg, and more than 3.00 kg. We compared changes in MetS parameters between the reference and other groups using Analysis of covariance (ANCOVA).
Results: Significant between-group differences were evident among males in terms of abdominal circumference (AC), blood pressure, and triglyceride (TG) levels. More weight gain was associated with worse results with regard to these MetS parameters. The AC changes were 0.60, 1.55, 2.86, and 4.42 cm in the reference group, those who gained 1.00–1.99 kg, those who gained 2.00–2.99 kg, and those who gained over 3.00 kg, respectively; the differences between the reference group and all other groups were significant (all p values <0.001).
Conclusions: Weight gain (in kg) is a useful index of weight change and influences several parameters of MetS even over the course of 1 year.

1. Introduction

Metabolic syndrome (MetS) is a major risk factor for non-communicable diseases [1], mortality from which is high in Japan [2], rendering the prevention of MetS and the control of metabolic abnormalities important. However, the National Health and Nutrition Survey of Japan conducted in 2013 found that over 50% of males and about 20% of females aged 40–74 years were suspected to have MetS or preliminary MetS [3].

Previous studies have revealed a strong relationship between long-term weight gain and MetS [4,5]. One study of middle-aged subjects that explored the relationship between MetS and weight gain in individuals aged 20 years or older found that those who gained over 10 kilograms (kg) were at about an eight-fold (males) and a 12-fold (females) higher risk of MetS compared with those who did not gain over 10 kg [4]. In terms of biomarkers, Montonen et al. showed that body mass index (BMI) changes after the age of 25 years were significantly associated with elevated MetS biomarkers, including high-density lipoprotein cholesterol (HDL-C) and HbA1c levels [5].

Some studies have shown that long-term weight gain affects the development of MetS even in non-obese subjects [6,7]. Zhang et al. found that long-term weight gain was associated with increased risks of lipid abnormalities and hypertension. Additionally, when subjects were divided into obese (BMI $\geq$ 25 kg/m^2) and non-obese (BMI $<$ 25 kg/m^2) groups, such relationships were not evident in the obese group [6]. Suzuki et al. also showed that not only obese but also non-obese Japanese individuals (BMI $<$ 25 kg/m^2) who gained more than 10 kg after 20 years of age were at risk for MetS [7]. Thus, weight should be checked constantly to prevent weight gain even in non-obese individuals.

One study showed that weight gain even over the course of one year affected metabolic status. A Mexican report explored the relationship between change in body weight over one year and

* Corresponding author. Tel.: +81 3 5978 5680; fax: +81 3 5978 5680.
E-mail address: akamatsu.rie@ocha.ac.jp (R. Akamatsu).
[1] Present address: Sundaigakuen Junior & Senior High School, 6-1-10, Ohji, Kita-ku, Tokyo 114-0002, Japan.

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blood pressure and fasting glucose levels (diagnostic criteria for MetS) [8]. A one-year change in body weight was associated with increased systolic arterial and diastolic blood pressure (DBP) in both males and females, independent of baseline BMI. Weight gain of 5% or more was positively associated with increases in blood pressure in females but not males. This study assessed relationships between body weight and metabolic changes in terms of percentages (%). In general, when weight is to be controlled, the actual weight (kg) is the relevant criterion. It is easy to assess changes in body weight using data on absolute weight (kg) rather than on the rate of such change (%); however, no study has yet explored the relationship between metabolic parameters and weight gain (in kg) over one year. To determine precisely how weight gain impacts MetS parameters, weight gain (in kg) can be routinely measured at annual health check-ups or via regular self-weighing. Thus, the present study focused on non-obese Japanese subjects and explored the number of increased kgs associated with development of MetS risk factors over the course of one year using observational longitudinal study.

2. Materials and methods

2.1. Subjects

We obtained baseline and follow-up data from 3802 employees (1840 males, 1962 females) aged 24–63 years of a Japanese financial company during Specific Health Check-ups [9] that were conducted by a health insurance company between April 2010 and March 2011 and between April 2011 and March 2012, respectively. A total of 27 prefectural and city governments were involved. The Specific Health Check-up, which is conducted by a health insurance society, is used by the national insurance plan to help prevent lifestyle-related disease.

We focused on those who gained weight over the course of one year but remained non-obese (BMI $< 25\ kg/m^2$). A total of 1739 participants (895 males and 846 females) who lost weight over the year were initially excluded. A total of 410 subjects (248 males and 162 females) who were obese (BMI $\geq 25\ kg/m^2$) were eliminated next. Finally, data on 1653 workers (698 males, 955 females; 43.5% of the overall population) were analyzed. The study was approved by the Ochanomizu University Ethics Review Committee (approval no. 24-16).

2.2. Data collection

Gender and age were considered to be relevant demographic characteristics, and body weight and height were considered to be significant anthropometric measures. Height was measured via stadiometer, and weight was measured on a calibrated scale. BMI was calculated in kg/m^2. We calculated weight gain from baseline to follow up and divided all subjects into four groups according to weight gain: 0–0.99 kg (reference), 1.00–1.99 kg, 2.00–2.99 kg, and more than 3.00 kg. We explored changes in MetS parameters between the reference and other groups during the one-year study period.

We also evaluated six items at both baseline and follow up that were collected by trained staffs; abdominal circumference (AC), DBP, systolic arterial pressure (SAP), fasting blood glucose (FBG) level (in Japan, this term generally refers to plasma glucose level [10]), triglyceride (TG) level, and HDL-C level. These six measurements serve as MetS criteria in Japan [11]. All measurements were determined using the methods of the "Standard Health Check-up and Health Instruction Program [9]." We calculated changes in the six parameters from baseline to follow up.

2.3. Statistical analyses

The χ^2 test was used to compare categorical baseline variables and the *t*-test to compare consecutive baseline variables. Analysis of covariance (ANCOVA) was used to explore relationships between body-weight change and MetS parameters. We compared changes in MetS parameters between the reference and the other groups, with adjustment for age, BMI, and medication use (treatment of dyslipidemia, hypertension, and diabetes) at baseline. We analyzed the data from men and women separately because the numbers of each gender in the various weight-change groups differed significantly. Missing values were excluded from each analysis. All data were analyzed using SPSS (version 19 for Windows, 2010, SPSS Institute, IBM, Tokyo, Japan). All tests were two-tailed, and p-values <0.05 were considered to indicate statistical significance.

3. Results

3.1. Subject characteristics

The mean age of all subjects ($n = 1653$) at baseline was 38.9 (SD 9.2) years, and 698 subjects (42.2%) were males. The mean BMI of all subjects was 20.5 (SD 2.0) kg/m^2 at baseline. A total of 696 workers (42.1%, 265 males and 431 females) gained 0–0.99 kg over the year (reference group); 514 (31.1%, 219 males and 295 females) gained 1.00–1.99 kg; 251 (15.2%, 119 males and 132 females) gained 2.00–2.99 kg; and 192 (11.6%, 95 males and 97 females) gained more than 3.00 kg. Significant sex differences were observed among all four groups ($p = 0.008$). The reference group had a significantly higher proportion of females. Table 1 shows the subject characteristics at baseline by weight change. Among males, no significant difference in age, BMI, or any MetS parameter was evident among the four groups at baseline. Data from females were similar. Only a few subjects in any group were medicated.

3.2. Changes in MetS parameters over one year in the four groups

We assessed the relationships between weight gain over one year and changes in MetS parameters using ANCOVA and compared changes between the reference and other groups in the MetS parameters.

Fig. 1 shows the results for males. Significant differences were evident with regard to AC ($p < 0.001$), DBP ($p < 0.001$), SAP ($p = 0.001$), and TG ($p = 0.030$) levels. The AC changes were 0.60, 1.55, 2.86, and 4.42 cm for the 0–0.99 kg (reference), 1.00–1.99 kg, 2.00–2.99 kg, and over 3.00 kg weight-gain groups, respectively. Significant differences were evident between the reference and all other groups (all p values <0.001). In terms of blood pressure, significant differences were evident between the reference group and those who had gained more than 3.00 kg group in terms of DBP and between those who had gained 2.00–2.99 kg and those who had gained over 3.00 kg with regard SAP. More weight gain was associated with worse results regarding the MetS parameters. In terms of TG level, a significant difference was evident between the reference group and those who had gained over 3.00 kg. The TG changes were significantly greater in those who had gained over 3.00 kg (27.3 mg/dL) than in those in the reference group (0.63 mg/dL) ($p < 0.05$).

Fig. 2 shows the results for females. Significant differences were evident in terms of AC and TG changes according to the ANCOVA (both p values <0.001). In terms of AC, the results were similar to those of males. More weight gain was associated with greater increases in AC. In terms of TG levels, the reference group and those who had gained over 3.00 kg showed a significantly greater change