Effects of BMI changes over two years on lifestyle-related diseases

ABSTRACT

Objective: Increase in lifestyle-related diseases with high BMI has been shown in numerous epidemiological studies. The present study was a comparative investigation of the effects of changes in BMI over two years on representative lifestyle-related disease onset and normalization.

Subjects: A total of 10,109 subjects (5,766 males and 4,343 females) who underwent annual health check-ups at Tokai University Hospital's Health Screening Center in 2014 and 2016 were included in this study.

Methods: Based on the WHO classification of obesity, and standard weight according to the Japan Society of Obesity, in 2014 the subjects were divided into four groups, by BMI, and in 2016 each group was divided into four groups, by BMI, to make 16 groups in total. The new-onset and normalization rates for hypertension, diabetes and dyslipidemia during this two year period were compared between the groups, with classification by sex.

Results: With both males and females, the hypertension new-onset rate increased with increasing BMI, but the new-onset rate also increased significantly in the groups showing BMI decrease. The diabetes new-onset rate increased with increasing BMI, but females who were slimmer than standard body type also showed increased normalization rate with BMI increase. With both males and females, the dyslipidemia new-onset rate increased with increasing BMI, and the normalization rate increased with decreasing BMI, but these relationships were weak with females.

Conclusion: Changes in BMI are associated with new-onset and normalization rates, especially for dyslipidemia. Although hypertension and diabetes are associated with changes in BMI and new-onset and normalization rates, the involvement of other lifestyle-related factors must also be considered.

Key words: BMI, Obesity, Hypertension, Diabetes, Dyslipidemia

I. INTRODUCTION

Curb et al. have reported that BMI is a predictor of cardiovascular disease, and that lifestyle changes leading to increased obesity increase the risk of cardiovascular disease\(^1\). Shaper et al. have reported that BMI is closely associated with increases in the prevalence of diabetes and cardiovascular diseases, and increases in test results for blood pressure, blood sugar, and blood lipids\(^2\). Furthermore, the American Health Foundation has reported that weight loss reduces the risk factors for cardiovascular disease and diabetes\(^3\), and it is considered that maintaining appropriate body shape is important for health management.

In order for each individual to ascertain the risk of cardiovascular disease on a daily basis, a simple index that can be measured at home is required, and BMI is a simple index that can be measured at home if height and weight can be measured. BMI is an index of physique that started being used when Quetelet observed that adult weight was proportional to the square of height\(^4\). Revicki has reported that it eliminates the effect of height on weight by dividing weight by height squared\(^5\). In addition, BMI is not a direct measurement of fat accumulation, but it has been shown in studies by Gallagher et al. that it is closely correlated with the results of body fat accumulation measurement methods such as dual-energy X-ray absorptiometry\(^6\).

Therefore, the present study, a retrospective cohort study, involved investigation of changes in BMI and lifestyle-related disease morbidity rates over two years, and the contributions of improvements in obesity to improvements in these morbidity rates were thus elucidated.

II. SUBJECTS AND METHODS

1. Subjects

A total of 10,109 subjects (5,766 males, with a mean age of 58.7 ± 10.8, and 4,343 females, with a mean age of 57.8 ± 10.4) who underwent annual health check-ups at Tokai University Hospital's Health Screening Center in 2014 and 2016 were included in this study.

2. Methods

For obesity, the BMI was calculated, and, with reference to the WHO obesity classification and the Japan Society for the Study of Obesity’s criteria\(^7\), levels of obesity were classified as follows:
slim: BMI below 18.5 kg/m²; moderately slim: BMI 18.5 to 22 kg/m²; standard body type: BMI 22 to 25 kg/m²; and obese: BMI over 25 kg/m².

On the basis of the Japanese Society of Hypertension’s Guidelines for Management of Hypertension, subjects were taken to have hypertension if they met one or more of the following criteria: (i) systolic blood pressure at least 140 mmHg; (ii) diastolic blood pressure at least 90 mmHg; and (iii) currently undergoing drug therapy for hypertension.

On the basis of the Japan Diabetes Society’s guidelines, subjects were taken to have diabetes if they had fasting blood glucose levels of at least 126 mg/dL and/or were undergoing drug therapy for diabetes.

On the basis of the Japan Atherosclerosis Society’s Guidelines for Prevention of Atherosclerotic Cardiovascular Diseases, subjects were taken to have dyslipidemia if they met one or more of the following criteria: (i) low-density lipoprotein cholesterol at least 140 mg/dL; (ii) high-density lipoprotein cholesterol below 40 mg/dL; (iii) triglycerides at least 150 mg/dL; and (iv) currently undergoing drug therapy for dyslipidemia.

In order to analyze the changes in BMI, subjects were classified as slim, moderately slim, standard body type, or obese, on the basis of the physical measurements made in 2014, and then again on the basis of those made in 2016. For each disease (hypertension, diabetes and dyslipidemia), in each body-type group, the number of subjects who did not have the disease in 2014 but did have it in 2016 was divided by the total number of subjects in the group to obtain the new-onset rate, and the number of subjects who did have the disease in 2014 but did not have it in 2016 was divided by the total number in the group to obtain the normalization rate.

For each disease, the new-onset rate and normalization rate were analyzed using the McNemar test, with classification by sex. The software used for statistical analysis was SPSS (version 25; IBM, Chicago, Illinois, USA). The statistical significance level was below 5%.

3. Ethical considerations

This study was approved by Tokai University School of Medicine’s Ethics Committee. For this study, the people who had been examined were notified, with inclusion on an opt-out basis. The data collected in the health check-ups were anonymized, and sufficient information management and security measures were ensured at every step.

III. RESULTS

1. Changes in obesity

An age distribution of an investigation object is indicated. When men and women had most percentages of the check-up person in sixties current as of 2014, it was indicated. (Table 1)

In 2014, among males the group with the most members was the standard body type group, with 2,394 members, and among females it was the moderately slim group, with 1,932 members. With respect to the changes in distribution by 2016, numerous subjects showed no change, and among both males and females there were none who were slim in 2014 and obese in 2016, or who were obese in 2014 and slim in 2016. In addition, among females there were none who were of standard body type in 2014 and slim in 2016 (Table 2-1, 2-2).

### Table 1 Age distribution of examinees

| Total (n=10,109) | Age (years) | 39≧ | 40-49 | 50-59 | 60-69 | 70≦ |
|-----------------|-------------|------|-------|-------|-------|------|
| Male (n=5,766)  |             | 216  | 1,074 | 1,687 | 1,796 | 993  |
|                 |             | (3.7%) | (18.6%) | (29.3%) | (31.2%) | (17.2%) |
| Female (n=4,343)|             | 186  | 828   | 1,327 | 1,409 | 593  |
|                 |             | (4.3%) | (19.1%) | (30.6%) | (32.4%) | (13.6%) |

Age (years): Age in 2014

### Table 2-1 Changes in male obesity

| 2016 | slim | moderately slim | standard body type | obese |
|------|------|-----------------|--------------------|-------|
| 2014 |      |                 |                    |       |
| n=178  |      |                 |                    |       |
| n=1,637 |      |                 |                    |       |
| n=2,394 | 1    |                 |                    | 249   |
| n=1,557 | 0    |                 |                    | 1,344 |

slim: BMI<18.5 kg/m²; moderately slim: 18.5≤BMI<22 kg/m²; standard body type: BMI<25 kg/m²; obese: BMI≧25 kg/m²

### Table 2-2 Changes in female obesity

| 2016 | slim | moderately slim | standard body type | obese |
|------|------|-----------------|--------------------|-------|
| 2014 |      |                 |                    |       |
| n=470  |      |                 |                    |       |
| n=1,932 |      |                 |                    |       |
| n=1,233 | 0    |                 |                    | 125   |
| n=707   | 0    |                 |                    | 642   |

slim: BMI<18.5 kg/m²; moderately slim: 18.5≤BMI<22 kg/m²; standard body type: BMI<25 kg/m²; obese: BMI≧25 kg/m²

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2. Hypertension

With respect to hypertension new-onset and normalization rates, males who were in any group and showed no change in obesity, who were moderately slim in 2014 and of standard body type in 2016, who were of standard body type in 2014 and moderately slim or obese in 2016, or who were obese in 2014 and of standard body type in 2016 had significantly elevated new-onset rates. Females in any group in 2014 who showed no change in obesity, or who showed BMI increase between 2014 and 2016 had significantly elevated new-onset rates (Table 3-1, 3-2).

Table 3-1  Changes in the incidence of male hypertension morbidity over two years

|            | 2014                  | 2016                  |          |          |          |          |          |          |
|------------|-----------------------|-----------------------|----------|----------|----------|----------|----------|----------|
|            | slim                  | moderately slim       | standard body type | obese    |          |          |          |          |
|            | Hypertension (−)      | Hypertension (+)      | Hypertension (−)  | Hypertension (+) | Hypertension (−) | Hypertension (+) |          |          |
| slim       | Hypertension (−)      | 66.2%                 | 11.8%     | 63.4%     | 14.6%    | 0.0%     | 0.0%     |          |
|           | Hypertension (+)      | 0.7%                  | 21.3%     | 2.4%      | 19.5%    | 100.0%   | 0.0%     |          |
| P value    | p<0.001               | NS                   | NS       | p<0.001   | p<0.001  | NS       |          |          |
| moderately|                       |                       |          |          |          |          |          |          |
| slim       | Hypertension (−)      | 59.1%                 | 9.1%     | 58.5%     | 11.1%    | 56.8%    | 10.4%    | 0.0%     |
|           | Hypertension (+)      | 6.8%                  | 25.0%    | 2.5%     | 27.9%    | 1.6%     | 31.2%    | 0.0%     |
| P value    | p<0.001               | p<0.001              | NS       | p<0.001   | p<0.001  | p<0.001  |          |          |
| standard body type | Hypertension (−) | 0.0%                   | 0.0%     | 53.8%     | 6.6%     | 43.6%    | 13.9%    | 41.4%    |
|           | Hypertension (+)      | 0.0%                  | 100.0%   | 2.2%     | 37.4%    | 2.0%     | 40.5%    | 1.6%     |
| P value    | p<0.001               | p<0.001              | p<0.001  | p<0.001   | p<0.001  | p<0.001  |          |          |
| obese      | Hypertension (−)      | 75.0%                 | 0.0%     | 45.1%     | 8.4%     | 28.9%    | 14.4%    |          |
|           | Hypertension (+)      | 25.0%                 | 0.0%     | 2.8%     | 43.7%    | 1.8%     | 54.9%    |          |
| P value    | p<0.001               | p<0.001              | p<0.001  | p<0.001   | p<0.001  | p<0.001  |          |          |

P values were calculated by using McNemar’s test.

Table 3-2  Changes in the incidence of female hypertension morbidity over two years

|            | 2014                  | 2016                  |          |          |          |          |          |          |
|------------|-----------------------|-----------------------|----------|----------|----------|----------|----------|----------|
|            | slim                  | moderately slim       | standard body type | obese    |          |          |          |          |
|            | Hypertension (−)      | Hypertension (+)      | Hypertension (−)  | Hypertension (+) | Hypertension (−) | Hypertension (+) |          |          |
| slim       | Hypertension (−)      | 76.8%                 | 9.2%     | 71.1%     | 12.2%    | 100.0%   | 0.0%     |          |
|           | Hypertension (+)      | 1.6%                  | 12.4%    | 0.0%     | 16.7%    | 0.0%     | 0.0%     |          |
| P value    | p<0.001               | p<0.01               |          |          |          |          |          |          |
| moderately|                       |                       |          |          |          |          |          |          |
| slim       | Hypertension (−)      | 77.1%                 | 6.7%     | 70.0%     | 9.1%     | 69.9%    | 9.7%     | 100.0%   |
|           | Hypertension (+)      | 2.9%                  | 13.3%    | 1.4%     | 19.5%    | 1.5%     | 18.9%    | 0.0%     |
| P value    | NS                    | p<0.001              | p<0.001  | p<0.001   | p<0.001  | p<0.001  |          |          |
| standard body type | Hypertension (−) | 65.0%                   | 7.9%     | 56.4%     | 10.1%    | 52.8%    | 14.4%    |          |
|           | Hypertension (+)      | 2.1%                  | 25.0%    | 1.3%     | 32.2%    | 0.8%     | 32.0%    |          |
| P value    | NS                    | p<0.001              | p<0.001  | p<0.001   | p<0.001  | p<0.001  |          |          |
| obese      | Hypertension (−)      | 50.0%                 | 0.0%     | 54.0%     | 11.1%    | 39.6%    | 11.6%    |          |
|           | Hypertension (+)      | 0.0%                  | 50.0%    | 3.1%     | 31.8%    | 2.8%     | 46.0%    |          |
| P value    | NS                    | NS                   | p<0.001  | p<0.001   | p<0.001  | p<0.001  |          |          |

P values were calculated by using McNemar’s test.

slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m²
When examined in consideration of age-related changes, there was no significant difference in the new morbidity rate and normalization rate due to the increase or decrease in BMI in both men and women in their 40s or younger. In the 50s and 60s, the new prevalence was significantly higher with the increase in BMI. (Table 3-3-12)

**Table 3-3** Changes in the incidence of male hypertension morbidity over two years. Persons under 39 years old in 2014

|          | 2014 slim | 2016 moderately slim | 2016 standard body type | 2016 obese |
|----------|-----------|-----------------------|-------------------------|-----------|
| Hypertension (−) | slim       | moderately slim       | standard body type       | obese     |
| Hypertension (+) | 71.4% 14.3% 100.0% 0.0% | 87.7% 8.8% 66.7% 33.3% | 100.0% 0.0% 76.4% 11.8% 85.7% 14.3% | 100.0% 0.0% 46.7% 20.0% |
| P value | NS        | NS                   | p<0.01                   | p<0.05    |

slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m²
P values were calculated by using McNemar’s test

**Table 3-4** Changes in the incidence of male hypertension morbidity over two years. People aged 40-49 in 2014

|          | 2014 slim | 2016 moderately slim | 2016 standard body type | 2016 obese |
|----------|-----------|-----------------------|-------------------------|-----------|
| Hypertension (−) | slim       | moderately slim       | standard body type       | obese     |
| Hypertension (+) | 86.5% 4.5% 77.8% 11.1% 0.0% 0.0% | 100.0% 0.0% 78.2% 8.3% 86.0% 3.5% | 0.0% 0.0% 2.1% 11.4% 1.7% 8.8% | 71.4% 11.4% 67.2% 13.2% 71.2% 7.6% |
| P value | NS        | NS                   | p<0.01                   | NS        |

slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m²
P values were calculated by using McNemar’s test
Table 3-5  Changes in the incidence of male hypertension morbidity over two years. People aged 50-59 in 2014

|          | 2016                        |          |          |          |          |          |          |
|----------|-----------------------------|----------|----------|----------|----------|----------|----------|
|          | slim                        | moderately slim | standard body type | obese    |          |          |          |
|          | Hypertension (-)                                      | Hypertension (+)                                      | Hypertension (-)                                      | Hypertension (+)                                      | Hypertension (-)                                      | Hypertension (+)                                      |
| slim     | Hypertension (-) 84.0%     | Hypertension (+) 4.0%                                 | Hypertension (-) 83.3%                                 | Hypertension (+) 16.7%                                |          |          |
|          | Hypertension (+) 0.0%       | Hypertension (+) 12.0%                                 | Hypertension (+) 0.0%                                 | Hypertension (+) 0.0%                                 |          |          |
| P value  | NS                          | p<0.001                                           | NS                                                  | NS                                                  | p<0.01                                           | p<0.001                                           |

2014

|          | slim                        | moderately slim                                      | standard body type                                      | obese    |
|          | Hypertension (-) 58.7%      | Hypertension (+) 6.3%                                 | Hypertension (-) 49.6%                                 | Hypertension (+) 18.7%                                |
|          | Hypertension (+) 1.6%       | Hypertension (+) 33.4%                                 | Hypertension (+) 0.9%                                 | Hypertension (+) 30.8%                                |
| P value  | NS                          | p<0.001                                           | p<0.01                                             | p<0.01                                           |

Table 3-6  Changes in the incidence of male hypertension morbidity over two years. People aged 60-69 in 2014

|          | 2016                        |          |          |          |          |          |          |
|----------|-----------------------------|----------|----------|----------|----------|----------|----------|
|          | slim                        | moderately slim | standard body type | obese    |          |          |          |
|          | Hypertension (-)                                      | Hypertension (+)                                      | Hypertension (-)                                      | Hypertension (+)                                      | Hypertension (-)                                      | Hypertension (+)                                      |
| slim     | Hypertension (-) 52.2%     | Hypertension (+) 21.7%                                 | Hypertension (-) 33.3%                                 | Hypertension (+) 25.0%                                |          |          |
|          | Hypertension (+) 0.0%       | Hypertension (+) 26.1%                                 | Hypertension (+) 0.0%                                 | Hypertension (+) 41.7%                                |          |          |
| P value  | p<0.01                         | NS                                        | NS                                                  | p<0.05                                           | p<0.05                                           | p<0.05                                           |

2014

|          | slim                        | moderately slim                                      | standard body type                                      | obese    |
|          | Hypertension (-) 66.8%      | Hypertension (+) 12.5%                                 | Hypertension (-) 51.6%                                 | Hypertension (+) 12.9%                                |
|          | Hypertension (+) 6.2%       | Hypertension (+) 12.5%                                 | Hypertension (+) 2.4%                                 | Hypertension (+) 33.1%                                |
| P value  | p<0.001                         | NS                                        | p<0.001                                             | p<0.05                                           |

|          | slim                        | moderately slim                                      | standard body type                                      | obese    |
|          | Hypertension (-) 39.7%      | Hypertension (+) 8.2%                                 | Hypertension (-) 30.7%                                 | Hypertension (+) 13.4%                                |
|          | Hypertension (+) 2.7%       | Hypertension (+) 49.3%                                 | Hypertension (+) 2.8%                                 | Hypertension (+) 53.2%                                |
| P value  | p<0.001                         | p<0.001                                             | p<0.001                                             | p<0.05                                           |

P values were calculated by using McNemar’s test.
Table 3-7  Changes in the incidence of male hypertension morbidity over two years. People over 70 years old in 2014

|       | 2016 |       |       |       |       |       |
|-------|------|-------|-------|-------|-------|-------|
|       | 2014 |       |       |       |       |       |
|       | slim | moderately slim | standard body type | obese |       |       |
| Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) |
| slim | 58.3% | 8.4% | 0.0% | 33.3% | P value | NS |       |       |
| moderately slim | 38.9% | 5.6% | 44.2% | 9.7% | 34.2% | 21.1% | P value | NS | p<0.01 | NS |
| standard body type | 11.1% | 44.4% | 3.5% | 42.6% | 5.3% | 39.4% | P value | NS | p<0.01 | NS |
| obese | 0.0% | 0.0% | 49.0% | 2.1% | 30.0% | 8.9% | 25.0% | 11.1% | P value | NS | p<0.01 | NS |

slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m²
P values were calculated by using McNemar’s test

Table 3-8  Changes in the incidence of female hypertension morbidity over two years. Persons under 39 years old in 2014

|       | 2016 |       |       |       |       |       |
|-------|------|-------|-------|-------|-------|-------|
|       | 2014 |       |       |       |       |       |
|       | slim | moderately slim | standard body type | obese |       |       |
| Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) |
| slim | 95.8% | 0.0% | 100.0% | 0.0% | P value | NS |       |       |
| moderately slim | 100.0% | 0.0% | 97.5% | 2.5% | 80.0% | 0.0% | P value | NS |       |       |
| standard body type | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 20.0% | P value | NS |       |       |
| obese | 100.0% | 0.0% | 100.0% | 0.0% | 96.4% | 0.0% | 75.0% | 25.0% | P value | NS |       |       |
|       | slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m² |
|       | P values were calculated by using McNemar’s test |
### Table 3-9 Changes in the incidence of female hypertension morbidity over two years. People aged 40-49 in 2014

| Female Body Type | Hypertension Prevalence 2014 | Hypertension Prevalence 2016 | P value |
|------------------|-----------------------------|-----------------------------|---------|
| slim             |                             |                             |         |
| Hypertension (-) | 93.0%                       | 93.0%                       | NS      |
| Hypertension (+) | 0.0%                        | 0.0%                        | NS      |
| moderately slim  |                             |                             |         |
| Hypertension (-) | 100.0%                      | 89.1%                       | p<0.001 |
| Hypertension (+) | 0.0%                        | 0.0%                        | NS      |
| standard body type |                             |                             |         |
| Hypertension (-) | 96.2%                       | 86.3%                       | NS      |
| Hypertension (+) | 0.0%                        | 3.8%                        | NS      |
| obese            |                             |                             |         |
| Hypertension (-) | 100.0%                      | 62.5%                       | NS      |
| Hypertension (+) | 0.0%                        | 0.0%                        | NS      |

slim: BMI<18.5 kg/m², moderately slim: 18.5≤BMI<22 kg/m², standard body type: 22≤BMI<25 kg/m², obese: BMI≥25 kg/m²

P values were calculated by using McNemar’s test.

### Table 3-10 Changes in the incidence of female hypertension morbidity over two years. People aged 50-59 in 2014

| Female Body Type | Hypertension Prevalence 2014 | Hypertension Prevalence 2016 | P value |
|------------------|-----------------------------|-----------------------------|---------|
| slim             |                             |                             |         |
| Hypertension (-) | 82.9%                       | 62.5%                       | p<0.05  |
| Hypertension (+) | 1.0%                        | 0.0%                        | NS      |
| moderately slim  |                             |                             |         |
| Hypertension (-) | 85.3%                       | 75.5%                       | p<0.001 |
| Hypertension (+) | 2.9%                        | 1.8%                        | p<0.05  |
| standard body type |                             |                             |         |
| Hypertension (-) | 58.7%                       | 63.2%                       | NS      |
| Hypertension (+) | 1.8%                        | 1.7%                        | NS      |
| obese            |                             |                             |         |
| Hypertension (-) | 62.5%                       | 6.3%                        | p<0.001 |
| Hypertension (+) | 6.3%                        | 3.0%                        | p<0.001 |

slim: BMI<18.5 kg/m², moderately slim: 18.5≤BMI<22 kg/m², standard body type: 22≤BMI<25 kg/m², obese: BMI≥25 kg/m²

P values were calculated by using McNemar’s test.
Table 3-11  Changes in the incidence of female hypertension morbidity over two years. People aged 60-69 in 2014

|                | Female | 2016 |         |         |         |         |         |         |
|----------------|--------|------|---------|---------|---------|---------|---------|---------|
|                |        | slim | moderately slim | standard body type | obese |         |         |         |
|                |        | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) |
| slim           |        | 70.9% | 11.2% | 76.7% | 6.6% |         |         |         |         |
|               |        | 3.0%  | 14.9% | 0.0%  | 16.7% |         |         |         |         |
| P value        |        | p<0.05 | NS     |         |         |         |         |         |         |
| moderately slim |      | 59.0% | 7.7%  | 60.9% | 10.8% | 63.5% | 7.9%  | 100.0% | 0.0%  |
|               |        | 5.1%  | 28.2% | 2.2%  | 26.1% | 3.2%  | 25.4% | 0.0%  | 0.0%  |
| P value        |        | p<0.001 | NS     |         |         |         |         |         |         |
| standard body type |    | Hypertension (−) | Hypertension (+) |         |         |         |         |         |         |
|               |        | 56.9% | 5.9%  | 46.5% | 10.8% | 32.4% | 23.5% |         |         |
| P value        |        | p<0.001 | NS     |         |         |         |         |         |         |
| obese          |        | 0.0%  | 0.0%  | 52.4% | 14.3% | 25.5% | 13.0% |         |         |
| P value        |        | NS    | p<0.001 | NS     |         |         |         |         |         |

slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m²
P values were calculated by using McNemar’s test

Table 3-12  Changes in the incidence of female hypertension morbidity over two years. People over 70 years old in 2014

|                | Female | 2016 |         |         |         |         |         |         |
|----------------|--------|------|---------|---------|---------|---------|---------|---------|
|                |        | slim | moderately slim | standard body type | obese |         |         |         |
|                |        | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) | Hypertension (−) | Hypertension (+) |
| slim           |        | 44.4% | 20.0% | 9.0%  | 45.5% |         |         |         |         |
|               |        | 2.3%  | 23.3% | 0.0%  | 45.5% |         |         |         |         |
| P value        |        | p<0.05 | NS     |         |         |         |         |         |         |
| moderately slim |      | 66.7% | 11.1% | 38.9% | 14.8% | 33.4% | 23.3% |         |         |
|               |        | 0.0%  | 22.2% | 1.4%  | 44.9% | 3.3%  | 40.0% |         |         |
| P value        |        | p<0.001 | NS     |         |         |         |         |         |         |
| standard body type |    | Hypertension (−) | Hypertension (+) |         |         |         |         |         |         |
|               |        | 43.5% | 8.7%  | 26.2% | 12.1% | 33.3% | 20.0% |         |         |
| P value        |        | p<0.001 | NS     |         |         |         |         |         |         |
| obese          |        | 22.2% | 11.1% | 24.4% | 4.7%  |         |         |         |         |
| P value        |        | NS    | NS    |         |         |         |         |         |         |

slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m²
P values were calculated by using McNemar’s test
3. Diabetes
With respect to diabetes new-onset and normalization rates, males who were moderately slim, of standard body type, or obese in 2014, and showed no change in obesity by 2016, or who were of standard body type in 2014 and obese in 2016 had significantly elevated new-onset rates. Females who were moderately slim or obese in 2014, and showed no change in obesity by 2016 had significantly elevated new-onset rates. Females who were of standard body type in 2014 and obese in 2016 had significantly elevated normalization rates. Females who were of standard body type in 2014 and obese in 2016 had significantly elevated new-onset rates. Females who were moderately slim in 2014 and slim in 2016 had significantly elevated normalization rates. Females who were of standard body type in 2014 and obese in 2016 had significantly elevated new-onset rates.

4. Dyslipidemia
With respect to dyslipidemia new-onset and normalization rates, males who were moderately slim or of standard body type in 2014 and had increased BMI in 2016 had significantly elevated new-onset rates. Males who were of standard body type or obese in 2014, and had decreased BMI in 2016 had significantly elevated normalization rates. Females who were of standard body type in 2014 and obese in 2016 had significantly elevated new-onset rates. Females who were moderately slim in 2014 and slim in 2016 had significantly elevated normalization rates. Females who were of standard body type in 2014 and obese in 2016 had significantly elevated new-onset rates.

Table 4-1 Changes in the incidence of male diabetes morbidity over two years

| Male                | slim     | moderately slim | standard body type | obese     |
|---------------------|----------|-----------------|--------------------|-----------|
|                     | 2016     |                 |                    |           |
| Diabetes (-)        | 89.0%    | 92.7%           | 100.0%             |           |
| Diabetes (+)        | 2.2%     | 0.0%            | 0.0%               |           |
| P value             | NS       | NS              | NS                 |           |

Table 4-2 Changes in the incidence of female diabetes morbidity over two years

| Female              | slim     | moderately slim | standard body type | obese     |
|---------------------|----------|-----------------|--------------------|-----------|
|                     | 2016     |                 |                    |           |
| Diabetes (-)        | 95.3%    | 95.6%           | 100.0%             |           |
| Diabetes (+)        | 0.5%     | 0.0%            | 0.0%               |           |
| P value             | NS       | NS              | NS                 |           |

P values were calculated by using McNemar’s test.
Table 5-1  Changes in the incidence of male dyslipidemia morbidity over two years

|       | 2016 |           |           |           |           |           |           |           |
|-------|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|       | slim | moderately slim | standard body type | obese     |           |           |           |           |
|       | Dyslipidemia (−) | Dyslipidemia (+) | Dyslipidemia (−) | Dyslipidemia (+) | Dyslipidemia (−) | Dyslipidemia (+) | Dyslipidemia (−) | Dyslipidemia (+) |
| 2014  | slim |           |           |           |           |           |           |           |
|       | Dyslipidemia (−) | 56.2% | 8.7% | 56.7% | 10.0% | 0.0% | 0.0% |           |           |
|       | Dyslipidemia (+) | 9.2% | 25.9% | 7.8% | 25.6% | 0.0% | 100.0% |           |           |
|       | P value | NS | NS |       |       |       |       |           |           |
| 2014  | moderately slim |           |           |           |           |           |           |           |
|       | Dyslipidemia (−) | 47.6% | 5.7% | 46.3% | 7.8% | 38.3% | 10.2% | 100.0% | 0.0% |
|       | Dyslipidemia (+) | 17.2% | 29.5% | 7.4% | 38.5% | 4.6% | 46.9% | 0.0% | 0.0% |
|       | P value | p<0.05 | NS | NS |       |       |       |           |           |
| 2014  | standard body type |           |           |           |           |           |           |           |
|       | Dyslipidemia (−) |       |           |       |           |       |           |           |           |
|       | Dyslipidemia (+) |       |           |       |           |       |           |           |           |
|       | P value |       |           |       |           |       |           |           |           |
| 2014  | obese |           |           |           |           |           |           |           |
|       | Dyslipidemia (−) |       |           |       |           |       |           |           |           |
|       | Dyslipidemia (+) |       |           |       |           |       |           |           |           |
|       | P value |       |           |       |           |       |           |           |           |

slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m²
P values were calculated by using McNemar’s test

Table 5-2  Changes in the incidence of female dyslipidemia morbidity over two years

|       | 2016 |           |           |           |           |           |           |
|-------|------|-----------|-----------|-----------|-----------|-----------|-----------|
|       | slim | moderately slim | standard body type | obese |           |           |           |
|       | Dyslipidemia (−) | Dyslipidemia (+) | Dyslipidemia (−) | Dyslipidemia (+) | Dyslipidemia (−) | Dyslipidemia (+) | Dyslipidemia (−) | Dyslipidemia (+) |
| 2014  | slim |           |           |           |           |           |           |           |
|       | Dyslipidemia (−) | 37.9% | 4.2% | 29.9% | 8.2% | 36.8% | 13.6% |           |           |
|       | Dyslipidemia (+) | 10.7% | 47.2% | 7.0% | 54.9% | 3.2% | 46.4% |           |           |
|       | P value | NS | NS |       |       |       |       |           |           |
| 2014  | moderately slim |           |           |           |           |           |           |           |
|       | Dyslipidemia (−) | 0.0% | 0.0% | 31.8% | 7.9% | 22.4% | 6.6% |           |           |
|       | Dyslipidemia (+) | 50.0% | 50.0% | 9.5% | 50.8% | 5.8% | 65.2% |           |           |
|       | P value | NS | NS |       |       |       |       |           |           |

slim: BMI<18.5 kg/m², moderately slim: 18.5≦BMI<22 kg/m², standard body type: 22≦BMI<25 kg/m², obese: BMI≧25 kg/m²
P values were calculated by using McNemar’s test
prevalence of cardiovascular disease and diabetes, is strongly associated with hypertension and dyslipidemia, and is a predictor of elevated ALT \(^{16,17}\). Therefore, maintaining an appropriate body shape is important for preventing cardiovascular disease, but daily lifestyle habits need to be improved, and such improvements are not easy to maintain. With respect to body shape, BMI can easily be measured on a daily basis, and is considered to be a useful index that excludes the effect of weight on height. In fact, the subjects were people who were examined at Tokai University Hospital’s Health Screening Center in both 2014 and 2016, and the increases and decreases in new-onset and normalization rates for hypertension, diabetes and dyslipidemia were investigated in relation to changes between different groups classified by BMI.

In this study, with respect to hypertension, the greater the BMI increase between 2014 and 2016, the higher the new-onset rate, and the greater the decrease in BMI the higher the normalization rate. These findings are consistent with the reports by Huang \(^{20}\) and Moore \(^{29}\) et al. that there is significant correlation between body weight decrease and hypertension risk decrease, and that on the other hand body weight increase results in increased disease risk. However, the finding in the present study was that, although the new-onset rate decreased as a result of BMI decrease, it did not fall below the normalization rate. It is considered that this is because hypertension is associated with dietary salt intake. The dietary salt intake recommended by the Japanese Society of Hypertension is 6 g/day \(^8\), but, according to the 2018 National Health and Nutrition Survey, in both male and female Japanese people aged over 20 the mean dietary salt intake is 10.1 g/day, which is markedly higher than that \(^{20}\). Dietary salt intake is a risk factor for blood pressure increase as well as obesity \(^{21}\), and, although the actual dietary salt intake of the subjects in this study was not measured, it probably tended to be similar to that reported previously, and this is considered to be one reason why the new-onset and normalization rates did not show reversal when BMI was reduced.

With respect to diabetes also, the new-onset rate increased with BMI increase, and the disease risk decreased with BMI decrease. According to a report by Colditz et al. \(^{22}\), BMI changes were an important factor in changes in insulin resistance, and similar findings were made with males in the present study. In addition, even in the group showing no BMI change, the new-onset rate was significantly higher than the normalization rate, and this is considered to be linked to the lean body weight. Goodpaster et al. have reported a close correlation between decreased muscle mass and insulin resistance \(^{23}\). In addition, Micocci et al. have reported a close correlation between BMI decrease and muscle mass decrease \(^{24}\). Skeletal muscles have been reported to make 50 to 75% of the contribution to insulin-responsive glucose uptake \(^{25}\), and deterioration in glucose metabolism can be expected with decrease in muscle mass. It is therefore probable that lean body weight and/or skeletal muscle mass are factors in glucose metabolism together with body fat mass. In addition, females with BMI below 22 in 2014 showed more of a tendency toward increased normalization rate and decreased new-onset rate if they were in groups showing BMI increase by 2016 than in groups showing BMI decrease. It has been reported that muscle mass decreases with aging less than in males \(^{26}\), and it has also been reported that, when a male versus female comparison of low-BMI individuals was made, the males showed decreased skeletal muscle mass, and the females showed decreased subcutaneous fat mass \(^{27}\). For this reason, it is considered that female body weight increases when the skeletal muscle mass is maintained, and this is linked to the sex differences in the findings.

With respect to dyslipidemia also, in both males and females increased new-onset rate and decreased normalization rate were found with increased BMI, and decreased new-onset rate and increased normalization rate were found with decreased BMI. In this context, dyslipidemia is considered to be one of the most generally occurring and representative of obesity-related metabolic diseases, and is also known to be linked to BMI \(^{28}\).

In addition, it has been reported that, by means of exercise and total energy intake restriction, decrease in triglyceride level, low-density lipoprotein cholesterol, body weight, and body fat mass can be expected, and, especially when the body weight decrease is by more than 5%, increase in high-density lipoprotein cholesterol can also be expected \(^{20,21}\).

The correlations between these changes and BMI increase and decrease are more marked in males than females. This appears to be linked to the distribution of fat in the body, and it has been reported that male obesity is most commonly of the visceral-fat type, whereas in females, due to the effects of sex hormones, subcutaneous fat tends to accumulate in the buttocks and thighs \(^{22}\).

Dyslipidemia has also been reported to be closely correlated with visceral fat mass \(^{33}\), and it is therefore considered that in males increases and decreases in BMI result in the phenomenon of reversal between the new-onset and normalization rates, and the reason why this phenomenon does not occur in females is that there are sex differences in visceral fat mass, which is closely linked to dyslipidemia.

Lifestyle-related diseases do have a direct causal relationship with BMI, but age-related changes also affect many of these diseases. O’Rourke reports that reduced macrovascular compliance increases systolic blood pressure but rather diastolic blood pressure in men and women over the age of 60, resulting in increased pulse pressure \(^{34}\). In fact, a survey in Japan also shows that the older the age group, the higher the prevalence of both men and women \(^{20}\).

Zimmet reports an increase in the prevalence of type 2 diabetes with age, regardless of race \(^{35}\). In Japan, the Aito study also showed that the new prevalence of diabetes increases with age in both men and women \(^{36}\).

In Yihua’s report, the prevalence of premenopausal and post-menopausal dyslipidemia was significantly higher, with or without obesity \(^{37}\). According to the National Nutrition Survey in Japan, the prevalence of dyslipidemia increased with aging in both men and women, and it was considered that not only BMI changes but also increasing age had an effect on the changes \(^{20}\).

In this study as well, the BMI of males was unchanged in the
and new-onset and normalization rates, it is necessary to investigate what kinds of lifestyle changes actually occurred during the relevant period, because no information on diet and exercise was available. BMI changes are consequences of lifestyle changes and there have been numerous reports that lifestyle changes affect test results. Secondly, the subjects were individuals who wished to undergo health check-ups, and were therefore self-chosen, and perhaps of relatively high intelligence, for example. In future, it will be necessary to investigate how changes in lifestyle quality affect changes in BMI. Third, climacteric and postmenopause are periods in which dynamic hormonal balance changes occur in women’s life stages. It contributes greatly to the morbidity of lifestyle-related diseases regardless of BMI change. However, this study did not investigate climacteric or postmenopause, and did not take into account changes in female hormones.

CONCLUSIONS
Changes in BMI were associated with changes in new-onset and normalization rates, especially for dyslipidemia. Although hypertension and diabetes are associated with changes in BMI and new-onset and normalization rates, it is necessary to investigate the involvement of other lifestyle-related factors.

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

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Suzuki et al.: BMI changes and life-style related disease

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