Medical costs of obese Japanese: a 10-year follow-up study of National Health Insurance in Shiga, Japan

Koshi Nakamura¹, Tomonori Okamura¹, Hideyuki Kanda², Takehito Hayakawa³, Akira Okayama⁴, Hirotsgu Ueshima¹, The Health Promotion Research Committee of the Shiga National Health Insurance Organizations⁵

Background: For the Japanese population, a body mass index (BMI) of 25.0–29.9 is classified as obesity and is a risk factor for cardiovascular disorders such as hypertension. Methods: A cohort study to clarify obesity costs for a Japanese population was conducted utilizing baseline BMI and medical costs over a 10-year follow-up period. The participants were 4502 community dwelling Japanese National Health Insurance (NHI) beneficiaries aged 40–69 years. According to their baseline BMI values (kg/m²), participants were classified into the following three categories: BMI < 18.5, 18.5 ≤ BMI < 25.0 and 25.0 ≤ BMI. Medical costs per person per month were compared among the three categories. Excess medical costs attributable to the 25.0 ≤ BMI category compared to the 18.5 ≤ BMI < 25.0 category were estimated. Results: Approximately 20% of the Japanese population studied had a BMI of 25.0 or over. A J-shaped relationship between BMI and personal total medical costs was observed. Personal total medical costs per month determined from the 10-year follow-up in each category were 189 Euros (BMI < 18.5), 134 Euros (18.5 ≤ BMI < 25.0) and 155 Euros (25.0 ≤ BMI). A J-shaped pattern was observed after adjusting for age, sex, smoking and drinking habits, and excluding early deceased participants. Furthermore, smoking habit did not modify the J-shaped pattern of total medical costs. The estimated excess medical costs for the 25.0 ≤ BMI category represented 3.1% of the total medical costs for the entire study population (634 105 Euros). Conclusion: The Japanese NHI beneficiaries with a BMI of 25.0 or over showed increased medical costs compared to those with a BMI of 18.5–24.9.

Keywords: obesity, body mass index, medical costs, Japan

Introduction

Obesity is an important public health problem, and a cause of excess death¹⁻³ and medical costs⁶⁻¹² in many developed countries. In the United States, the impact of obesity on medical economics has been a major burden which has been examined by many studies.⁶⁻¹⁰ However, the mean body mass index (BMI) in Asian populations is quite different from that found in Western populations¹³,¹⁴, and the results of studies in the United States may not be directly relevant or adaptable to the Japanese population. Furthermore, no long-term cohort studies investigating obesity costs have been conducted for Asian populations. Therefore, we attempted to measure the effect of obesity, evaluated by BMI, on medical economics, using a 10-year follow-up study in a community-based population in Japan.

Methods

Medical costs

In Japan, medical costs are based on the original medical insurance institution¹⁵,¹⁶ which is under control of the National Government. This official medical insurance institution consists of two insurance systems, and everyone living in Japan is required to enroll in one of these insurance systems. There is no private medical insurance. The eligibility for each insurance system is as follows: the first system is for employees and their dependants and covers 65.3% of the overall population, while the other system is for self-employed individuals such as farmers and fishermen, as well as retirees and their dependants, and covers the remaining 34.7% of the population. All eligible beneficiaries in both insurance systems must pay an annual fee to help fund the system. In principle, both insurance systems guarantee that each beneficiary can have access to medical services for any condition at any clinic or hospital throughout Japan. Medical costs depend upon the medical services which a beneficiary receives at a clinic or hospital. No taxes are imposed on the medical costs. The clinic or hospital requests medical costs from both the insurance system and the beneficiary, with insurance paying 70% and the beneficiary paying 30% of the total costs. In the present study, total medical costs were divided into outpatient and inpatient medical costs.

Study design and participants

The cohort in the present study comprised 4535 Japanese beneficiaries of the National Health Insurance (NHI), the insurance system for self-employed individuals. The details of the present cohort have been reported previously.¹⁷

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¹ Department of Health Science, Shiga University of Medical Science, Otsu City, Shiga, Japan
² Department of Preventive Cardiology, National Cardiovascular Center, Suita City, Osaka, Japan
³ Department of Health Science, Shiga University of Medical Science, Otsu City, Shiga, 520-2192, Japan, tel:+81-77-548-2191; fax:+81-77-543-9732; e-mail: ksnkmr@belle.shiga-med.ac.jp
⁴ Department of Preventive Medicine, Fukushima Medical University, Fukushima City, Fukushima, Japan
⁵ Members of the committee are listed in the Appendix

Correspondence: Koshi Nakamura, MD, PhD, Department of Health Science, Shiga University of Medical Science, Otsu City, Shiga, 520-2192, Japan, tel:+81-77-548-2191; fax:+81-77-543-9732; e-mail: ksnkmr@belle.shiga-med.ac.jp

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The participants, aged 40–69 years, lived in seven rural towns and one village in Shiga Prefecture, West Japan and had undergone a voluntary baseline survey in 1989–1991. In 1990, the study area had 82,155 residents, including 31,564 individuals aged 40–69 years old, of whom 11,900 were NHI beneficiaries. Therefore, the participants in the present study represented approximately 38% of all NHI beneficiaries aged 40–69 years living in this area. Of the 4535 participants, 33 were excluded because of missing information at the time of the baseline survey. The remaining 4502 participants were included in the analysis. Monthly NHI claim history files of the Shiga NHI Organizations were linked with the baseline survey data files at the organizations. In order to protect the participants’ privacy their names were deleted from the linked data at the organizations. Therefore, the data were analysed without knowledge of the participants’ identity. The present study was approved by the Institutional Review Board of Shiga University of Medical Science for ethical issues (No. 16–15).

**Data collection**

A baseline survey was performed in the period 1989–1991 using standardized methods according to the Manual for Health Check-ups under the Medical Service Law for the Aged, issued by the Japan Public Health Association in 1987. Body height and weight were measured, and BMI was calculated as body weight (kg) divided by the square of body height (m). Referring to the obesity classification of the World Health Organization and that of the Japan Society for the Study of Obesity, the participants were classified into the following three categories: BMI < 18.5 kg/m², 18.5 ≤ BMI < 25.0 kg/m² and 25.0 ≤ BMI kg². Obesity is defined as a BMI of 25.0 or over for the Japanese population, although it is defined as a BMI of 30.0 or over for Western populations. Thus, we also defined obesity as a BMI ≥ 25.0 in the present study. Smoking and drinking habits, and medication status for hypertension or a history of diabetes mellitus were evaluated from interviews performed by well-trained public health nurses. Blood pressure was measured using a standard mercury sphygmomanometer on the right arm of each participant in the sitting position after at least a five-minute rest. Serum total cholesterol levels were measured by an enzymatic method. Hypertension was defined as a systolic blood pressure ≥140 mmHg, a diastolic blood pressure ≥90 mmHg or taking anti-hypertensive medication. Hypercholesterolemia was defined as a serum total cholesterol level ≥5.69 mmol/l (220 mg/dl). Diabetes was defined as having a history of diabetes.

We evaluated medical costs per person after a 10-year follow-up, as well as all-cause mortality for each BMI category. We used the 18.5 ≤ BMI < 25.0 category as a reference in the evaluation. Medical costs per person in the two sub-categories of obesity (25.0 kg/m² ≤ BMI < 30.0 kg/m² and 30.0 kg/m² ≤ BMI) were also evaluated. Information on medical costs for each participant, as well as on participants who withdrew from the NHI or those who died, were obtained from monthly NHI-claim history files, beginning from April in the year following their initial health check-up until March 2001. Costs were expressed in Euros (i.e. 1 Euro = 143 Japanese Yen or 1.21 US Dollars, at the foreign exchange rate on 1 April 2006). Data on medical costs for each participant differed depending upon the period of subscription to the NHI. Therefore, medical costs for each participant were divided by the period of subscription and expressed as costs per month of follow-up. If a beneficiary withdrew from the NHI or died, the follow-up was stopped at that point, but was restarted for beneficiaries who withdrew and then re-enrolled in the NHI. Reasons for withdrawal from the NHI included moving to regions outside of Shiga Prefecture or transfer to the other insurance system.

**Data analysis**

Because the distribution of real medical costs was positively skewed, the data were logarithmically transformed in order to normalize the distribution, and the results were expressed as geometric means. For participants with 0 Euros (per month) in costs, the logarithmic transformations were performed by replacing 0 Euros with 0.01 Euros. There were 15 participants with total medical costs of 0 Euros and 16 participants with outpatient medical costs of 0 Euros. For comparisons of total and outpatient medical costs per person in each BMI category, we performed an analysis of covariance with the Bonferroni correction to adjust the P-value for multiple post-hoc comparisons. The analysis of covariance incorporated the following variables as covariates: age, sex, smoking habit (non-smoker or current smoker), and drinking habit (non-, current occasional or current daily drinker, using two dummy variables with the non-drinker as a reference). Because 2389 participants (57.5%) had inpatient medical costs of 0 Euros, logarithmic transformations were not performed, and the Wilcoxon’s rank sum test was used to compare medical costs in each BMI category.

A Cox proportional hazards model for all-cause mortality was used to calculate the hazard ratio in each BMI category compared to the 18.5 ≤ BMI < 25.0 category. This model also incorporated the same covariates previously listed. Initially, the significance of an interaction for total medical costs and for all-cause mortality between BMI and sex was tested using an interaction term for the categorical variables in each multivariate-adjusted model. Next, medical costs per person and the hazard ratio for all-cause mortality in each of the three BMI categories were evaluated. Smoking habit or poor health status is significantly associated with unintentional weight loss. This may affect the relationship between BMI and medical costs, especially the medical costs of underweight people. Therefore, similar analyses were performed after taking into account smoking habit—i.e. non-smoking, including ex-smoking, or current smoking—for the three BMI categories. In addition, similar analyses were performed after excluding participants who had died in the first 5 years of follow-up.

Finally, we examined excess medical costs attributable to the 25.0 ≤ BMI category compared to the 18.5 ≤ BMI < 25.0 category by using the arithmetic means of total medical costs, when a significant difference in medical costs between the two BMI categories was observed. The excess medical costs attributable to the 25.0 ≤ BMI category were calculated as follows: (total medical costs in the 25.0 ≤ BMI category — total medical costs in the 18.5 ≤ BMI < 25.0 category) × number of the participants in the 25.0 ≤ BMI category.

The statistical package SPSS 14.0J for Windows (SPSS Japan Inc., Tokyo, Japan) was used for the statistical analyses. All probability values were two-tailed and the significance level was set at P < 0.05.

**Results**

The baseline risk characteristics of the 4502 participants grouped by BMI are summarized in Table 1. For both sexes, approximately 20% of all participants had a BMI of 25.0 or over, and approximately 1% had a BMI of 30.0 or over. For both sexes, the 25.0 ≤ BMI category had the highest prevalence of hypertension, hypercholesterolaemia and diabetes mellitus in the three BMI categories. The BMI < 18.5 category had the highest mean age and the highest prevalence of current smokers and drinkers.
The total person-years were 40,565 and mean follow-up period was 9.0 years. There was no interaction for total medical costs and all-cause mortality between BMI and sex. Furthermore, when we performed sex-specific analyses of the relationships between BMI and total medical costs or all-cause mortality, the pattern of results was similar for both men and women. Therefore, we reported the relationships for both sexes combined. The relationship between BMI and total medical costs per person was J-shaped, with the nadir of the curve occurring at a BMI of 18.5–24.9, as shown in Table 2. For the multivariate-adjusted geometric means of total medical costs, the differences among the three BMI categories were statistically significant (P < 0.01). The 25.0 < BMI < 30.0 BMI category showed a statistically significant 1.3-fold increase compared to the 18.5 < BMI < 25.0 category. The BMI < 18.5 category also showed a 1.2-fold increase compared to the 18.5 < BMI < 25.0 category, although the increase was not statistically significant. Similar statistically significant differences were observed in outpatient medical costs as well (P < 0.01). Inpatient medical costs showed statistically significant differences among the three BMI categories (P < 0.01). When we performed the analyses with the obese participants classified into the two sub-categories, the arithmetic means for total medical costs were 139 Euros (per month) (25.0 < BMI < 30.0; n = 888) and 386 Euros (30.0 < BMI) (data not shown in the table). The adjusted geometric means of the total medical costs were 70 Euros (per month) (25.0 < BMI < 30.0) and 125 Euros (30.0 < BMI) (data not shown in the table). On the other hand, the relationship between BMI and all-cause mortality was inversely J-shaped, as shown in Table 2.

The pattern of personal medical costs was J-shaped among the non-smoking participants as well as the current smokers (data not shown in the table). The adjusted geometric means

Table 1 Baseline risk characteristics of 4502 National Health Insurance beneficiaries in Shiga, Japan from 1989–1991, grouped by sex and body mass index

<table>
<thead>
<tr>
<th>Body mass index (BMI) (kg/m²) category</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of participants (percentage)</strong></td>
<td>95 (4.9%)</td>
<td>125 (4.9%)</td>
</tr>
<tr>
<td><strong>Age (year)</strong></td>
<td>58.3 ± 8.0</td>
<td>56.3 ± 7.9</td>
</tr>
<tr>
<td><strong>Body mass index (kg/m²)</strong></td>
<td>17.6 ± 0.7</td>
<td>17.5 ± 0.9</td>
</tr>
<tr>
<td><strong>Current smoker (%)</strong></td>
<td>74.7</td>
<td>11.2</td>
</tr>
<tr>
<td><strong>Occasional drinker (%)</strong></td>
<td>18.9</td>
<td>13.6</td>
</tr>
<tr>
<td><strong>Daily drinker (%)</strong></td>
<td>46.3</td>
<td>7.2</td>
</tr>
<tr>
<td><strong>Hypertension (%)</strong></td>
<td>27.4</td>
<td>23.2</td>
</tr>
<tr>
<td><strong>Hypercholesterolaemia (%)</strong></td>
<td>11.6</td>
<td>21.6</td>
</tr>
<tr>
<td><strong>Diabetes mellitus (%)</strong></td>
<td>5.3</td>
<td>2.4</td>
</tr>
</tbody>
</table>

a: One way analysis of variance.
b: Chi-square test.
c: Significant difference among the three BMI categories, P < 0.05.

Table 2 Medical costs per person and all-cause mortality grouped by body mass index, from a 10-year follow-up from 1990 to 2001, in National Health Insurance in Shiga, Japan

<table>
<thead>
<tr>
<th>Body mass index (BMI) (kg/m²) category</th>
<th>Number of participants</th>
<th>Total Costs</th>
<th>Outpatient Costs</th>
<th>Inpatient Costs</th>
<th>All-cause mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arithmetic mean</strong></td>
<td><strong>Adjusted geometric mean</strong></td>
<td><strong>Arithmetic mean</strong></td>
<td><strong>Adjusted geometric mean</strong></td>
<td><strong>Arithmetic mean</strong></td>
<td><strong>Number</strong></td>
</tr>
</tbody>
</table>

BMI < 18.5 | 220 | 189 Euros | 65 Euros | 83 Euros | 65 Euros | 1.76 (1.12–2.77) |
18.5 < BMI < 25.0 | 3334 | 134 Euros | 56 Euros | 74 Euros | 42 Euros | 105 Euros | 1.00 |
25.0 < BMI | 948 | 155 Euros | 73 Euros | 86 Euros | 53 Euros | 68 Euros | 40 | 1.21 (0.85–1.73) |

1 Euros = 143 Japanese Yen or 1.21 US Dollars, at the foreign exchange rate on 1 April 2006
a: Analysis of covariance adjusted for age, sex, smoking habit and drinking habit.
b: Significant difference, vs. 18.5 < BMI < 25.0, for multiple post-hoc comparisons with Bonferroni correction, P < 0.05.
c: Wilcoxon’s rank sum test.
d: Analysis of a Cox proportional hazards regression model adjusted for age, sex, smoking habit and drinking habit.
for the total medical costs were 66 Euros (per month) (BMI < 18.5 non-current smokers: n = 135), 55 Euros (18.5 ≤ BMI < 25.0 non-current smokers: n = 2376), 72 Euros (25.0 ≤ BMI non-current smokers: n = 741), 63 Euros (BMI < 18.5 current smokers: n = 85), 59 Euros (18.5 ≤ BMI < 25.0 current smokers: n = 988) and 75 Euros (25.0 ≤ BMI current smokers: n = 207).

The pattern of personal medical costs was J-shaped after excluding the early deceased participants (data not shown in the table). The adjusted geometric means for the total medical costs were 61 Euros (per month) (BMI < 18.5; n = 212), 54 Euros (18.5 ≤ BMI < 25.0; n = 3264) and 70 Euros (25.0 ≤ BMI; n = 931).

The excess medical costs attributable to the 25.0 ≤ BMI category as contrasted with the 18.5 ≤ BMI category was estimated to be 19,908 Euros (per month), and were calculated as follows: (155 Euros – 134 Euros) × 948 participants with a BMI of 25.0 or over. Accordingly, the excess medical costs attributable to obesity, which was defined as a BMI of 25.0 or over, represented 3.1% of the total medical costs for all the 4502 participants (634,105 Euros), and was calculated as follows: 19,908 Euros/634,105 Euros.

Discussion

To our knowledge, few studies on medical costs for obesity have been conducted for Asian populations, and no long-term investigations have been conducted. The strength of the present study is that we conducted a much longer follow-up period (10-year) compared to previous studies. We demonstrated that the relationship between BMI and medical costs in a general Japanese population was J-shaped, with the nadir of the curve occurring at a BMI between 18.5 and 24.9, after adjusting for confounding factors. In particular, personal total medical costs for groups with a BMI of 30.0 or over were much higher than those in groups with a BMI between 25.0 and 29.9. Smoking habit did not modify the J-shaped pattern of total medical costs. A similar J-shaped pattern was observed even after excluding participants who had died in the first 5 years of follow-up. After a 10-year follow-up, the excess medical costs attributable to participants with a BMI of 25.0 or over represented 3.1% of the total medical costs for all groups.

Obesity has been identified as a significant risk factor for hypertension, diabetes mellitus and dyslipidemia. A combination of these syndromes is known as metabolic syndrome, which is a major risk factor for cardiovascular disease. Obesity has also been identified as a significant risk factor for colorectal, prostate, endometrial, ovary and breast cancer. Furthermore, obesity is a risk for knee osteoarthritis. Some obese patients with knee osteoarthritis may require symptomatic relief or joint replacement surgery. Obesity can lead to increased mortality and medical costs as a result of the associated diseases previously mentioned. In fact, the present study showed that the obese participants had a higher prevalence of hypertension, hypercholesterolaemia and diabetes mellitus at baseline. The prevalence of hypertension in the obese participants was substantially high. Accordingly, some obese participants in the present study may have incurred medical costs due to these disorders. Furthermore, serious diseases caused by these disorders (e.g. cardiovascular disease) may also have led to increased medical costs of the obese participants. The latter possible explanation is supported by the higher hazard ratio for all-cause mortality in the obese participants.

Kuriyama et al. reported a J-shaped relationship between BMI and medical costs after a 4-year follow-up in Miyagi Prefecture, East Japan. In their study, the estimated excess medical costs attributable to obesity from a BMI of 25.0 or over represented 3.2% of the entire costs for their study population. Our results are consistent with this finding in spite of the different regions and follow-up periods. Accordingly, our results may be applicable to the Japanese population in general, despite some regional differences in lifestyle. Wolf et al. reported that medical costs associated with obesity defined as a BMI of 30.0 or over represented 5.7% of National Health Expenditure in the United States in 1995. The prevalence of people with a BMI of 30.0 or over in Western populations is 20–30% which is almost equal to the prevalence of people with a BMI of 25.0 or over in the Japanese population. These results suggest that the impact of people with a BMI of 25.0 or over on medical economics for the entire Japanese population is almost two-thirds that of people with a BMI of 30.0 or over in the United States.

Being underweight, which is usually defined as a BMI below 18.5, also represents a high risk of death when there has been unintentional weight loss. Unintentional weight loss is significantly associated with older age, a lower BMI, a smoking habit or poor health status. Furthermore, Wannamethee et al. reported that increased mortality of underweight people was likely to be a direct result of a pre-existing disease which led to the underweight condition. Smokers are especially likely to have a lower BMI than non-smokers due to serious diseases associated with smoking. Therefore, some of the underweight participants in the present study, especially those with smoking habit, may also have had a serious disease which caused unintentional weight loss, thus leading to increased mortality and medical costs. Meanwhile, it is also possible that some of the normal weight participants may have experienced weight loss prior to baseline due to pre-existing diseases, which may have influenced medical costs during follow-up. The differences in medical costs between the obese participants and the normal weight participants, as well as the underweight participants, may have been underestimated in the present study. In order to examine the effects of smoking habit or pre-existing diseases, we performed analyses taking into account smoking habit and excluded premature death. We still found a J-shaped pattern of personal medical costs in these further analyses. Medical costs of underweight people are likely to be higher than those of normal weight people, irrespective of smoking habit or premature death. As for smoking habit, Hayashi et al. reported increased all-cause mortality in the lower BMI groups regardless of smoking status (never smokers, ex-smokers and current smokers) for Japanese men. This result supports our result demonstrating increased medical costs of underweight participants with or without current smoking habit. The present study has several limitations. First, medical cost data from the official medical insurance records in Japan do not include costs for any services used to prevent disease or to promote health status (e.g. special diet for weight control). If the obese participants took advantage of such services more frequently than the normal weight participants, the obese participants would have incurred medical costs more in excess of what we observed. Therefore, there may be a possibility that we underestimated obesity cost in the present study. However, all beneficiaries can take advantage of therapeutic services without paying an extra insurance fee, even if he or she suffers from a serious disease. Therefore, the results in the present study may be sufficient to reveal long-term medical costs of obese people. Second, participation was limited to NHBI beneficiaries belonging to self-employed occupational groups in one area of Shiga prefecture in Japan. The socioeconomic status and lifestyle of these NHBI beneficiaries may have had an effect on their health status, and may be a confounding factor among the three BMI categories. However,
socioeconomic status and lifestyle were not available in the present study. Third, we had no serial data for obesity-associated factors such as blood pressure after the baseline survey. Furthermore, medical diagnosis, medical treatment status and causes of mortality during the follow-up period were also not available in the present study. Therefore, we could not identify the events which directly increased medical costs among the obese participants. Finally, it is better to classify obesity into the two subcategories, 25.0 ≤ BMI < 30.0 and 30.0 ≤ BMI. However, we did not classify obesity further in the analysis, because the number of obese participants with a BMI of 30.0 or over was very small (n = 60) in our study population.

In spite of the limitations previously mentioned, we believe that medical costs of the obese or underweight participants increased due to diseases associated with a higher or lower BMI, and that the J-shaped relationship between BMI and medical costs in the present study are reasonable, and are supported by similar relationships between BMI and mortality in previous studies on Japanese populations.3-5

In conclusion, approximately 20% of the Japanese NHI beneficiaries in the present study had a BMI of 25.0 or over, and this BMI level was associated with a burden on medical economics in Japan.

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Key points
- The relationship between BMI and medical costs in a general Japanese population was J-shaped, with the nadir of the curve occurring at a BMI between 18.5 and 24.9, after a 10-year follow-up.
- Smoking habit did not modify the J-shaped pattern of total medical costs.
- The excess medical costs attributable to obese individuals having a BMI of 25.0 or over represented 3.1% of the total medical costs for all groups.
- Our results are consistent with finding reported after a 4-year follow-up, in spite of differing regions and follow-up periods, and may be applicable to the Japanese population in general.
- A BMI level of 25.0 or over may be associated with a burden on medical economics in Japan.

References
Appendix

The Health Promotion Research Committee of the Shiga NHI Organizations.

Chairman: Hirotsugu Ueshima (Department of Health Science, Shiga University of Medical Science).

Participating Researchers: Shigeo Yamashita (Kohoku General Hospital), Tomonori Okamura (Department of Health Science, Shiga University of Medical Science), Yoshinori Tominaga (Kohka Public Hospital), Kazuaki Katsuyama (Otsu Public Health Center), Fumihiko Kakuno (Nagahama Public Health Center), Machiko Kitanishi (Higashimi City Yokaichi Public Health Center).

Associate Researchers: Koshi Nakamura (Department of Health Science, Shiga University of Medical Science), Hideyuki Kanda (Department of Hygiene and Preventive Medicine, Fukushima Medical University).

Secretary Members: Yukio Tobita, Kanehiro Okamura, Kiminobu Hatta, Takao Okada, Michiko Hatanaka (the Shiga NHI Organizations).

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