Updated Japanese growth references for infants and preschool children, based on historical, ethnic and environmental characteristics

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ABSTRACT
Aim: To provide updated growth references for Japanese children from birth to 6 years of age, for use in both growth monitoring and child care.

Methods: We analysed data from two national representative surveys that provided cross-sectional data on 3000 areas in the 2005 national census and longitudinal data from 136 hospitals. Growth references for length/height, weight, head circumference and chest circumference were constructed using the lambda-mu-sigma (LMS) method, with estimates of the $L$, $M$ and $S$ parameters. These updated values were then compared with growth references published by the World Health Organization.

Results: The 3rd, 50th and 97th smoothed percentile values of length/height, weight, head circumference and chest circumference for boys and girls from birth to 6 years are presented. The comparisons show some large differences in median measurements between the charts.

Conclusion: Our growth references are based on a current, nationally representative sample of Japanese children. The results provide deep insight into child growth from a historical, ethnic and environmental point of view.

INTRODUCTION
Comparing a child’s body measurements with growth references, representative of the corresponding population is one of the most useful ways of assessing their growth. National growth surveys provide useful references for assessing individual children and monitoring the overall growth of children from a public health point of view (1).

Japanese national growth references for infants and preschool children, based on a representative national sample consisting of an almost homogeneous population, have been monitored at 10-year intervals for more than half a century. The first growth reference for Japanese infants and preschool children was published as the Kuriyama/Yoshinaga reference (University of Tokyo, Department of Pediatrics Values) in 1929 and was based on an investigation of healthy children in the suburbs of Tokyo (2). Subsequent growth references were primarily compiled by the National Institute of Public Health, on the basis of surveys funded by the Ministry of Education. The Saito/Shimizu reference was conducted in 1940, and the Saito/Funakawa reference was conducted in 1950 (3,4). Governmental surveys have been carried out every 10 years since 1960 by the Ministry of Health and Welfare, with the latest carried out in 2010 by the Ministry of Health, Labour and Welfare (5–9). Our study is based on the updated references from the 2010 survey.

Normal neonates experience weight loss during the first few days of life (10). Therefore, growth references for weight during the first few months of life are more useful if the

Key notes
• This paper presents updated growth references for Japanese children from birth to 6 years of age.
• It shows that Japanese preschool children are smaller than children raised in Western countries and some Asian countries and are smaller than children of Japanese origin raised in America.
• The findings reflect changes in Japan’s socioeconomic status, infant feeding practices and birthweight and provide a useful weight reference for infants in the first few months of life.
references are constructed taking neonatal weight loss into account. Therefore, hospital data, including daily weight measurements during the first 5 days, were included in the analysis.

In this paper, we present the length/height, weight, head circumference and chest circumference references for infants and children in Japan using data from a current sample of Japanese children from birth to 6 years of age and compare the resulting selected centiles with chosen growth references. We also took advantage of the large sample, representative of the population, to provide updated growth references for Japanese children, including body weight changes during the neonatal period.

METHODS
The 2010 growth survey of infants and children was conducted by the Equal Employment, Children and Families Bureau of the Ministry of Health, Labour and Welfare in Japan. The study design and evaluation of the results were discussed by a committee of academic experts, and the growth references were created by the working group funded by the Ministry.

Subjects
The survey consisted of two components: a cross-sectional general survey and a longitudinal hospital survey. Subjects included in the community-based, cross-sectional general survey were all infants and preschool children aged from 14 days to 2 years on the day of measurement, who were living in the 3000 areas randomly sampled by stratification from the 2005 census areas (11). Preschool children aged from two to 6 years in 900 areas, selected randomly from the 3000 areas mentioned above, were also recruited. The municipalities were asked to look at the resident files that were used in the 2005 census, and in August 2010, a letter was mailed to all residents in the 2005 census, asking them general questions about the number of infants and preschool children they would have in September 2010. As a result of the letter, we identified 10,880 infants and preschool children who were eligible for the current study. The 1-month survey was performed between 1 and 30 September 2010. Municipality health centres gathered infants and preschool children on the appointed day and health personnel measured them and carried out health examinations. Home visits were made to those who failed to attend the examination on that day. These two initiatives resulted in data from 7,652 infants and preschool children, with a response rate of 70.3%.

The hospital survey collected longitudinal growth data over a 1-month period Hospitals throughout Japan (n = 150) with an obstetrics department, and inpatient beds were sampled randomly from the basic file of medical facilities from the national survey of medical facilities (12). Data were obtained on all infants who were born in the hospitals and underwent their 1-month health check during the 1-month study period in September 2010. This yielded data on 4,774 infants from 146 hospitals.

Survey items
During the community survey, the length/height, weight, head circumference and chest circumference of infants and preschool children were measured and their general health status was assessed by a physician. The parents provided the following information interviewed by health personnel: the medical history of the children, including past and present diseases, medication used, date of birth, birth weight and social status.

During the hospital survey, all recorded measurements of the four items of length/height, weight, head circumference and chest circumference during the baby’s hospital stay and at their 1-month health check-up after birth were collected. The study team also checked their medical records for items such as gestational age, multiple birth and birth order, mode of delivery and any disorders during delivery and the neonatal period that can affect the growth of neonates. The longitudinal hospital data were collected in addition to cross-sectional community data so that body weight changes were clear from birth to around 1 month of age. Although the data were collected longitudinally, they were analysed cross-sectionally.

Ethical issues
The two surveys were conducted as official Government surveys approved by the Ministry of General Affairs. The present research was approved by the Institutional Review Board of the National Institute of Public Health. The procedures followed were in accordance with the Helsinki Declaration of 1975, as revised in 1983.

Measurements
All the children and infants were measured by trained staff. The nurses and public health personnel used standardised instruments and methods that conformed with the guidelines outlined in the study manual. A neonatometer was used to measure the length of infants and children under the age of 2, to the nearest 0.1 cm. The infants were naked, in the supine position, head in the Frankfurt plane, knees loosely fixed and plantars perpendicular to both the vertical axis and horizontal plane. A stadiometer was used to measure the height of children aged 2 and over, to the nearest 0.1 cm. The children were standing upright, with their heels, hips and back straight against the pillar and their head in the Frankfurt plane. The body weight of the infants was measured before feeding and after they passed stools and urine, to the nearest 10 g. If they wore diapers or clothes, the weight of them was subtracted.

The head circumference was measured along the line passing the glabella and external occipital protuberance, and the chest circumference was measured in the plane passing the bilateral nipples and perpendicular to the body axis. The measurement was to the nearest 0.1 cm using a plastic measure.

Data processing
The data were processed centrally, with data entry performed by trained staff, according to the study’s data entry manual.
The data were initially checked to see whether there were values of <0.3 kg or over 50 kg for weight, under 25 cm of over 80 cm for height/length and under 15 cm or over 80 cm for head circumference and chest circumference. If the values were over or under these figures, the original sheets were checked and the data entry errors were corrected. Data on the individual cards that were confirmed to be abnormal were excluded. Outliers were excluded. They were defined as values larger or smaller than 0.01% among the distribution of the data and which appeared to be artificial errata during data recording and/or transfer. A total of 0.46% of the data were excluded from the analysis.

Centile curves
The distribution of the data was somewhat skewed, especially the data for weight and chest circumference. Therefore, the Z-scores and centiles could not be calculated from the mean and standard deviation, which assume a normal distribution. Therefore, the LMS method was used to create the growth reference (13) except for the age group from 8 to 22 days. We performed weighted calculations by sample size for smoothing. The assumption underlying the LMS method is that after the Box–Cox power transformation, the data at each age are normally distributed.

The LMS method uses three quantities: the power (L), median (M) and coefficient of variation (S) calculated for each group. It then uses these values to determine the value that best approximates the median (50th centile of the distribution). The parameter L shows the skewness of the distribution. The distribution is symmetrical when L = 1, trails long to smaller values when L > 1, and trails long to larger values when L < 1.

From the values of L, S and M, smoothed by the cubic equation, a given percentile value can be calculated using the following equation: \( M(1 + ZLS)^{1/L} \), where Z is the Z-score of the normalised distribution. To calculate the third, 50th and 97th percentile values, Z was substituted as −1.88079, 0 or 1.88079, respectively.

The three corresponding values, L, M and S, were calculated for each age interval which were set at 5-day intervals until 2 months after birth, 1-month intervals until 2 years after birth and 6-month intervals after the age of 2 years, because growth is more rapid in the earlier ages of life. The sample size for each age group is shown in Table 1 for both boys and girls. Each sample size was above the sample size for LMS smoothing recommended by Cole (13), except for the age group from 8 to 22 days.

All of the data in all age groups were used for LMS smoothing for length/height, head circumference and chest circumference, but only the data after 5 days of life were used for weight, because of neonatal weight loss (10). Neonates show abrupt body weight changes in the first few days of life. The daily values for body weight for the first 5 days of life, which is the age at which most neonates are discharged from hospitals in Japan, were calculated from the hospital records.

The values of L, M and S, calculated for each age level, were smoothed using a cubic spline function, which smoothly connects several cubic equations at knots and is one of the most frequently used methods of smoothing. At each knot, the linear and quadratic differential coefficients are equal. The calculation of spline smoothing was carried out by proc transreg in SAS statistical software version 9.2 (SAS Institute, Cary, NC, USA) with weights according to the number of samples in each age group. Several combinations of knots were examined for the corresponding age values of knots, and the most appropriate for creating the reference was chosen. We chose the positions of the knots where the smoothed curves were in good agreement with the percentile values that had been directly calculated from the data set of each age group, showing no unnatural ups and downs nor unnatural widening and narrowing of the intervals. The age in months for the corresponding knots for each item is shown in Table 2.

Difference between supine length and standing height
Stature is shorter when measured in the standing than the supine position. When the World Health Organization (WHO) 2006 reference was created, it was estimated that the length in the supine position was 0.7 cm more than the height measured in the standing position (14). To fit a single model for the whole age range, 0.7 cm was therefore added to the measured height values. After the model was fitted, the final curves were shifted downwards by 0.7 cm for children aged 2 years and above to create the height for age standards. The Centers for Disease Control and Prevention (CDC) 2000 reference estimated that length measurements were 0.8 cm higher than height measurements (15).

In the present study, the difference was estimated from our data set. Data were divided into children under 2 years of age and children 2 years of age and over and two partial regressions coefficients were calculated for the constants. The difference between two partial regression coefficients was 1.319 cm for boys and 1.366 cm for girls, which correspond to the difference between the two types of measurement.

Comparison with chosen growth references
Based on ethnic differences and historical usage, the medians were compared with growth references for Japanese children in 1970 (6) and 2000 (9) and the WHO 2006 reference (16). The standard deviation scores of the 1970, 2000 and 2010 Japanese references were then compared with the WHO 2006 reference.

RESULTS
The three quantities used in the LMS method were calculated for length/height, weight, head circumference and chest circumference in both boys and girls from birth to 6 years of age. The third and 97th centiles were calculated from the parameters L, M and S.

References for length/height, weight, head circumference and chest circumference
L, M and S values along with the 3rd and the 97th percentile values are presented for length/height, weight,
head circumference and chest circumference in Tables 3–6, respectively. For height/length, head circumference and chest circumference, smoothed $L$, $M$ and $S$ values are presented from birth to the age of 75 months. For weight, percentile values were directly calculated from the data set of each day from birth to 4 days of age, and LMS smoothed values are presented from the fifth day to the age of 75 months. There was a decrease in the median values of body weight from birth to 2 days of life by 162 g for boys and 174 g for girls.

**Comparison of length/height with chosen references**

Figure 1 shows the median values for length/height for the Japanese 1970, 2000 and 2010 references, in relation to the WHO 2006 reference. This shows that the standard deviation scores of the Japanese references, compared with the

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**Table 1 Age distribution of the reference sample**

| Age                | Boys                   |         |         |         |         |         |         |
|--------------------|------------------------|---------|---------|---------|---------|---------|---------|
|                    | Longitudinal hospital data | Cross-sectional community data |
| Birth              | 2414                   | 2284    |
| 1 day              | 2135                   | 2026    |
| 2 days             | 2160                   | 2050    |
| 3 days             | 2187                   | 2084    |
| 4 days             | 2188                   | 2093    |
| 5 days             | 2078                   | 1936    |
| 8–22 days          | 10                     | 17      |
| 23–27 days         | 141                    | 154     |
| 28–32 days         | 1087                   | 1004    |
| 33–37 days         | 931                    | 884     |
| 38–42 days         | 190                    | 177     |
| 43 days–1.99 months| 41                     | 38      |
| 2–2.99 months      | 103                    | 89      |
| 3–3.99 months      | 1                      | 98      |
| 4–4.99 months      | 118                    | 112     |
| 5–5.99 months      | 103                    | 119     |
| 6–6.99 months      | 116                    | 119     |
| 7–7.99 months      | 110                    | 113     |
| 8–8.99 months      | 103                    | 99      |
| 9–9.99 months      | 121                    | 114     |
| 10–10.99 months    | 101                    | 92      |
| 11–11.99 months    | 112                    | 106     |
| 12–12.99 months    | 113                    | 111     |
| 13–13.99 months    | 111                    | 98      |
| 14–14.99 months    | 95                     | 86      |
| 15–15.99 months    | 80                     | 91      |
| 16–16.99 months    | 105                    | 106     |
| 17–17.99 months    | 106                    | 87      |
| 18–18.99 months    | 105                    | 106     |
| 19–19.99 months    | 101                    | 84      |
| 20–20.99 months    | 93                     | 89      |
| 21–21.99 months    | 101                    | 82      |
| 22–22.99 months    | 107                    | 93      |
| 23–23.99 months    | 105                    | 96      |
| 24–24.99 months    | 198                    | 195     |
| 30–35.99 months    | 163                    | 166     |
| 36–41.99 months    | 182                    | 130     |
| 42–47.99 months    | 155                    | 159     |
| 48–53.99 months    | 198                    | 164     |
| 54–59.99 months    | 147                    | 149     |
| 60–65.99 months    | 159                    | 149     |
| 66–71.99 months    | 156                    | 148     |
| 72–77.99 months    | 145                    | 159     |
WHO 2006 reference, decreased between three and 33 months of age, after which they became stable for each month of age. The 2000 and 2010 Japanese references were smaller, or equal to, the 1970 reference from three to 33 months of age. After that, they were larger than the 1970 reference.

Comparison of weight with chosen references
Figure 2 shows the median weight values for the Japanese 1970, 2000 and 2010 references in relation to the WHO 2006 reference. The gap between the Japanese reference and the WHO 2006 reference got larger as the children’s age increased. Among the Japanese references, the weight from 3 to 39 months of age decreased from 1970 to 2010.

Body weight in the early infantile period
Figure 3 compares the third, 50th and 97th percentile curves between the WHO 2006 reference and the present study. The WHO 2006 curves are based on the values

### Table 2

| Items                  | L (months) | M (months) | S (months) |
|------------------------|------------|------------|------------|
| Boys length/height     | 24         | 6, 12, 24, 48 | 12         |
| Girls length/height    | 24         | 6, 12, 24, 48 | 12         |
| Boys weight            | 12, 48     | 6, 10.8, 25.2, 42 | 12         |
| Girls weight           | 24         | 6, 10.8, 25.2, 42 | 12         |
| Boys head circumference| 24         | 6, 12, 24, 48 | 12         |
| Girls head circumference| 24         | 6, 12, 24, 48 | 12         |
| Boys chest circumference| 24        | 6, 12, 24, 48 | 12         |
| Girls chest circumference| 24        | 6, 12, 24, 48 | 12         |

### Table 3

Length and height (cm) from birth to 75 months of age in boys and girls

| Age       | Boys               | Centiles          | Girls               | Centiles          |
|-----------|-------------------|------------------|---------------------|------------------|
|           | LMS               | Third 97th       | LMS               | Third 97th       |
| Length    | L (cm)            |                  | L (cm)            |                  |
| Birth     | 4.03648           | 48.8269          | 0.048931          | 43.5             |
| 30 days   | 3.45039           | 53.5057          | 0.042617          | 47.8             |
| 1.5 months| 3.16789           | 55.6113          | 0.041182          | 50.9             |
| 2.5 months| 2.66263           | 59.1256          | 0.038788          | 54.5             |
| 3.5 months| 2.21290           | 61.9813          | 0.036874          | 57.5             |
| 4.5 months| 1.81573           | 64.3058          | 0.035389          | 59.9             |
| 5.5 months| 1.46812           | 66.2263          | 0.034283          | 61.9             |
| 6.5 months| 1.16706           | 67.8680          | 0.033506          | 63.6             |
| 7.5 months| 0.90957           | 69.3121          | 0.032688          | 65.0             |
| 8.5 months| 0.69265           | 70.5954          | 0.032733          | 66.3             |
| 9.5 months| 0.51331           | 71.7527          | 0.032637          | 67.4             |
| 10.5 months| 0.36856         | 72.8190          | 0.032668          | 68.4             |
| 11.5 months| 0.25539         | 73.8292          | 0.032774          | 69.4             |
| 12.5 months| 0.17081         | 74.8173          | 0.032906          | 70.3             |
| 13.5 months| 0.11184         | 75.8003          | 0.033040          | 71.2             |
| 14.5 months| 0.07547         | 76.7775          | 0.033173          | 72.1             |
| 15.5 months| 0.05871         | 77.7477          | 0.033307          | 73.0             |
| 16.5 months| 0.05857         | 78.7095          | 0.033440          | 73.9             |
| 17.5 months| 0.07205         | 79.6618          | 0.033574          | 74.8             |
| 18.5 months| 0.09616         | 80.6031          | 0.033707          | 75.6             |
| 19.5 months| 0.12791         | 81.5322          | 0.033840          | 76.5             |
| 20.5 months| 0.16429         | 82.4478          | 0.033974          | 77.3             |
| 21.5 months| 0.20232         | 83.3486          | 0.034106          | 78.1             |
| 22.5 months| 0.23899         | 84.2333          | 0.034239          | 78.9             |
| 23.5 months| 0.27133         | 85.1007          | 0.034372          | 79.7             |
| Height    | 4.03648           | 48.8269          | 0.048931          | 43.5             |
| Birth     | 0.32279           | 86.6700          | 0.048333          | 81.1             |
| 27 months | 0.21404           | 91.1293          | 0.036515          | 85.2             |
| 33 months | 0.21040           | 91.1293          | 0.036515          | 85.2             |
| 39 months | 0.36975           | 104.9390         | 0.038516          | 97.8             |
| 45 months | 0.36975           | 104.9390         | 0.038516          | 97.8             |
| 51 months | 0.36975           | 104.9390         | 0.038516          | 97.8             |
| 57 months | 0.36975           | 104.9390         | 0.038516          | 97.8             |
| 63 months | 0.36975           | 104.9390         | 0.038516          | 97.8             |
| 69 months | 0.36975           | 104.9390         | 0.038516          | 97.8             |
| 75 months | 1.14888           | 114.9162         | 0.040305          | 106.2            |
appearing in the tables of weight for age in weeks. At birth, the Japanese reference was 0.4 kg lower in both boys and girls. At 1 week of age, the Japanese reference was 0.6 kg lower in boys and 0.7 kg lower in girls. The Japanese reference was 0.3 kg lower at 4 weeks of age and 0.2 kg lower at 8 weeks of age in both boys and girls.

**DISCUSSION**

This paper provides updated growth references for Japanese infants and preschool children. The length/height, weight, head circumference and chest circumference references were constructed using data from a contemporary and nationally representative sample. The sampling scheme resulted in an accurate social and geographical representation of the population.

The present study included children up to 6 years of age because the growth survey was carried out by the Ministry of Health, Labour and Welfare, which is mainly incharge of observing the welfare of children up to that age. Another survey on children over 6 years of age was carried out by the Ministry of Education, Culture, Sports, Science and Technology, but that used different methods to the present study. The response rate in this current study was 70.3% and it is

### Table 4 Weight (g) from birth to 75 months of age in boys and girls

| Age       | Boys LMS | Centiles | Girls LMS | Centiles |
|-----------|---------|----------|-----------|----------|
| L         | M       | S        | Median    | Third 75th |
| Birth     | 3000    | 2104     | 3760      | 2935     |
| 1 day     | 2894    | 2060     | 3634      | 2814     |
| 2 days    | 2838    | 2010     | 3560      | 2761     |
| 3 days    | 2840    | 2000     | 3590      | 2761     |
| 4 days    | 2880    | 2034     | 3618      | 2788     |
| 5 days    | 1.3215 | 2891     | 3760      | 2926     |
| 30 days   | 1.3290 | 2891     | 3760      | 2905     |
| 15 months | 1.3254 | 2891     | 3760      | 3358     |
| 2.5 months| 1.2915 | 2891     | 3760      | 4190     |
| 3.5 months| 1.2350 | 2891     | 3760      | 4837     |
| 4.5 months| 1.1753 | 2891     | 3760      | 5346     |
| 5.5 months| 1.0618 | 2891     | 3760      | 5744     |
| 6.5 months| 0.9519 | 2891     | 3760      | 6061     |
| 7.5 months| 0.8312 | 2891     | 3760      | 6318     |
| 8.5 months| 0.7030 | 2891     | 3760      | 6529     |
| 9.5 months| 0.5708 | 2891     | 3760      | 6707     |
| 10.5 months| 0.4380 | 2891   | 3760      | 6864     |
| 11.5 months| 0.3081 | 2891   | 3760      | 7015     |
| 12.5 months| 0.1844 | 2891   | 3760      | 7164     |
| 13.5 months| 0.0684 | 2891   | 3760      | 7312     |
| 14.5 months| -0.0398| 2891  | 3760      | 7460     |
| 15.5 months| -0.1408| 2891  | 3760      | 7608     |
| 16.5 months| -0.2374| 2891  | 3760      | 7755     |
| 17.5 months| -0.3202| 2891  | 3760      | 7902     |
| 18.5 months| -0.4028| 2891  | 3760      | 8049     |
| 19.5 months| -0.4775| 2891  | 3760      | 8195     |
| 20.5 months| -0.5463| 2891  | 3760      | 8342     |
| 21.5 months| -0.6066| 2891  | 3760      | 8488     |
| 22.5 months| -0.6675| 2891  | 3760      | 8635     |
| 23.5 months| -0.7205| 2891  | 3760      | 8782     |
| 27 months  | -0.8709| 2891  | 3760      | 9299     |
| 33 months  | -1.0304| 2891  | 3760      | 10184    |
| 39 months  | -1.1198| 2891  | 3760      | 11038    |
| 45 months  | -1.2015| 2891  | 3760      | 11828    |
| 51 months  | -1.3328| 2891  | 3760      | 12359    |
| 57 months  | -1.4498| 2891  | 3760      | 13273    |
| 63 months  | -1.3676| 2891  | 3760      | 14009    |
| 69 months  | -0.8961| 2891  | 3760      | 14808    |
| 75 months  | 0.1549| 2891   | 3760      | 15710    |
possible that the nonresponders may have included higher percentages of children who had been poorly raised or had an illness or disability.

**Smoothing**

Using the LMS method, smooth curves for $L$, $M$ and $S$ can be fitted by a statistical method such as cubic spline or polynomial equations or can be drawn by eye (13). In the reference charts for height and weight of schoolchildren in Malaysia, $L$, $M$ and $S$ parameters were smoothed by the LOWESS method (17). The penalised likelihood method was introduced for smoothing $L$, $M$ and $S$ curves, which led to natural cubic splines with knots at the age of observation (18). Although many recent studies have smoothed $L$, $M$ and $S$ by the maximum penalised likelihood (19,20), the present study aimed to show the mathematical functions for smoothing more simply. This means that municipal health personnel can calculate the percentile level of the measured values using ordinary business software on a personal computer in their public health practice.

**Comparison between references**

In this paper, the Japanese growth references were compared with the 2006 WHO reference (16), which is currently one of the most popular international references. The present analysis showed that recent Japanese growth references are smaller than the WHO 2006 and CDC 2000 references.

Western growth references (15,19) were similar to the CDC 2000 and WHO 2006 references and are larger than the Japanese reference. Chinese growth references for preschool children have been calculated, and their values are larger than the respective values in the CDC 2000 reference (21). In a Taiwanese reference from birth to 5

**Table 5** Head circumference (cm) from birth to 75 months of age in boys and girls

| Age       | Boys                        | Girls                       |
|-----------|-----------------------------|-----------------------------|
|           | LMS Centiles                | Centiles                   |
|           | Third | 97th |         | Third | 97th |         |
| Birth     | 3.57516 | 33.5340 | 0.041033 | 30.6 | 35.9 |         |
| 30 days   | 3.51357 | 36.6508 | 0.038015 | 33.8 | 39.1 |         |
| 1.5 months| 3.47730 | 39.7537 | 0.036657 | 35.1 | 40.4 |         |
| 2.5 months| 3.39959 | 39.9479 | 0.034410 | 37.1 | 42.4 |         |
| 3.5 months| 3.31270 | 41.3592 | 0.032639 | 38.6 | 43.7 |         |
| 4.5 months| 3.21754 | 42.3408 | 0.031291 | 39.7 | 44.7 |         |
| 5.5 months| 3.11495 | 43.0462 | 0.030314 | 40.4 | 45.4 |         |
| 6.5 months| 3.00576 | 43.6255 | 0.029657 | 41.0 | 45.9 |         |
| 7.5 months| 2.89081 | 44.1563 | 0.029267 | 41.6 | 46.5 |         |
| 8.5 months| 2.77094 | 44.6439 | 0.029092 | 42.1 | 47.0 |         |
| 9.5 months| 2.64698 | 45.0903 | 0.028901 | 42.5 | 47.5 |         |
| 10.5 months| 2.51976 | 45.4977 | 0.028718 | 42.9 | 47.9 |         |
| 11.5 months| 2.39013 | 45.8680 | 0.028534 | 43.2 | 48.3 |         |
| 12.5 months| 2.25893 | 46.2032 | 0.028350 | 43.5 | 48.7 |         |
| 13.5 months| 2.12698 | 46.5059 | 0.028168 | 43.8 | 49.0 |         |
| 14.5 months| 1.99512 | 46.7783 | 0.027991 | 44.1 | 49.3 |         |
| 15.5 months| 1.86419 | 47.0232 | 0.027816 | 44.3 | 49.6 |         |
| 16.5 months| 1.73503 | 47.2431 | 0.027643 | 44.5 | 49.9 |         |
| 17.5 months| 1.60847 | 47.4406 | 0.027470 | 44.7 | 50.1 |         |
| 18.5 months| 1.48535 | 47.6181 | 0.027306 | 44.9 | 50.4 |         |
| 19.5 months| 1.36650 | 47.7783 | 0.027143 | 45.0 | 50.5 |         |
| 20.5 months| 1.25277 | 47.9238 | 0.026980 | 45.2 | 50.6 |         |
| 21.5 months| 1.14498 | 48.0570 | 0.026816 | 45.3 | 50.8 |         |
| 22.5 months| 1.04397 | 48.1806 | 0.026653 | 45.4 | 50.9 |         |
| 23.5 months| 0.95058 | 48.2970 | 0.026490 | 45.5 | 51.1 |         |
| 27 months  | 0.69015 | 48.6746 | 0.026026 | 45.9 | 51.5 |         |
| 33 months  | 0.45065 | 49.2382 | 0.025563 | 46.5 | 52.0 |         |
| 39 months  | 0.39445 | 49.7113 | 0.025100 | 46.9 | 52.5 |         |
| 45 months  | 0.43079 | 50.1119 | 0.024637 | 47.4 | 53.0 |         |
| 51 months  | 0.46891 | 50.5477 | 0.024174 | 47.8 | 53.5 |         |
| 57 months  | 0.51804 | 50.7642 | 0.023711 | 48.2 | 54.0 |         |
| 63 months  | 0.18741 | 51.0444 | 0.023248 | 48.4 | 54.3 |         |
| 69 months  | −0.31374 | 51.3113 | 0.022785 | 48.6 | 54.7 |         |
| 75 months  | −1.17618 | 51.5780 | 0.022322 | 48.8 | 55.0 |         |
American-born Japanese children might also be larger than those raised in Japan. Therefore, recent native Japanese-born children. With the same genetic background and potentiality, American-born Japanese children are larger because of socio-economic factors such as the American lifestyle (24). Japanese children are generally well nourished, so their growth potential is fully realised. The reason why Japanese children are smaller than children in both Western countries and other Asian countries, such as China and Taiwan, is uncertain.

**Secular trends in child growth**

When we examined the Japanese growth references trends over the decades, we could see that the median values for both length/height and weight decreased slightly from birth to 3 years of age. It is suggested that this trend is due to the consistent decline in birth weight after 1975 in Japan (25), as child growth during the early years of life is affected by birth weight (26). The feeding practice of infants changed over the decades, we could see that the median values for...

### Table 6 Chest circumference (cm) from birth to 75 months of age in boys and girls

| Age       | LMS     | Centiles | | LMS     | Centiles |
|-----------|---------|----------| |         |----------|
|           | L       | M        | S     | Third   | 97th     |
| Birth     | 3.16516 | 31.7371  | 0.057430| 27.8    | 34.8     |
| 30 days   | 2.58105 | 35.8494  | 0.054964| 31.8    | 39.3     |
| 1.5 months| 2.29569 | 37.5436  | 0.053802| 33.5    | 41.1     |
| 2.5 months| 1.77769 | 40.0833  | 0.051770| 36.0    | 43.8     |
| 3.5 months| 1.30631 | 41.8029  | 0.050017| 37.8    | 45.7     |
| 4.5 months| 0.87925 | 42.9125  | 0.048517| 39.0    | 46.8     |
| 5.5 months| 0.49421 | 43.6223  | 0.047244| 39.8    | 47.6     |
| 6.5 months| 0.14889 | 44.1382  | 0.046173| 40.4    | 48.1     |
| 7.5 months| 0.015902| 44.5721  | 0.045278| 41.0    | 48.6     |
| 8.5 months| 0.043182| 44.9418  | 0.044532| 41.4    | 48.9     |
| 9.5 months| 0.067181| 45.2610  | 0.043909| 41.8    | 49.3     |
| 10.5 months| 0.088130| 45.5433  | 0.043385| 42.1    | 49.6     |
| 11.5 months| 1.06259| 45.8023  | 0.042932| 42.4    | 49.9     |
| 12.5 months| 1.21799| 46.0516  | 0.042527| 42.7    | 50.1     |
| 13.5 months| 1.34979| 46.2977  | 0.042154| 42.9    | 50.3     |
| 14.5 months| 1.46030| 46.5408  | 0.041814| 43.2    | 50.6     |
| 15.5 months| 1.55182| 46.7806  | 0.041505| 43.5    | 50.8     |
| 16.5 months| 1.62666| 47.0169  | 0.041227| 43.7    | 51.1     |
| 17.5 months| 1.68713| 47.2494  | 0.040979| 43.9    | 51.3     |
| 18.5 months| 1.73351| 47.4778  | 0.040761| 44.2    | 51.5     |
| 19.5 months| 1.77412| 47.7020  | 0.040572| 44.4    | 51.8     |
| 20.5 months| 1.80527| 47.9216  | 0.040411| 44.6    | 52.0     |
| 21.5 months| 1.83124| 48.1365  | 0.040277| 44.8    | 52.2     |
| 22.5 months| 1.85436| 48.3464  | 0.040171| 45.0    | 52.4     |
| 23.5 months| 1.87691| 48.5510  | 0.040090| 45.2    | 52.7     |
| 27 months | 1.97327| 49.2247  | 0.040006| 45.9    | 53.4     |
| 33 months | 2.19528| 50.2508  | 0.040111| 46.8    | 54.6     |
| 39 months | 2.44558| 51.1673  | 0.041712| 47.6    | 55.8     |
| 45 months | 2.67353| 52.0357  | 0.043468| 48.3    | 57.1     |
| 51 months | 2.82852| 52.9161  | 0.045638| 49.0    | 58.4     |
| 57 months | 2.85991| 53.8332  | 0.048079| 49.7    | 59.8     |
| 63 months | 2.71708| 54.7763  | 0.050649| 50.3    | 61.2     |
| 69 months | 2.34941| 55.7332  | 0.053206| 50.9    | 62.5     |
| 75 months | 1.70625| 56.6917  | 0.055610| 51.5    | 63.6     |
| 103 days  | 3.10503| 31.5588  | 0.053836| 27.9    | 34.5     |
| 30 days   | 2.50596| 35.1340  | 0.052168| 31.4    | 38.4     |
| 1.5 months| 2.21644| 36.6310  | 0.051376| 32.9    | 40.0     |
| 2.5 months| 1.69714| 38.9212  | 0.049978| 35.1    | 42.5     |
| 3.5 months| 1.23293| 40.5301  | 0.048757| 36.8    | 44.2     |
| 4.5 months| 0.82090| 41.6220  | 0.047698| 37.9    | 45.4     |
| 5.5 months| 0.45814| 42.3611  | 0.046785| 38.7    | 46.2     |
| 6.5 months| 0.14177| 42.9087  | 0.046004| 39.3    | 46.8     |

Years of age (22), the length/height was 0.1 cm shorter than the respective value in the WHO 2006 reference and the weight was 0.3 kg heavier in boys and 0.2 kg heavier in girls. These are much larger than the respective values in the present Japanese reference.
after 1975. In 1970, the proportion of 1-month-old infants who were exclusively breastfed was 32%, by 1980 it had increased to 45% and by 2010 it had reached 52%. In addition, the concentrations of proteins and carbohydrates in formula became lower after 1975 (9).

Since Japanese growth references before 1960 are provided as means and standard deviations, not as medians or percentiles, they cannot be compared with median values after 1970. Despite this, the mean weight and length/height increased clearly and consistently from 1940 to 1970 (3–6), showing similar characteristics after 1970 (Table 7). In Japan, consistent improvements in the physique of schoolchildren and adults are clearly observed (27). There are a number of factors that can affect the growth rates of children, including economic conditions. For example, in Poland, gross domestic product rose from a very low level to half the EU average in the 1990s, and this could explain why children born in the early 1990s were smaller than those born around 2000 (20). In addition, when Komlos and Breitfelder (28) analysed the growth trend of African American children from 1940 until 2000, they found that African American children were taller than Caucasian children in 1940 and that a cumulative improvement occurred thereafter. They suggested that this could be explained by improvements in the incomes of African American citizens compared to the incomes of Caucasians (28). In Japan, rapid economic growth was observed from 1950 to 1970 (29), and this might be one of the factors that has contributed to the rapid improvement in the physique of children.

Updated reference

Data for the Japanese 2010 reference were collected by a single survey over a period of 1 month. There were a number of limitations, including the small data size and seasonal bias due to the fact that the study period was in September, towards the end of the hot summer weather, which could reduce the appetites, and therefore weight, of infants and preschool children. However, the growth references have been updated every 10 years for more than half a century, which could be a strength in spite of the limitations of sample size and seasonal bias.

Karlberg et al. (30) discussed the optimal interval for updating growth references. For a population with large secular changes in body size, updates should be carried out every 5–10 years, and for populations with little change, updates should preferably be carried out every 15–20 years.

Neonatal weight loss

Newborn infants experience physiological body loss in the first few days of life and then rapid weight gain occurs. Growth assessment can be more effective if it is compared with a reference that takes neonatal weight loss into account. For example, when the Belgian reference was created, extra data were collected during the neonatal period and added to the data in the later age groups (19). If the body weight of babies up to a few months of age is
evaluated using a reference where neonatal weight loss is not taken into account, low body weight could be overestimated. Cut-off values for low body weight differed by 0.7 kg between the present study and the WHO 2006 reference.

CONCLUSION
The length/height, weight, head circumference and chest circumference references we present in this paper are based on a current, nationally representative sample of Japanese infants and preschool children. This showed that they were smaller than infants and children raised in Western countries and in Asian countries such as China and Taiwan. They were also smaller than infants and children of Japanese origin raised in America. In addition, the growth of Japanese children under 3 years of age showed a reverse secular trend from 1970 until 2010. The results provide a detailed insight into the growth of Japanese children from a historical, ethnic and environmental point of view.

English language versions of the growth charts are available as pdfs – entitled 201117020A0006.pdf and 201117020A0007.pdf – that can be downloaded from the website: http://mhlw-grants.niph.go.jp/niph/search/NIDD 00.do?resrchNum=201117020A.

Table 7: Secular trend of length/height and weight of Japanese infants and preschool children

| Year | Boys | | | | | Girls | | | |
|------|------|----|-----|----|-----|------|----|-----|-----|
| 1940 | 1.99 months | 85 | 54.6 | 3.3 | 185 | 54.2 | 2.9 | 91 | 54.2 | 2.3 |
| 1950 | 1.99 months | 193 | 69.7 | 2.9 | 255 | 70.0 | 3.1 | 98 | 71.6 | 2.4 |
| 1960 | 2.99 years | 1123 | 83.3 | 4.5 | 1339 | 83.0 | 4.1 | 1229 | 85.3 | 3.5 |
| 1970 | 3.99 years | 1207 | 90.2 | 4.4 | 1003 | 89.1 | 4.1 | 1265 | 92.2 | 3.9 |
| 2010 | 1.99 months | 1357 | 103.1 | 4.7 | 1107 | 102.0 | 4.4 | 1523 | 105.8 | 4.4 |

The Japan 2010 reference in the present study, Japan 1940 reference (3), Japan 1950 reference (4), Japan 1960 reference (5), Japan 1970 reference (6).

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