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# Analysis of Multiple Birth Rates in Japan

## 1. Secular Trend, Maternal Age Effect, and Geographical Variation in Twinning Rates

Yoko Imaizumi,<sup>1</sup> Eiji Inouye<sup>2</sup>

<sup>1</sup> *Institute of Population Problems, Ministry of Health and Welfare, Tokyo;* <sup>2</sup> *Institute of Brain Research, University of Tokyo School of Medicine, Tokyo, Japan*

Mean twin, triplet, and quadruplet birth rates in Japan from 1951 to 1968 were 6.41, 0.056, and 0.00094 per 1,000, respectively. In 1974 the corresponding figures were 5.83, 0.059, and 0.00329. No quintuplets were born in the former period, but a set was born in the latter year, the rate being 0.47 per million. From 1955 to 1966 the MZ twinning rate increased slightly, but decreased thereafter. This increase was limited to live-born MZ twins, particularly in the higher maternal age groups. The DZ twinning rate declined in the entire period, particularly in higher maternal age groups. This decline appeared to be essentially limited to fetal deaths. Among live births the MZ twinning rate underwent a nearly linear increase with maternal age, whereas the DZ twinning rate attained a mode in the maternal age group 35–39 years. The MZ and the DZ twinning rates among fetal deaths by maternal age had unimodal distributions with modes in maternal age groups 25–29 and 30–34 years, respectively. As to the DZ twinning rate, a geographical cline was noted, with a high rate in the northeast of Japan; the rate was positively correlated with latitude, which also positively correlated with the presence of multiple births among relatives. A negative but nonsignificant correlation was seen between the DZ twinning rate and the proportion of mothers treated with ovulation-inducing hormone. The proportion was higher in mothers of unlike-sexed twins than in those of like-sexed twins and in mothers of triplets than in those of twins. An association between DZ twinning rate and age-specific fertility per married woman is suggested to exist among higher maternal age groups in the northeast part of Japan in earlier years.

**Key words:** Twinning rates, Secular trend, Maternal age, Ovulation-inducing hormones, Geographical variation, Inheritance of twinning

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## INTRODUCTION

Studies on secular change in the rates of multiple births have been reported in the United States [18, 24], Canada [6], Australia [1], and Scotland [11]. In the first three countries, the rates declined during the late 1920s and the 1960s, whereas the rate in Scotland declined during the late 1950s and the 1960s. The same tendency was observed in Hungary [3], Belgium, Denmark, Holland, Italy, New Zealand, Norway, Sweden, and Switzerland during the 1960s [11]. The above surveys indicated that, when twins were separated according to zygosity, decline in twinning rates was seen only in dizygotic (DZ) twins.

In Japan the frequencies of twin births were estimated by Komai and Fukuoka [21] and Inouye [10], whose estimates were 0.69% and 0.61%, respectively. In both studies monozygotic (MZ) twinning rate was around 0.4%. Kamimura [20] has also tabulated the twinning rates of Japan, which were obtained through a number of investigations.

Genetic or epidemiologic studies of multiple births in Japan have been quite few. Recently, Kamimura reported on a relationship between the rate and maternal age, while Sawazaki and Tsubata reported on secular changes during 1951–1968 [19, 22].

Kamimura also reported that the twinning rates increased from a low level in the southwest of Japan to a high level in the northeast [19], somewhat similarly to what was reported by Bulmer for Southwest Europe [2].

The present study deals with the secular changes and geographical variations of multiple birth rates in all of Japan. It also deals with the effect of maternal age on multiple birth rates.

## MATERIALS AND METHODS

There were two sources of data available for the present analysis. The first source consists in the annual volumes of "Vital Statistics of Japan for the Years 1951–1968 and 1974" (Health and Welfare Statistics and Information Department, Ministry of Health and Welfare [16]). The statistics from 1955 to 1967 and for 1974 list the sex of the children, and were used for the estimate of the twinning rate according to zygosity. Maternal age is given in the statistics from 1960 to 1968 and for 1974, and the statistics from 1951 to 1959 and for 1974 provide figures for multiple births in each prefecture.

The second source of data consists in the "Survey on Socio-Economic Aspects of Vital Events – Plural Births in 1975" (Health and Welfare Statistics and Information Department, Ministry of Health and Welfare [17]). This consists of two surveys, A and B. In the survey A, on 25,192 children or fetuses born in plural deliveries to mothers of Japanese nationality, data were obtained from certificate records on the live birth and fetal death (after the beginning of the fourth month of fetal life) for all of Japan in 1974. Survey B was conducted in July 1975 on a part of the above 25,192 cases, namely, multiple births during the period of 1 January to 30 June 1974. The total number of households in survey B was 6,189. Questionnaires were directly distributed to all of them by Health Center officials, and 1,828 (29.5%) were not returned. Survey A includes information on parental ages, occupation of the head of the household, place of residence, number and sex of children in the plural birth according to birth order and live birth or fetal death, period of gestation, month of the year of live birth or fetal death, spontaneous or induced termination of pregnancy in case of fetal death, classified causes of fetal death, and body weight at birth or fetal death. Information on the numbers of previous pregnancies and live births were also included. Survey B includes, in addition to most of the above items, information on plural births in the relatives (not defined); previous plural births; family size; treatment with ovulation-inducing hormone (time is unknown); health condition of the mother before, during, and after the pregnancy; occupation of the mother during the pregnancy; body weight of the children at the age of one year; mortality of the children up to the time of the survey; whether or not twins were separated from mothers; monthly expenses of the household; and other items.

## RESULTS

### Secular Changes in Multiple Births

Table 1 shows the rates of twin and triplet births in 1951–1968 and 1974. Mean twinning rate in the former period was 6.41 per 1000 deliveries, but fell to 5.83 in 1974, a drop of 9%. The decrease is apparent after 1966. On the other hand, a rather constant triplet birth rate is seen, with a mean for the period 1951–1968 of 0.056 per 1000 deliveries.

The number of annual quadruplet births is small. However, between 1951 and 1968 there were 32 quadruplet births, with a rate of 0.94 million deliveries. In 1974, however, there were seven quadruplet births, with a rate of 3.29 million. No quintuplet births were reported during 1951 to 1968, whereas one set of quintuplets was born in 1974, with a rate of 0.47 per million.

When twins are divided into like-sexed and unlike-sexed pairs, annual rates of the former show a slight but gradual increase from 5.07 per 1000 in 1955 to 5.46 in 1966; then there is a marked decrease to 4.83 in 1974. In contrast, the annual rates of unlike-sexed pairs indicate a decrease during the entire period observed. These variations up to 1966 are due to changes in the MZ and DZ twinning rates to the opposite directions, as indicated by the estimates obtained by Weinberg's method [23] (Fig. 1). In applying this method, pairs were excluded if the sex of one or both of the twins was unknown. This turns out to underestimate MZ and DZ twinning rates but does not much affect the result of each analysis (eg, secular change).

### Effect of Maternal Age on Twinning Rates

Table 2 shows annual twinning rates by maternal age in the years 1960–1967 and 1974. In all years twinning rates increased with maternal age except in mothers over 40 years of age. The maternal age effect was analysed separately for MZ and DZ rates in both periods (Table 3, Fig. 2). The DZ rates increased up to the age group of 35–39 years and decreased thereafter for both periods. The same tendency is seen in the MZ rate, but the maternal age effect is less marked than in the DZ rate.

The aforementioned secular decline of the DZ twinning rates was also analysed by maternal age (Table 3, Fig. 3). The decline is evident in mothers over 25 years of age, especially in the age group 35 years or more. As for the MZ twinning rate (Fig. 4), it remained most constant in the maternal age group of 20–24 years. The increase of the rate up to 1966 becomes more evident as maternal age increases. In the youngest maternal age group (< 20 years) a slight decrease rather than increase in the rate is seen.

### Twinning Rate According to the Survival Status of Twins

Twinning rates from 1960 to 1967 and for 1974 were analysed separately for zygosity and for live birth or fetal death (Table 4, Fig. 5). The number of pairs with one twin live birth and the co-twin fetal death was divided by two and added to the respective categories of survival states. The rate obtained in this way will be referred to as the "adjusted rate." The MZ twinning adjusted rate increased slightly up to 1966 among live births, but the DZ adjusted rate remained nearly constant. Among fetal deaths, the DZ rate indicated a decline, but the MZ rate did not.

TABLE 1. Twin and Triplet Birth Rates, 1951-1968 and 1974

Year	Total deliveries	Twin deliveries			Triplet deliveries	Triplet rate per 1000 deliveries	Twinning rate per 1000 deliveries	Triplet deliveries	Triplet rate per 1000 deliveries
		Total	Like-sexed	Unlike-sexed					
1951	2,339,505	15,143	...	...	136	0.058	6.47	136	0.058
1952	2,194,723	14,007	...	...	125	0.057	6.38	125	0.057
1953	2,048,079	13,053	...	...	91	0.044	6.37	91	0.044
1954	1,943,832	12,655	...	...	103	0.053	6.51	103	0.053
1955	1,911,640	12,042	9,704	2,286	130	0.068	6.30	130	0.068
1956	1,832,347	11,725	9,535	2,131	102	0.056	6.40	102	0.056
1957	1,731,458	11,407	9,207	2,135	96	0.055	6.59	96	0.055
1958	1,826,576	11,817	9,486	2,253	109	0.060	6.47	109	0.060
1959	1,796,212	11,579	9,383	2,115	95	0.053	6.45	95	0.053
1960	1,773,984	11,159	9,125	1,961	88	0.050	6.29	88	0.050
1961	1,757,661	11,394	9,270	2,030	103	0.059	6.48	103	0.059
1962	1,784,320	11,454	9,438	1,934	101	0.057	6.42	101	0.057
1963	1,823,097	11,638	9,597	1,954	105	0.058	6.38	105	0.058
1964	1,872,438	12,168	9,972	2,110	93	0.050	6.50	93	0.050
1965	1,972,831	12,266	10,061	2,106	107	0.054	6.22	107	0.054
1966	1,499,186	9,848	8,197	1,559	91	0.061	6.57	91	0.061
1967	2,071,597	13,212	10,989	2,128	110	0.053	6.38	110	0.053
1968	2,002,514	12,347	...	...	117	0.058	6.17	117	0.058
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1974	2,126,948	12,392	10,276	1,974	124	0.059	5.83	124	0.059

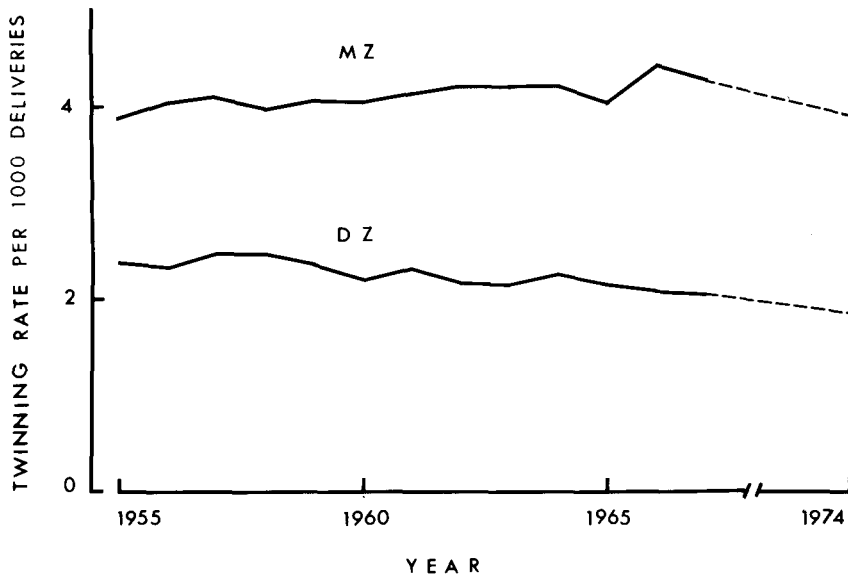


Fig. 1. Secular change of total MZ and DZ twinning rates during 1955–1967 and 1974.

TABLE 2. Twinning Rates per 1000 Deliveries by Maternal Age, 1960–1967 and 1974

Year	Maternal age (years)					
	Under 20	20–24	25–29	30–34	35–39	Over 40
1960	5.44	5.63	6.35	6.65	8.11	6.94
1961	4.66	5.88	6.39	7.14	8.58	7.08
1962	5.33	5.77	6.35	7.20	8.17	6.09
1963	5.64	5.73	6.35	7.02	7.97	7.01
1964	5.13	6.02	6.54	6.88	7.83	6.59
1965	5.18	5.62	6.12	6.93	8.28	6.33
1966	5.17	5.82	6.56	7.49	7.92	7.34
1967	5.26	5.84	6.24	7.07	8.13	7.58
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1974	4.12	5.40	5.80	6.40	6.95	5.92

Statistics for 1974 were also used for the analysis of twinning rates by zygosity, survival status of twins, and maternal age (Table 5, Fig. 6). Among fetal deaths the adjusted MZ and DZ twinning rates showed a unimodal distribution, with an earlier mode in the former than in the latter, whereas among live births both MZ and DZ adjusted twinning rates showed an increase with maternal age, except for age 40 years or more in DZ twins. Exactly the same patterns were observed in the years 1960–1967.

TABLE 3. *Twinning Rates per 1000 Deliveries by Maternal Age and Zygosity, 1960-1967 and 1974*

Year	Maternal age (years)											
	Monozygotic twins					Dizygotic twins						
	Under 20	20-24	25-29	30-34	35-39	Over 40	Under 20	20-24	25-29	30-34	35-39	Over 40
1960	4.37	3.89	4.10	4.11	4.06	3.69	1.03	1.72	2.21	2.48	3.91	3.21
1961	3.70	4.12	4.09	4.09	4.50	4.59	0.97	1.70	2.25	3.01	3.97	2.39
1962	4.09	4.00	4.15	4.52	4.65	4.40	1.21	1.71	2.17	2.63	3.44	1.59
1963	4.31	4.15	4.20	4.22	4.07	4.61	1.29	1.55	2.10	2.75	3.81	2.22
1964	3.88	4.13	4.29	4.10	4.36	3.53	1.09	1.87	2.20	2.74	3.39	2.89
1965	3.58	3.91	3.99	4.16	4.84	3.92	1.53	1.66	2.09	2.70	3.34	2.17
1966	3.78	4.07	4.41	4.89	5.05	5.32	1.29	1.69	2.11	2.52	2.77	1.82
1967	4.16	4.21	4.17	4.50	4.76	5.03	1.04	1.59	2.03	2.53	3.27	2.35
Total	3.99	4.06	4.17	4.31	4.52	4.35	1.18	1.69	2.14	2.67	3.50	2.37
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1974	3.14	3.71	3.91	4.18	4.12	3.78	0.90	1.63	1.83	2.16	2.69	2.00

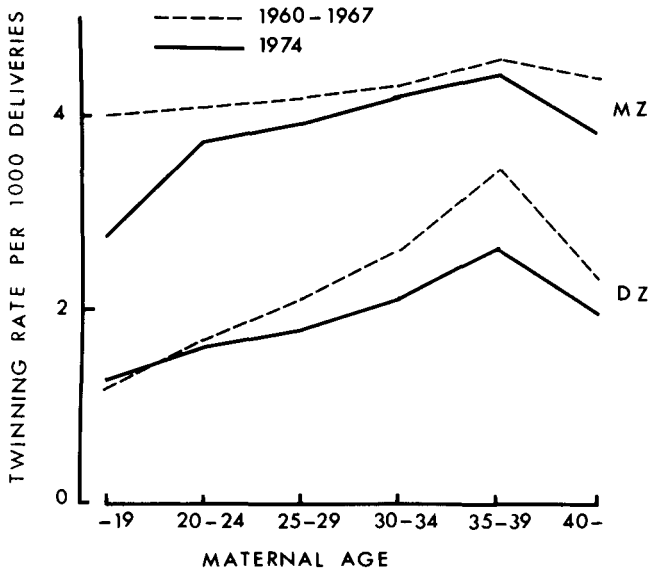


Fig. 2. Total MZ and DZ twinning rates by maternal age, 1960-1967 and 1974.

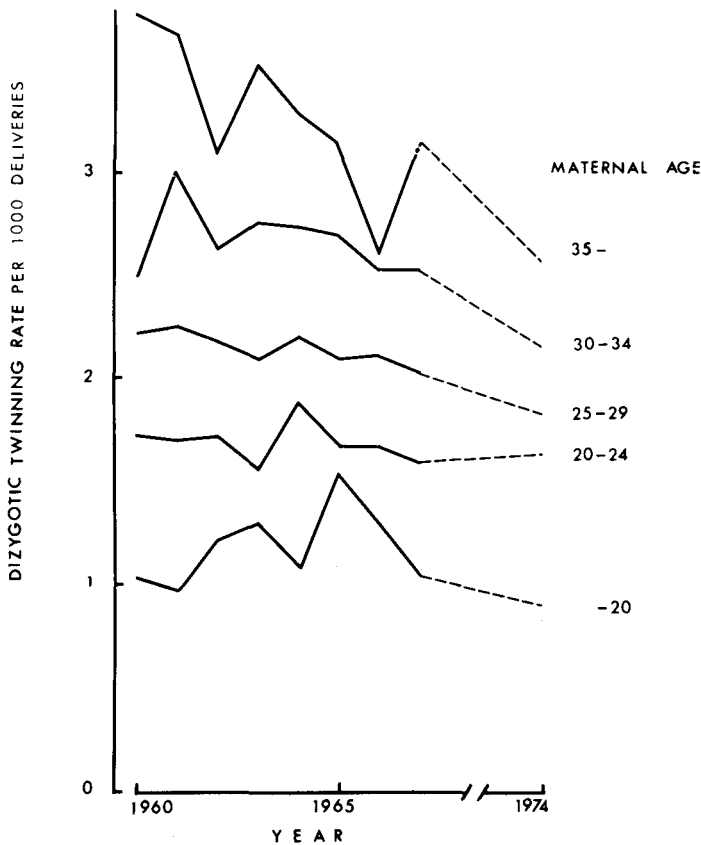


Fig. 3. Secular change of total DZ twinning rate by maternal age, 1960-1967 and 1974.

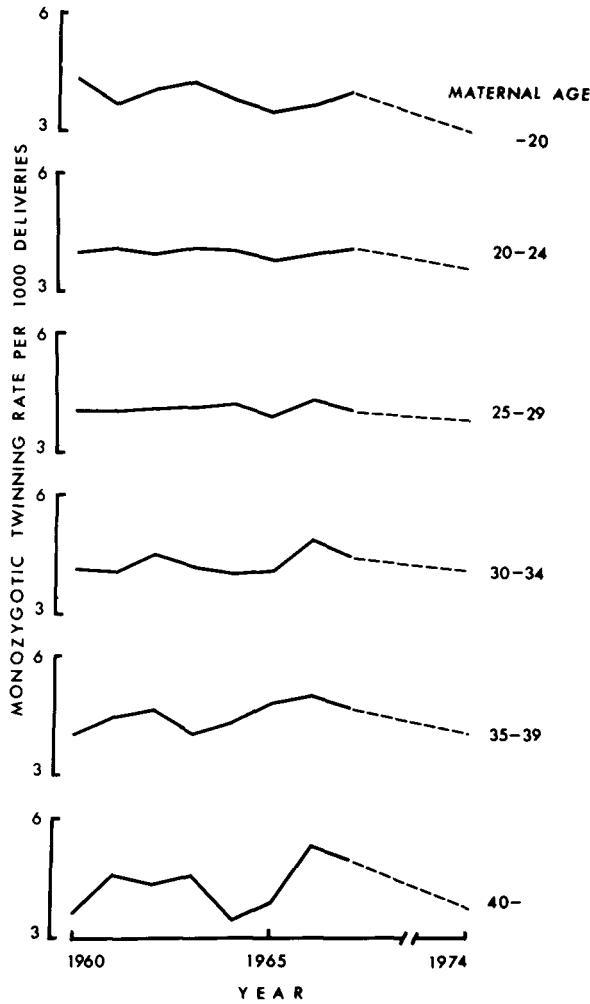


Fig. 4. Secular change of total MZ twinning rate by maternal age, 1960-1967 and 1974.

TABLE 4. Adjusted Twinning Rates per 1000 Deliveries Among Live Births and Fetal Deaths by Zygosity, 1960-1967 and 1974

Year	Live births		Fetal deaths	
	MZ	DZ	MZ	DZ
1960	3.25	1.90	10.81	4.90
1961	3.29	2.02	11.17	4.74
1962	3.39	1.94	11.34	4.14
1963	3.39	1.91	11.54	4.20
1964	3.48	2.06	11.22	4.11
1965	3.39	1.98	11.00	3.75
1966	3.71	1.93	10.75	3.31
1967	3.71	1.92	11.30	3.56
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1974	3.54	1.75	10.19	3.56



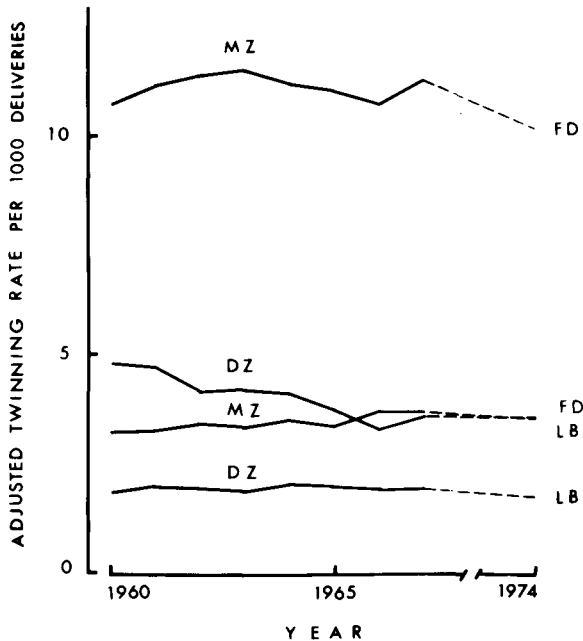


Fig. 5. Secular change of the "adjusted" MZ and DZ twinning rates among live births and fetal deaths, 1960–1967 and 1974 (see text).

### Geographical Variation in Twinning Rates

The overall rate, as well as MZ and DZ twinning rates, were computed in each prefecture for 1974. The MZ rate was rather constant throughout Japan, whereas the DZ rate increased from a low level in the southwest of Japan to a high level in the northeast, except for the Okinawa prefecture located on the southwest tip of Japan. The proportion of twin pairs with multiple births among relatives was also computed in each prefecture. This proportion also varies geographically, with higher values in the northeast and lower values in the southwest, except for the Okinawa prefecture, and seems to be positively correlated with the DZ twinning rate and latitude. Excluding the Okinawa prefecture, there was a correlation coefficient of 0.095 between this proportion and the DZ twinning rate, and of 0.329 between the DZ twinning rate and the latitude of the prefecture capital, the latter being significant at the 5% level. The correlation coefficient between the above proportion and the latitude of the prefecture capital was still higher, 0.589. The proportion of mothers treated with ovulation-inducing hormones was computed for each prefecture and each district. Excluding the Okinawa prefecture, the highest values were obtained in southwest Shikoku and Chugoku districts, and the lowest in northeast Tohoku District, with a negative but nonsignificant ( $r = -0.256$ ) correlation with the DZ twinning rate. Table 6 shows the proportion of mothers treated with ovulation-inducing hormones by sex combination of the multiple births: 4.53% in the mothers of same-sexed twins vs 9.16% in the mothers of opposite-sexed twins. It can also be seen that the rate of same-sexed twins born to mothers treated with the hormone is 68% (158/230) and that of opposite-sexed twins is 31% (72/230). The corresponding rates of twins born to mothers not treated are 92% (3327/4041) and 17% (714/4041), respectively, the difference being highly significant. Among mothers of triplets the proportion was higher than among mothers of twins, suggesting high rates of DZ twins and triplets following hormone treatment.

TABLE 5. Adjusted Twinning Rates per 1000 Live Births or per 1000 Fetal Deaths by Maternal Age and Zygosity, 1974

		Maternal age (years)					
		Under 20	20-24	25-29	30-34	35-39	Over 40
MZ twinning rate	per 1000 live births	2.81	3.32	3.54	3.84	3.83	3.76
	per 1000 fetal deaths	4.1	10.08	13.09	9.97	6.16	3.75
DZ twinning rate	per 1000 live births	0.81	1.56	1.73	2.01	2.48	1.91
	per 1000 fetal deaths	1.15	2.80	4.07	4.57	4.14	2.18

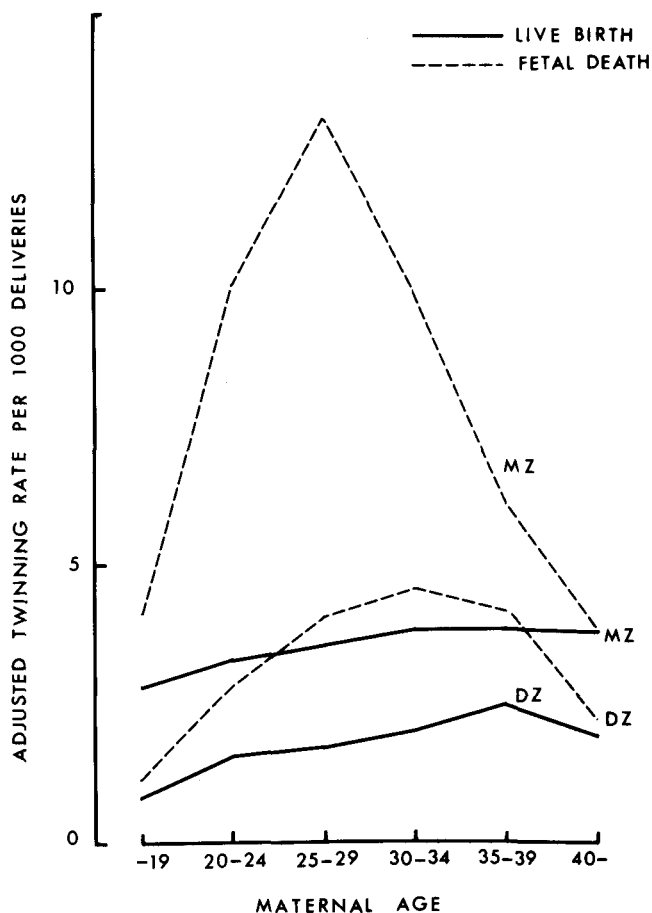


Fig. 6. "Adjusted" MZ and DZ twinning rates among live births and fetal deaths by maternal age, 1974 (see text).

TABLE 6. Proportion of Mothers Treated With Ovulation-Inducing Hormone in Same-Sexed vs Opposite-Sexed Pairs

Multiple births	Same-sexed pairs			Mixed-sexed pairs		
	Total mothers	Number of mothers treated with ovulation-inducing hormone	Proportion	Total mothers	Number of mothers treated with ovulation-inducing hormone	Proportion
Twins	3485	158	0.045	786	72	0.092
Triplets	25	4	0.160	15	3	0.20
Quadruplets	0	0	...	1	0	...

## DISCUSSION

From 1955 to 1966 an increase in the total (live birth and fetal death) MZ twinning rate was observed [16]. The increase becomes more evident as maternal age increases, as indicated by the analysis of data after 1960, although a slight decrease was seen in the youngest maternal age group (Fig. 4). This increase was seen in live births but not in fetal deaths (Fig. 5). When twinning rates are adjusted for pairs with one fetal death, the adjusted live-born MZ twinning rate among total births appears to have increased, particularly in higher maternal age groups (Fig. 7).

The decline in the total DZ twinning rate was noticed particularly in the higher maternal age groups after 1960 (Table 3, Fig. 3). In addition, the decline in the total DZ twinning rate was associated with that of the adjusted DZ twinning rate among fetal deaths (Fig. 5). Detailed analysis revealed that among fetal deaths the decline of the adjusted DZ twinning rate was seen in all but the youngest maternal age groups, whereas among live births the decline was apparent only in higher maternal age groups, except the group aged 40 years or more (Figs. 8 and 9).

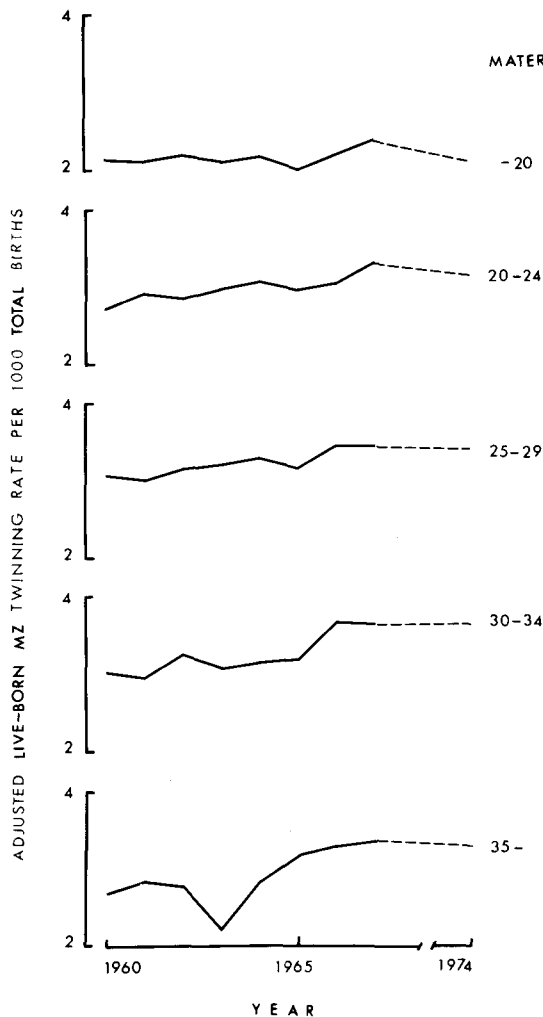


Fig. 7. "Adjusted" live-born MZ twinning rate among total births by maternal age, 1960-1967 and 1974 (see text).

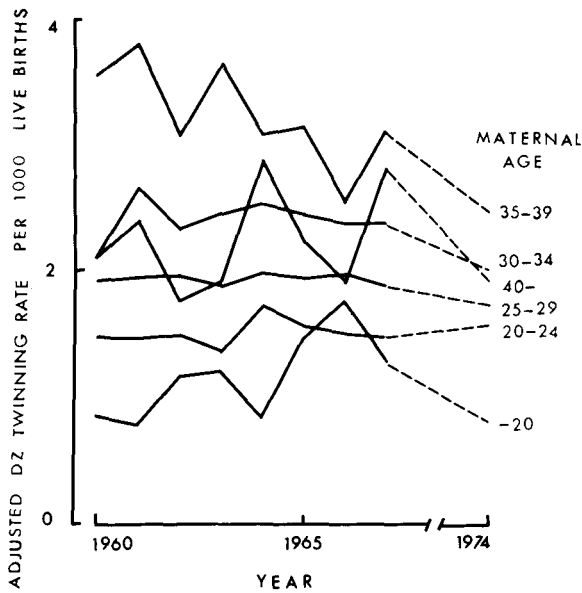


Fig. 8. Secular change of "adjusted" DZ twinning rate among live births by maternal age, 1960-1967 and 1974.

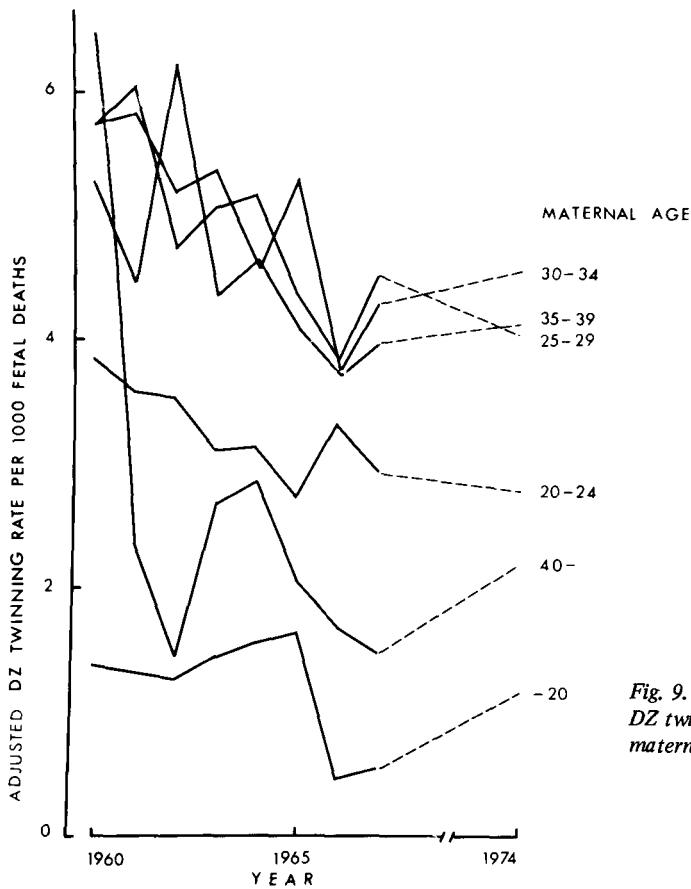


Fig. 9. Secular change of "adjusted" DZ twinning rate among fetal deaths by maternal age, 1960-1967 and 1974.

An interesting finding is that the decline of the total DZ twinning rate (Fig. 3) indicated the same pattern as the standardized birth rate computed by applying age-specific fertility per married woman [13, 15] (Fig. 10). During 1960–1975, corresponding to the period of the present analysis, the standardized birth rates were constant for the younger maternal age groups but were declining in mothers over 30 years of age. It seems likely that the secular decline of polyovulation, particularly that resulting in fetal death, may share a common basis with the decline of age-specific fertility in older mothers. The use of ovulation-inducing hormone would be expected to have resulted in an increase of the DZ twinning rate. However, this was not reflected in the total DZ twinning rate, possibly because of a small counter-effect of the hormone treatment to the decline of the DZ twinning rate.

In both MZ and DZ twins the secular changes of total rates indicated a seemingly marked variation in the older and youngest maternal age groups (Figs. 3 and 4). This is due to small sample size in these groups, as indicated by a smaller expected-to-observed variance ratio in these groups than in middle-aged groups.

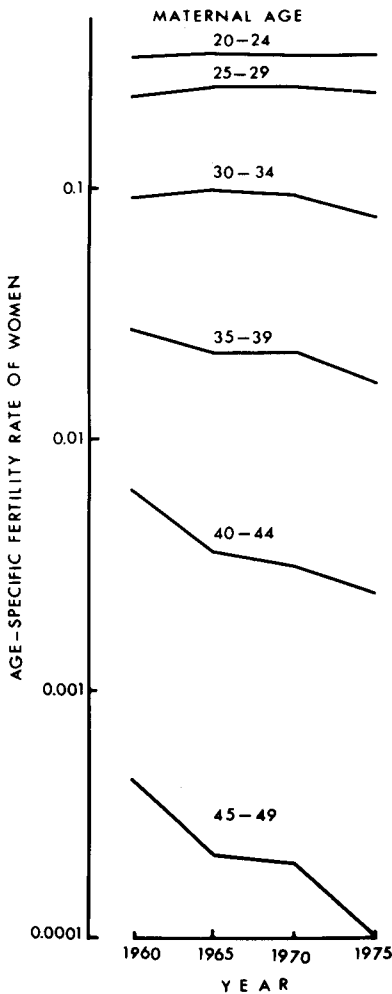


Fig. 10. Age-specific fertility rate per married woman (Institute of Population Problems).

Among live births nearly linear increase with maternal age was seen in the MZ twinning rate, and increase up to maternal age 35–39 and decrease thereafter was seen in the DZ twinning rate (Fig. 6). With respect to twinning rates among fetal deaths, the maternal age effect is entirely different from that observed among live births, indicating unimodal distributions in both MZ and DZ twinning rates. The earlier mode in the MZ twinning rate is due to higher stillbirth rates, particularly in younger maternal age groups (Fig. 11).

As to geographical variation, it has been argued since Davenport [5] that there is a positive correlation between total twinning rate and latitude. Higher DZ twinning rate in the northeast of Japan was also noted in statistics from 1955 to 1959. The present analysis indicated a positive and significant correlation between the DZ twinning rate and latitude in accordance with the results reported by Kamimura [20]. Dahlberg [4] suggested that the mothers of twins are more fertile. The analysis of the aforementioned age-specific fertility per married woman in 1960 and 1975 according to district (Fig. 12) indicates a positive correlation with latitude extending from Hokkaido to Kinki districts in older maternal age groups in the former year, which disappeared in recent years [12, 14]. It may be concluded that a positive correlation between total DZ twinning rate and fertility if any, can be seen in higher maternal age groups in earlier years.

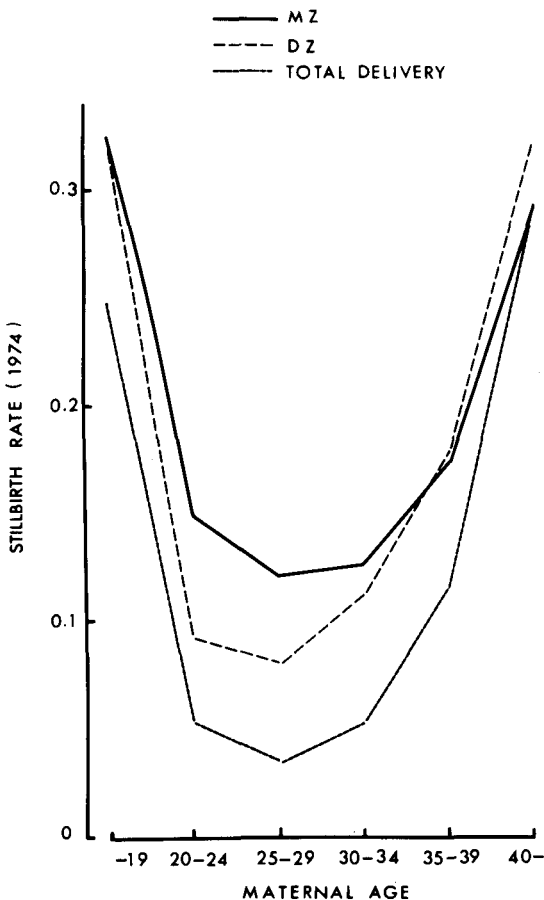


Fig. 11. Stillbirth rates among MZ twins, DZ twins and total population by maternal age in 1974.

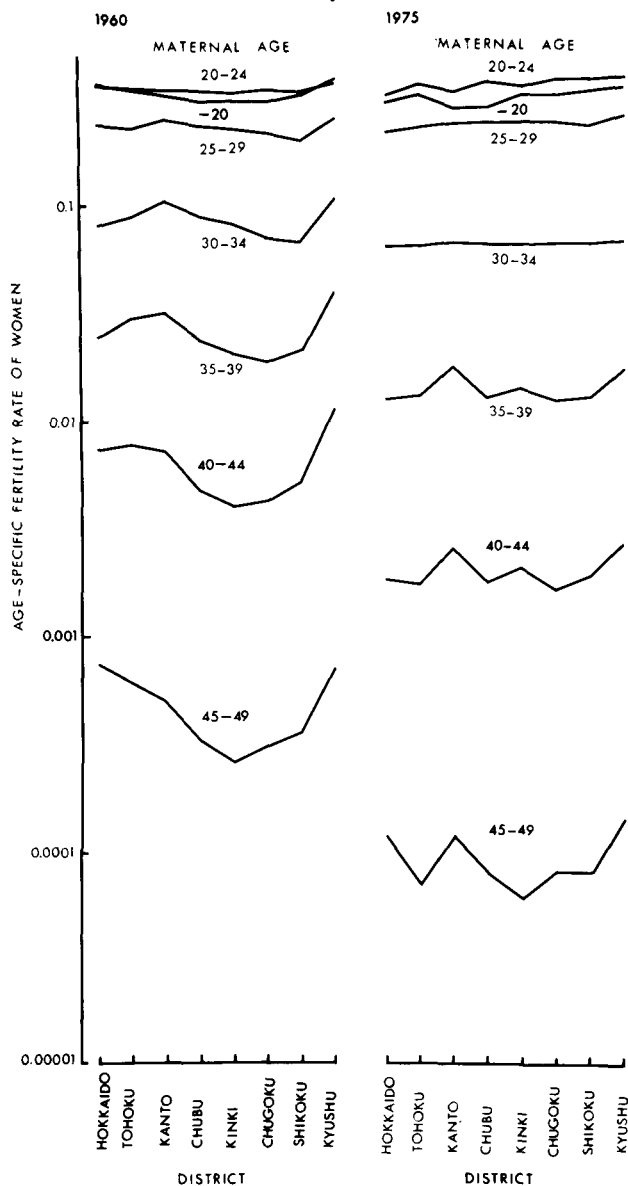


Fig. 12. Age-specific fertility rate per married woman by maternal age in eight districts of Japan.

Greulich [8] found that the relatives of both mothers and fathers of twins had increased tendencies toward twinning among their offspring. This trend is shown among the relatives of DZ twins but not among those of MZ twins. In the present study, the proportion of twins' parents having multiple births among relatives was 43.3% (1851/4271). If the proportion is computed among like- and unlike-sexed twin pairs, the former (43.4%) is not different from the latter (42.9%) (Table 7).

The higher rate of twinning in rural areas of Madhya Pradesh, India, was suggested to be due to higher inbreeding [7]. However, in Japan, the twinning rate in rural areas (0.584%) was not different from that in urban areas (0.578%), though the former are characterized by a higher inbreeding coefficient (0.00286) than the latter (0.00144) [9].



TABLE 7. Number of Cases of Multiple Births Among the Relatives of Same-Sexed vs Opposite-Sexed Pairs

Multiple births	Relatives of same-sexed pairs			Relatives of opposite-sexed pairs		
	Numbers of observations	Numbers of cases of multiple births	Proportion	Numbers of observations	Number of cases of multiple births	Proportion
Twins	3485	1514	0.434	786	337	0.429
Triplets	25	9	0.360	15	4	0.267
Quadruplets	0	0	...	1	0	...

Further analysis of the present data is now under way, and the results will be reported in separate articles.

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**Correspondence:** Dr. Yoko Imaizumi, Institute of Population Problems, 2-2, 1-Chome, Kasumigaseki, Chiyoda-Ku, Tokyo, Japan.