Motor Development of Japanese Twins in Childhood as Reported by Mothers

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Abstract

Objective: Twins tend to lag behind singletons in their motor development, though the causes of this appear to be complicated and are not yet fully understood. The present study was performed to clarify the factors associated with the motor development of twins.

Methods: The twins in the first group consisted of school applicants, including 1131 twin pairs, and the second group consisted of children of members of several maternal associations, and included 951 pairs. All data were gathered by questionnaire survey, and six gross-motor development milestones were analyzed in individuals or pairs.

Results: Relative to general population norms in Japan, twins tended to be delayed in reaching several motor development milestones. Stepwise regression analysis showed that of all the variables measured, gestational age was the most influential on all six milestones. Birthweight was also influential on most milestones. Other factors affecting motor development milestones were parity for 'sitting without support,' 'pulling up to a standing position,' and 'walking without support,' and zygosity for 'walking without support.' In these cases, longer gestational age, heavier birthweight, primiparity, and dizygosity showed a tendency toward earlier attainment of development. Motor development within pairs was more similar in monozygotic pairs compared with dizygotic pairs regarding each item, suggesting genetic contributions.

Conclusion: The results of the present study showed specific and nonspecific factors that affect motor development of twins. These findings should prove useful in understanding the motor development of twin children and help clinicians to refine maternal and child health care for multiple-birth children.

Key words: twins, motor development, database, zygosity, maternal and child health care

Introduction

In Japan, as in other developed countries, multiple birth rates have been increasing during the last two decades. The higher rates of twin births since 1987 have been attributed to both the higher proportion of mothers treated with ovulation-inducing hormones and to the increasing use of in-vitro fertilization (1). Under such circumstances, there is an increasing need to provide appropriate information to parents and nursing staff on the biological characteristics of twins, such as their intrauterine growth, physical growth after birth, and motor and

language development.

Many studies have shown that twins tend to lag behind singletons in terms of motor development (2–7), although the causes of this delay are not explained simply by the earlier gestational age at birth or the lighter birthweight of twins compared to singletons and appear to be influenced by more complicated factors. In general, the birthweight of twins is lower and the gestational age of twins is shorter compared to singletons (8), but the differences between twins and singletons are not limited to the birthweight or gestational periods. For example, the psychosocial environment can also differ between families with twins and those with singletons, and these factors may well influence early development.

As there are no large-scale data collections on twins' growth in Japan, the motor development of twins must be evaluated using the standards for the general population (9–11), that is, essentially the standards for singletons. In recent years in Japan, the developmental norms for motor development

Received Dec. 17, 2004/Accepted Dec. 8, 2005

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milestones in childhood have been examined every ten years (for example, in 1980, 1990, and 2000) and have been presented together with measures of language development by the Ministry of Health, Labor and Welfare (9–11). According to these measurements, many twins may be regarded as showing poor development, causing their parents much anxiety and concern. In general, professional advisors regarding the growth and development of children, such as pediatricians and public health nurses, do not have adequate information to answer parents' questions concerning these children's motor development. To resolve this situation, it is essential to obtain objective data on motor development based on a large sample of Japanese twins.

The present study was performed to clarify the factors associated with motor development of twins.

Methods

Subjects and outline of data collection

Continuous data on twins in childhood and on their families has been gathered for the purpose of contributing to twins' health care and to the genetic epidemiologic study of twins and their families (8, 12, 13). The data used in this study was a portion of this body of data.

The present sample consisted of two independent groups of subjects. The first group consisted of 1131 mothers and their twin children living in the Tokyo metropolitan area. All of the twins in this group had applied to (though not necessarily enrolled in) the secondary school attached to the Faculty of Education of the University of Tokyo between 1981 and 2004 (school applicants group). The second group of subjects consisted of 951 mothers in several associations for the parents of multiples throughout Japan (maternal associations group). Twins in the school applicants group were born between 1968 and 1992 (mean 1979, standard deviation (SD) 7 years), and twins in the maternal associations group were born between 1986 and 2003 (mean 1995, SD 4 years). At the time data were collected, the majority of twins in the school applicants group were 12 years old, and the twins in the maternal associations group ranged in age from 0 to 15 years (mean 6.0 years, SD 3.8 years, median age 5.0 years).

Data were collected through mailed or hand-delivered questionnaires, which had nearly the same format between the two groups. The questions concerned family structure; obstetrical findings on the mothers; the twins' physical growth, zygosity, motor, language, and mental development; the twins' and parents' medical histories; and any behavioral problems the twins had had (8, 12, 13). Obstetric findings were obtained from the "Maternal and Child Health Handbook," provided by the Ministry of Health, Labor and Welfare to all pregnant women.

Data on the socioeconomic and educational status of the parents were not obtained.

Zygosity classification

The zygosity of the twins was determined primarily from a questionnaire (14, 15) that, in the present study, was completed by the mothers in both groups. The zygosity types were monozygotic (MZ), unclassified, and dizygotic (DZ), according to the similarity score, which was calculated using five ques-

tions regarding the physical similarity and confusion of identity between the twins. When zygosity determination by DNA/genetic markers was regarded as the gold standard, the accuracy of the zygosity questionnaire was 97.5% (14).

In total, 775 MZ pairs and 327 DZ pairs with 29 pairs of unclassified zygosity were determined for the school applicants group, and 522 MZ pairs and 412 DZ pairs with 17 pairs of unclassified zygosity were determined for the maternal associations group. This is one of the advantageous features of the present data, as zygosity diagnosis of same-sex twins is seldom performed in Japan.

Questions concerning motor development

Six items regarding motor development milestones, namely, 'maintaining head,' 'rolling over,' 'sitting without support,' 'crawling,' 'pulling up to a standing position,' and 'walking without support,' were selected on the basis of the "Maternal and Child Health Handbook." The same expressions of milestones as those used in the survey by the Ministry of Health, Labor and Welfare were used for both groups. For example, the word 'hai-hai' was used for 'crawling' irrespective of the year of data collection. The age of attainment of a set of markers of gross-motor development and a within-pair difference were questioned in terms of month. Since data on 'rolling over' was presented by the Ministry of Health, Labor and Welfare only from the 1990 survey (10, 11), the data of this milestone was gathered only after 2000 in the school applicants group, and there is little data on this measurement for this group.

The present data are based on maternal retrospective reports according to the age of the twins at data collection. The data were based mainly on mothers' records in the "Maternal and Child Health Handbook" or, alternatively, personal records. The data of children based on mass examinations in Japan are usually recorded in the Handbook, and the mothers were advised to refer to those records when completing the questionnaire. If mothers could not remember events in their children's motor development, the author recommended that, in the questionnaire, they should not use incorrect answers merely to complete the questionnaire, but give a blank response. For the school applicants group, one of the parents of each applicant, usually the mother, participated in a medical interview performed by two or three interviewers (the author being one of the interviewers from 1987 onward,) in which their responses to the questionnaire were checked carefully.

The growth standards presented by the Ministry of Health, Labor and Welfare (9–11) were considered as exclusion criteria. Eight subjects were excluded because of unreliable data or extremely delayed development.

Statistical analyses

In the statistical calculation, the following adjustment was performed. Because the age given by mothers was by month and each month theoretically contained about 30 days, 0.5 months was added, assuming that the age at the first occurrence of each milestone in each month was normally distributed.

First, basic statistics were calculated. The means and SDs of the items for the age of motor development milestones were calculated and compared to the few detailed reports of motor

development milestones of twins performed by Peter et al. (7) and Goetghebuer et al. (6). Then, cumulative frequency distribution regarding the age at motor developmental milestones was calculated and compared with data presented by the Ministry of Health, Labor and Welfare (9–11), wherein the values of cumulative relative frequency for selected months after birth were presented. Standards of the general population in 1980, 1990, and 2000 were used as a reference considering the twins' birth year.

Next, factors that affect the age of attainment of motor development milestones of twins were confirmed. Eleven variables with less than a 3% frequency of missing values were selected. The quantitative variables considered were gestational age (weeks), birthweight (g), birth year of twins, maternal age at twin birth, and the number of birth injuries if any. The component of birth injuries of mothers or twins included, for example, placenta previa, placental abruption, coiling of the umbilical cord, neonatal asphyxia, and twin-to-twin transfusion syndrome. Each component was treated as binary data. The frequency of each injury is relatively low and inappropriate for the following analyses, so the numbers of total injuries were summed and used as a quantitative item. The qualitative variables considered were sex, birth order of twins, parity, zygosity, method of delivery, and health condition at birth. For qualitative variables, the following codes were used: sex, female: 0, male: 1; birth order in twin pair, first born: 0, second born: 1, parity, multiparity: 0, primiparity: 1; zygosity, dizygotic: 0, monozygotic: 1; method of delivery, transvaginal: 0, Caesarean section: 1; health condition at birth, healthy: 0, unhealthy (hyposthenia and neonatal asphyxia): 1. The effects of a single variable on the motor development were checked in detail using correlations or associations, and then stepwise regression analysis was performed with a threshold significance level of 0.05.

Finally, within-pair differences for the age of attainment of motor development milestones were analyzed according to zygosity to estimate genetic contribution to motor development.

All statistical analyses were performed using SAS® for Windows (16). Smoothing of the cumulative frequency distri-

bution was performed using the PROC TRANSREG program, specifying the 'pspline' model.

Ethical issues

The mothers in the maternal associations cooperated voluntarily in this research, mainly through the president of their associations. It was clearly mentioned in the questionnaire that only statistical analysis was performed on the data obtained. Informed consent concerning statistical analysis of the data in the school applicants was obtained in writing from each twin and their parents as part of the application process.

Results

The descriptive statistics are provided to give a general idea of the range of variation for the motor development milestones in this sample. The means and SDs of the development milestones, gestational age, and birthweight are shown in Table 1, in comparison with the results obtained by Peter et al. (7) and Goetghebuer et al. (6). The results obtained by Goetghebuer et al. should be viewed with caution, as their subjects comprised only singletons and twins with birthweight >2.5 kg.

The means of the data for the present subjects fall, for the most part, between those of Peter et al. (7) and Goetghebuer et al. (6), except that the 'pulling up to a standing position' milestone of the present data showed a delay compared with both previous reports. These results were in accordance with gestational period or birthweight, which the present data showed to be longer and heavier than those reported by Peter et al. (7) and shorter and lighter than those reported by Goetghebuer et al. (6). Subjects studied by Goetghebuer et al. (6) sat without support much earlier, partly reflecting the difference in the definition. Regarding the present subjects, the attainment of all milestones by children in the maternal associations group was apt to be significantly later compared to that for children in the school applicants group, except for the 'pulling up to a standing position' milestone.

Table 1 Basic statistics of six motor development milestones, gestational age, and birthweight

	Current study				Peter et al. (1999) (7)				Goetghebuer et al. (2003) ^a (6)	
	S group		M group		Singletons (n=622)	MZ twins (n=60)	DZ twins (n=140)	All twins ^b	Singletons (n=72)	Twins (n=168 ^c)
	n (twins)	Mean±SD	n (twins)	Mean±SD						
Maintaining head	1947	3.69±0.96	1680	4.02±0.93					2.53	3.09
Rolling over	337	5.69±1.26	1624	6.01±1.37	4.28±1.25	5.71±0.65	6.13±0.82	6.00	4.61	4.98
Sitting without support	1865	7.29±1.21	1574	7.85±1.43	7.24±1.62	9.12±1.33	9.56±1.39	9.43	4.34	4.79
Crawling	1859	8.52±1.51	1622	8.68±1.60					6.86	7.20
Pulling up to a standing position	1932	10.15±1.82	1634	9.79±1.87	8.42±1.81	9.36±1.61	9.63±1.30	9.55	8.18	8.91
Walking without support	2068	13.21±2.17	1719	13.39±2.24	12.70±2.28	14.84±2.91	15.19±3.07	15.09	10.78	11.20
Gestational Age (weeks)	2232	37.92±2.15	1866	36.95±2.32	39.31±2.23	36.37±2.22	36.66±2.63	36.57	38.3	38.9
Birthweight (kg)	2253	2.48±0.44	1893	2.33±0.45	3.16±0.54	2.26±0.32	2.44±0.54	2.39	3.24	2.79

1) Mean±SD months are shown. S group: school applicants group. M group: maternal associations group.

2) ^a The subjects of Goetghebuer et al. (2003) were only twins and singletons with birthweight >2.5 kg.

3) ^b Data of Peter et al. (1999) had some missing values (number not shown in report). The author calculated weighed means assuming that no missing values exist.

4) ^c Follow-up was incomplete and about half the twins dropped out at 18 months. The number of twins at attaining each milestone was not reported.

Fig. 1 Cumulative frequency distribution of twins for the age of attainment of six motor development milestones as reported by mothers. Cumulative frequency distributions of motor development milestones compared with general population norms for 1980 (9), 1990 (10), and 2000 (11) are shown. S group: school applicants group. M group: maternal associations group.

Cumulative frequency distribution compared with general population norms is shown in Fig. 1. As mentioned in the methods section, the present data were obtained in terms of month. For example, if mothers answered that the age at walking without support was 12 months, the data theoretically contained information from the age of 12 months and 0 days to an age of 12 months and 30 days (nearly 13 months). In general, an interval of about one month was considered. Therefore, both the earliest and the latest patterns were presented; thus, the results are shown as an area. Compared with general population curves, those for the current subjects indicated a delay of about

one to two months for 'rolling over' and 'pulling up to a standing position,' whereas no obvious delay was observed for 'maintaining head' or 'sitting without support.' These tendencies were obvious in the maternal associations group. Nevertheless, the months at which cumulative frequency reached about 97–99 percent were nearly the same between twins and the general population.

To further clarify the factors affecting twins' motor development, the author performed the following bivariate and multivariate analyses.

The correlations between quantitative variables are sum-

Table 2 Correlations of continuous variables

	S group				
	gestational age	birthweight	birth year	maternal age	birth injury
Maintaining head	-0.26 (n=1919)**	-0.25 (n=1940)**	-0.05 (n=1947)*	0.02 (n=1943)	-0.03 (n=1947)
Rolling over	-0.23 (n=331)**	-0.16 (n=336)**	0.03 (n=337)	0.07 (n=337)	0.01 (n=337)
Sitting without support	-0.23 (n=1841)**	-0.19 (n=1860)**	0.01 (n=1865)	0.10 (n=1857)**	-0.07 (n=1865)**
Crawling	-0.24 (n=1837)**	-0.19 (n=1852)**	-0.04 (n=1859)	0.05 (n=1851)*	-0.07 (n=1859)**
Pulling up to a standing position	-0.23 (n=1904)**	-0.16 (n=1926)**	-0.17 (n=1932)**	0.07 (n=1926)**	-0.08 (n=1932)**
Walking without support	-0.25 (n=2038)**	-0.22 (n=2061)**	-0.11 (n=2068)**	0.09 (n=2060)**	-0.06 (n=2068)**
Other significant correlations	gestational age×birthweight $r=0.58$ (n=2223)** birth year×birth injury $r=0.15$ (n=2262)** birthweight×birth injury $r=0.14$ (n=2253)** maternal age×birth year of twins $r=0.13$ (n=2254)** gestational age×birth injury $r=0.12$ (n=2232)** maternal age×birth injury $r=-0.09$ (n=2254)** gestational age×maternal age $r=-0.07$ (n=2224)**				
	M group				
	gestational age	birthweight	birth year	maternal age	birth injury
Maintaining head	-0.46 (n=1655)**	-0.42 (n=1677)**	0.21 (n=1680)**	0.08 (n=1680)**	-0.08 (n=1680)**
Rolling over	-0.30 (n=1603)**	-0.26 (n=1621)**	0.05 (n=1624)	0.03 (n=1624)	-0.04 (n=1624)
Sitting without support	-0.38 (n=1554)**	-0.32 (n=1571)**	0.08 (n=1574)**	-0.06 (n=1574)*	-0.00 (n=1574)
Crawling	-0.32 (n=1600)**	-0.27 (n=1619)**	0.06 (n=1622)*	-0.02 (n=1622)	-0.02 (n=1622)
Pulling up to a standing position	-0.29 (n=1614)**	-0.26 (n=1631)**	0.04 (n=1634)	0.04 (n=1634)	-0.04 (n=1634)
Walking without support	-0.33 (n=1696)**	-0.27 (n=1716)**	0.01 (n=1719)	0.01 (n=1719)	-0.01 (n=1719)
Other significant correlations	gestational age×birthweight $r=0.67$ (n=1859)** maternal age×birth year of twins $r=0.24$ (n=1894)** gestational age×birth injury $r=0.16$ (n=1866)** birthweight×birth injury $r=0.16$ (n=1885)** gestational age×birth year of twins $r=-0.12$ (n=1866)** maternal age×birth injury $r=-0.10$ (n=1894)** birthweight×birth year of twins $r=-0.08$ (n=1885)** birth year×birth injury $r=-0.06$ (n=1894)**				

1) S group: school applicants group. M group: maternal associations group.

2) ** $p<0.01$, * $p<0.05$ 3) $r>0.15$ shown in bold.**Table 3** Results of test of difference in mean age of attaining six motor milestones according to qualitative variables

	S group					
	sex	birth order	parity	zygosity	method of delivery	health condition at birth
Maintaining head	0.0083 a	ns	0.0301 a	ns	ns	ns
Rolling over	ns	ns	0.0437 b	ns	0.0244 b	ns
Sitting without support	ns	ns	0.0005 b	0.0202 a	0.0228 b	0.0015 a
Crawling	ns	ns	ns	0.0345 a	0.0009 b	0.0134 a
Pulling up to a standing position	ns	ns	<0.0001 b	<0.0001 a	0.0019 b	ns
Walking without support	<0.0001 a	ns	<0.0001 b	<0.0001 a	0.0046 b	0.0412 a
	M group					
	sex	birth order	parity	zygosity	method of delivery	health condition at birth
Maintaining head	ns	ns	ns	ns	<0.0001 a	<0.0001 a
Rolling over	0.0189 b	ns	0.0016 a	ns	0.0011 a	0.0002 a
Sitting without support	0.0394 b	ns	ns	0.0023 a	0.0034 a	<0.0001 a
Crawling	0.0029 b	ns	ns	ns	ns	<0.0001 a
Pulling up to a standing position	0.0010 b	ns	ns	ns	0.0002 a	0.0015 a
Walking without support	ns	ns	0.0023 b	0.0003 a	ns	<0.0001 a

1) P value is shown in the table.

2) S group: school applicants group. M group: maternal associations group.

3) For qualitative variables, the following codes were used: sex, female: 0, male: 1; birth order, first born: 0, second born: 1, parity, multiparity: 0, primiparity: 1; zygosity, dizygotic: 0, monozygotic: 1; method of delivery, transvaginal: 0, Caesarian: 1; health condition at birth, healthy: 0, unhealthy (hyposthenia and neonatal asphyxia): 1.

4) a: Code '0' indicates earlier development. b: Code '1' indicates earlier development.

marized in Table 2. Gestational age and birthweight showed strong influences on the motor development irrespective of the group, suggesting that children with a longer gestational age or heavier birthweight showed a tendency toward earliness in attaining motor development milestones, as was expected. Gestational age and birthweight themselves showed strong positive correlations. On the other hand, birth injuries showed slightly negative correlations with motor development, suggesting that children with more birth injuries showed a tendency toward earliness in attaining motor development milestones, contrary to the expectation. The correlations between gestational age and the number of birth injuries, or birthweight and the number of birth injuries also showed a slightly negative value, irrespective of the group.

In the school applicants group, the birth year of twins was correlated with ‘pulling up to a standing position’ and ‘walking without support’. Maternal age showed slightly positive correlations with motor development.

The associations between qualitative variables were analyzed using a chi-square test and tetrachoric correlations.

Significant associations were observed between sex and zygosity ($p<0.01$, $r=-.11$), health condition at birth and parity ($p<0.01$, $r=.10$), and health condition at birth and method of delivery ($p<0.05$, $r=.20$) for the school applicants group. Significant associations were observed between zygosity and parity ($p<0.01$, $r=.26$), zygosity and method of delivery ($p<0.01$, $r=-.16$), health condition at birth and parity ($p<0.05$, $r=.11$), and health condition at birth and method of delivery ($p<0.01$, $r=.28$) in the maternal associations group.

The results of a test of difference regarding the mean age of motor development are shown in Table 3. No birth order effect was observed in either of the two groups. In the school applicants group, parity, zygosity, and method of delivery tended to be associated with motor development. In these cases, primiparity, dizygosity, and Caesarian section showed a tendency toward earlier attainment of motor development. In the maternal associations group, sex, method of delivery, and health condition at birth tended to be associated with motor development. In these cases, males, transvaginal delivery, and healthy children showed a tendency toward earlier attainment of

Table 4 Results of stepwise regression analysis for the age of attaining six motor developmental milestones

	n	gestational age	birth weight	maternal age	birth year	birth injury	sex	birth order	parity	zygosity	method of delivery	health condition at birth
Maintaining head	S 1862	0.0677 **b	0.0132 **b	ns	ns	ns	0.0024 *a	ns	0.0021 *a	ns	ns	ns
	M 1580	0.2182 **b	0.0267 **b	0.0022 *a	0.0223 **a	ns	ns	ns	ns	ns	ns	0.0054 **a
Rolling over	S 327	0.0561 **b	ns	0.0125 *a	ns	ns	ns	ns	ns	ns	0.0181 *b	ns
	M 1532	0.0837 **b	0.0083 **b	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sitting without support	S 1784	0.0568 **b	0.0038 **b	0.0065 **a	ns	ns	ns	ns	0.0038 **b	ns	ns	ns
	M 1489	0.1414 **b	0.0110 **b	0.0049 **b	ns	0.0037 *a	ns	ns	0.0056 **b	ns	ns	ns
Crawling	S 1784	0.0622 **b	ns	ns	ns	0.0034 **b	ns	ns	ns	ns	0.0028 **b	ns
	M 1534	0.1014 **b	0.0077 **b	ns	ns	ns	ns	ns	ns	ns	ns	ns
Pulling up to a standing position	S 1849	0.0525 **b	ns	ns	0.0263 **b	ns	ns	ns	0.0122 **b	0.0100 **a	ns	ns
	M 1550	0.0813 **b	0.0068 **b	ns	ns	ns	0.0036 *b	ns	0.0030 *b	ns	ns	ns
Walking without support	S 1975	0.0660 **b	0.0084 **b	0.0033 **a	0.0112 **b	ns	0.0081 **a	ns	0.0094 **b	0.0100 **a	ns	ns
	M 1623	0.0970 **b	0.0060 **b	ns	ns	ns	ns	ns	0.0077 **b	0.0039 **a	ns	0.0096 **a

1) P value is shown in the table.

2) S: school applicants group. M: maternal associations group.

3) For qualitative variables, the following codes were used: sex, female: 0, male: 1; birth order, first born: 0, second born: 1, parity, multiparity: 0, primiparity: 1; zygosity, dizygotic: 0, monozygotic: 1; method of delivery, transvaginal: 0, Caesarian: 1; health condition at birth, healthy: 0, unhealthy (hyposthenia and neonatal asphyxia): 1.

4) a: Positive value of standardized estimate. b: Negative value of standardized estimate.

5) ** $p<0.01$, * $p<0.05$

6) Variables which both groups showed significant contribution are shown in bold.

Table 5 Within-pair difference in attaining motor development milestones according to zygosity

		S group				M group			
		n	0 month	1 month	2 or more months	n	0 month	1 month	2 or more months
		(pairs)	%	%	%	(pairs)	%	%	%
Maintaining head	MZ	702	94.2	5.3	0.6	460	92.8	5.7	1.5
	same-sex DZ	165	81.2	15.8	3.0	178	82.0	15.7	2.3
	opposite-sex DZ	102	81.4	17.7	1.0	185	77.8	18.4	3.8
Rolling over	MZ	121	85.1	14.1	0.8	442	78.1	19.2	2.7
	same-sex DZ	28	60.7	32.1	7.1	170	62.4	27.1	10.6
	opposite-sex DZ	17	52.9	35.3	11.8	180	56.1	30.0	13.9
Sitting without support	MZ	671	91.8	7.3	0.9	430	79.5	17.0	3.5
	same-sex DZ	163	76.7	20.9	2.5	170	65.3	27.7	7.1
	opposite-sex DZ	93	76.3	17.2	6.5	172	59.3	29.7	11.1
Crawling	MZ	663	85.2	12.7	2.1	448	74.3	21.2	4.5
	same-sex DZ	159	56.0	32.7	11.3	170	56.5	28.8	14.7
	opposite-sex DZ	100	62.0	30.0	8.0	180	50.0	36.1	13.9
Pulling up to a standing position	MZ	690	83.6	13.6	2.8	455	75.0	18.0	7.0
	same-sex DZ	166	60.8	28.3	10.8	175	54.3	28.0	17.7
	opposite-sex DZ	103	61.2	26.2	12.6	175	41.7	37.1	21.1
Walking without support	MZ	734	77.3	18.1	4.6	470	66.8	23.8	9.4
	same-sex DZ	183	55.7	26.8	17.5	182	38.5	34.1	27.5
	opposite-sex DZ	114	38.6	36.0	25.4	192	36.5	35.4	28.1

1) S group: school applicants group. M group: maternal associations group.

2) MZ: Monozygotic, DZ: Dizygotic.

motor development.

The results of the stepwise regression analysis are shown in Table 4. The factor most affecting all motor development milestones was gestational age, irrespective of subject group. In this case, children with a longer gestational age showed a tendency toward earliness in attaining motor development milestones. Other factors affecting motor development milestones, though the contributions of these factors themselves were very small, for both groups were the following: birthweight for ‘maintaining head,’ ‘sitting without support,’ and ‘walking without support,’ parity for ‘sitting without support,’ ‘pulling up to a standing position,’ and ‘walking without support,’ and zygosity for ‘walking without support.’ In these cases, children with higher birthweight, primiparity, and dizygosity showed a tendency toward earlier attainment of motor development.

In the school applicants group, the birth year of twins (from 1968 to 1992) affected ‘pulling up to a standing position’ and ‘walking without support.’ In these cases, recent birth year showed a tendency toward earlier attainment of motor development. This tendency was not observed in the maternal associations group.

Within-pair differences in the first appearance of motor development milestones according to zygosity are shown in Table 5. Irrespective of subject group, MZ pairs were more similar than were same-sex DZ or opposite-sex DZ pairs. This tendency became more obvious as the set of motor development skills advanced. More than half of the DZ pairs showed differences of one month or more in attaining ‘walking without support,’ whereas only 23–32% of the MZ pairs showed differences of one month or more in attaining this skill.

Discussion

(1) Representativeness of the samples

The age at which various motor development milestones are achieved by singletons varies considerably in the literature. This variation is probably as much due to differences in the definitions of the developmental stages and the methods of collecting data as it is due to differences in the population environment or genetics (6). For example, birth year effects are observed for the norms of the Japanese general population presented by the Ministry of Health, Labor and Welfare, and some of this effect is thought to be related to changes in the definition of the motor development milestones (9–11).

Reports on gross-motor development milestones in twins are very limited because of sampling difficulty. It is almost impossible to perform a longitudinal observational study of motor development in twins for a large number of subjects.

Among the available studies, Peters et al. (7) and Goetghebuer et al. (6) reported the mean age for the attainment of the set of motor development milestones using hospital data of about one or two hundred sets of twins, the results of which are close to our results, as shown in Table 1. The difference is thought to be associated not only with the measurement methods, but also with the sampling population (hospital data vs. volunteer-based data), cultural factors, racial differences, genetic background, and many other unknown factors. The reason why ‘pulling up to a standing position’ in the present data showed an exceptional delay is unclear. Although the present data was limited to only maternal reports, the data was thought to have no fatal defects compared with the previous studies.

It is well known that hospital data on the birthweight of twins shows a considerable negative selection bias, and consequently, hospital-reported twin birthweight is much lighter compared with volunteer-based twin data (8, 17). The present data consisted of two independent groups, a school applicants group and a maternal associations group. Both groups, particularly the former, may have positive selection bias, which would shift the age of attainment of motor development to an earlier age. Regarding these samples, it has already been ascertained that there was no positive selection bias, at least in the normal range of birthweight according to the gestational age (8), compared with twins' birthweight norms according to gestational age, as indicated by Japanese vital statistics (17). Therefore, it is difficult to think that motor development selectively showed a positive selection bias.

There must be the potential for recall bias. The author considered that in the questionnaire survey there was no other method of obtaining motor development data from a large number of mothers at the same time and with relatively the same accuracy than using the "Maternal and Child Health Handbook," as this booklet is the basic reference regarding maternal and child health care in Japan. The Ministry of Health, Labor and Welfare provides this booklet to all pregnant women. Most mothers have this handbook, and most important records and information about their children's development are predominantly recorded in this handbook (18). Regarding the school applicants group, to reduce recall bias, a medical interview was performed and the answers were checked.

As shown in Fig. 1, compared with norms of the Japanese general population, the present subjects showed a delay of several months for attaining some motor development milestones. The first possible explanation for this was the essential delay of development in twins compared with that in singletons, though the reasons for this delay are complicated and cannot be ascertained directly, as the present data did not include data from a singletons control group. Another possible explanation is the difference in the data collection methods between the general population and the present subjects. The present data was based on maternal retrospective reports, mainly by means of a mother's records entered in the "Maternal and Child Health Handbook." Developmental norms presented by the Ministry of Health, Labour and Welfare were determined based on observations during health examinations, performed at around the same time throughout Japan, on more than ten thousand subjects. The results were recorded in the questionnaire as binary data representing 'possible' or 'impossible,' and cumulative frequency of 'possible' were calculated according to the real age after birth (9–11). It is possible that the older the twins became, the more unreliable was the memory of the mother at data collection time, particularly if she depended only on memory. This difference in data collection methods between the general population and the twins in the present study cannot be adjusted for, and represents the largest limitation of the present questionnaire survey.

(2) Factors affecting motor development of twins

The results of regression analysis showed no major contradiction with the results of bivariate analyses shown in

Table 2 and Table 3. The effect of gestational age on the motor development was consistently the largest. The effect of birthweight was also significant for most types of motor development, though the effect itself was not so large compared with that of gestational age. As birthweight is strongly correlated with gestational age, the effect of birthweight was thought to be weakened. In singletons, birthweight, length, and prematurity are recognized risk factors for developmental delay (19). The strong effect of gestational age on the motor development of twins was also in accordance with the report of Peter et al. (7).

The effect of birth year of twins was observed on 'pulling up to a standing position' and 'walking without support' for children in the school applicants group. In this case, recent birth year showed a tendency toward earlier attainment of motor development. This effect was not observed in the maternal associations group. A possible reason is the difference of birth year between the groups; in the school applicants group, the twins were born between 1968 and 1992 (mean 1979, SD 7 years), and in the maternal associations group, the twins were born between 1986 and 2003 (mean 1995, SD 4 years). According to the growth standards presented by the Ministry of Health, Labor and Welfare (9–11), the age of attainment of motor development milestones by Japanese children in general became earlier from 1980 to 2000, particularly from 1980 to 1990. The present results for the school applicants groups may partly reflect this general tendency. As the age of twins at data collection was about 12 years for all subjects in the school applicants group, the effect of age at data collection can be ignored. Therefore, this result reflects the birth year effect.

In the maternal associations group, birth year and the age of data collection are almost perfectly negatively correlated. Therefore, the effect of birth year and recall bias, which depend on the age of the twins at data collection, cannot be separated.

The effect of zygosity and birth order is unique to twins. In the present subjects, no birth order effect was observed, as Goetghebuer et al. (6) reported. On the other hand, the effect of zygosity on 'walking without support' was observed in both groups. The effect of zygosity on body weight of infant twins has been well observed (8, 20). In this case, MZ twins are generally lighter than DZ twins because of the intrauterine growth delay. This effect decreases gradually with months after birth and disappears at about one year of age.

The effects of zygosity on the language development of twins are also often reported. In this case, MZ twins, particularly males, are reported to be delayed. Language development of twins is very complicated and is influenced by sex and zygosity in their various combinations. Moreover, the influence of so-called 'twin language' has often been reported (21, 22). In general 'twin language' is often observed to be used only within certain twin pairs, and it cannot be understood by others. This private language is more often observed in MZ pairs, and one possible cause is thought to be the twins' extremely close relationship and relative indifference to the outer world. In the present study, the zygosity effect was observed with regard to 'pulling up to a standing position' for the school applicants group, and 'walking without support' for both groups. In this case, MZ twins were delayed compared with DZ pairs. If this

delay is based on the intrauterine growth retardation of MZ twins, the effects may well be observed in the earlier stage of gross-motor development milestones. Therefore, the close relationship of MZ pairs, which gradually becomes obvious after birth, may be one of the risks of not only language development but also motor development in attaining the ability to walk. Further study is needed.

The effect of parity on 'sitting without support,' 'pulling up to a standing position,' and 'walking without support' was observed for both groups. In this case, twins of multiparity lagged slightly behind twins of primiparity. According to Goetghebuer et al. (6), a trend towards slower development in families with more than one sibling was found, suggesting that development could be related to the availability of the mother. In addition, the care given to families with twins may have an impact on development, though the present study did not consider this point. In a family with twins, the availability of the mother is restricted even without other siblings.

The effect of birth injury, method of delivery, and health condition at birth are very complicated regarding twin delivery. Health condition at birth and method of delivery were strongly associated in both groups. Namely, Caesarian section was associated with unhealthy condition at birth. Nevertheless, the effect of these variables on motor development was opposite, as shown in Table 4. One possible reason was that Caesarian section in twin delivery was more often preferred in light of safe delivery and not necessarily associated with risk to the neonates. Moreover, the numbers of birth injuries were slightly 'positively' correlated with birthweight or gestational age. The reason is unclear. Therefore, the effect of birth injury was not necessarily observed clearly. The present study dealt with birth injury as numbers from the statistical point of view, and the effect of each type of birth injury was not considered. More than one type of birth injury was observed in about 40% of the school applicants group and 60% of the maternal associations group with various severities. At the population level, this effect was weakened, confounded with many other variables. At the case study level, neonates with severe birth injury may well be delayed in total development, including motor development. Moreover, the delay observed in twins could be due to antenatal factors that do not affect birthweight or length, such as the mother being undernourished, reduced space in utero, or lower mobility of the mother during pregnancy (6). These total perinatal conditions of mothers should be analyzed carefully.

The difference in development between singletons and twins could also be due to postnatal environment. It has been reported that patterns of parent-child interaction and communication have environmentally mediated effects on language and account for twin-singleton differences in language development (23). The effect of parent-child interaction and communication on motor development was also suggested (6). For example, maternal verbal stimulation has been shown to be a significant predictor of motor development in infants (24). The present study gathered no data on mother-to-twin interaction in terms of motor development.

Moreover, maternal mental condition or stress is thought to affect the motor development of children. Maternal depression is reported to be significantly associated with poorer infant

mental and motor development at one year of age (25). Mothers of premature twins initiated less communication and gave fewer responses towards their offspring than did mothers of singletons (26). For singletons, breast-feeding has been shown to be associated with better development (27). Socioeconomic factors are likely to be important in child development, although studies reported a negligible influence on the attainment of motor development milestones (28). Some of these risk factors are more frequently observed in twin pregnancy and nurturing.

As shown in Table 5, motor development was obviously similar between MZ pairs compared with that between DZ pairs. Mothers of same-sex twins often did not know the correct zygosity of their children (15). Therefore, the similarity between MZ twin pairs, who have identical genetic composition, compared with that between DZ twin pairs, whose genetic similarity is only 50%, suggested a role of genetic background in motor development, even taking into consideration the accuracy of data. The genetic contribution to the attainment of motor development milestones has already been reported (6, 7), though the results with regard to heritability were inconsistent.

The development of twins is influenced by all the above complicated environmental and genetic factors, some of which were different from those for singletons. Uncovering the effects of these factors one by one is the next step.

Twins showed a tendency to lag behind singletons in terms of motor development in the present study, as many studies have already pointed out. Nevertheless, as twins mature, their development tends to catch up with that of singletons, as shown in Fig. 1. Moreover, twins show considerable within-pair differences in motor development, particularly in the case of DZ pairs. Thus it is reasonable to consider the genetic difference of individuals. Professional medical advisors overseeing growth and development of twins should advise the parents of twins based on these objective findings, not simply on their intuition or experiences.

The present data was limited to normally developed twins for data collection, and did not show when twins fully catch up with singletons or the prevalence of clinically significant difficulties in twins. A longitudinal follow-up study of total growth and development of twins is essential.

In conclusion, the results of the present study indicated, using the largest twin database available, that motor development of twins in some respects differs from that of singletons and that twins showed various differences of development within pairs. These findings will be useful for devising refined maternal and child health care for families with multiple-birth children.

Acknowledgements

The author gratefully acknowledges the help of Toshimi Ooma in the analysis of the data, the help of Dr. Noriko Kato of National Institute of Public Health for useful suggestion and information, and the help of Norio Yamanaka, the president of Bindeballe Publishing Company, Tsutomu Onodera, the president of Twins and Super Twins Mailing List Japan, Miyuki Sano, the president of the maternal association Twin Dream, Dr. Yukiko Amau, the president of The Japanese Association of

Twins' Mothers, and the many mothers of twins who helped to collect data. This work was supported in part by a Grant-in-Aid

from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

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