The Tokyo Twin Cohort Project: Overview and Initial Findings

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The Tokyo Twin Cohort Project (ToTCoP) is a large-scale longitudinal study of 5 years based on 1619 pairs of infant twins reared together. The purpose of the study is to construct a population-based twin registry in Japan and to investigate human growth and development and twin themselves. It covers behavioral, neurological, physical and environmental variables measured by questionnaire, home visiting and brain imaging technology. The full registry contains over 47,000 multiple births collected from the Basic Resident Register, and the targeted population is 3070 probable twins of 0 to 2 years old. Preliminary analysis of the entry questionnaire data showed no serious sampling biases. Descriptive statistics of parental characteristics (parental age, gestation age, parity and placentation, maternal weight, parenting stress) and children's characteristics (body size at birth, 4 and 10 months of age, milk consumption, and sleeping and social behavior) and their correlations, genetic and environmental contributions and correlations are reported.

The Tokyo Twin Cohort Project (ToTCoP) is a brand-new twin study established late 2004 to construct a population-based twin registry in Japan and to investigate human growth and development and twins themselves. This project is conducted under the national scientific program The Brain Science and Education (directed by Hideaki Koizumi) granted by the Japan Science and Technology Agency (JST), Research Institute of Science and Technology for Society (RISTEX). The ToTCoP is characterized as: (a) a large-scale longitudinal study of 5 years with over 1600 pairs of infant twins, (b) population-based resident register, (c) an age-homogeneous birth cohort (born in 2004 and 2005), and (d) a comprehensive developmental study which covers behavioral, neurological, physical and environmental variables measured by questionnaire, home visiting and brain imaging technology (NIRS, EEG/ERP).

Its overall purpose, procedure of recruiting participants, research plans and initial findings obtained in the first phase of this project are presented below.

Purpose of ToTCoP

This project aims to obtain relevant information 'of twins', 'by twins', and 'for twins'. The information 'of twins' is data collected on basic twin statistics such as the growth curves of body sizes, the prevalence of common diseases, and so forth. As this project is the largest twin study ever conducted in Japan for this age group, it will provide a 'gold standard' of traits for Japanese twins currently and enable comparison with the corresponding measures in other countries. Since some of the measures have already had their nontwin references reported in the literature, it is also possible to compare them with the results of singletons. 'By twins' refers to quantitative and behavioral genetic approaches of the classical twin method. Behavioral genetic theory and its methodology provide powerful frameworks for the investigation of genetic, environmental and their interactional contributions to quantitative traits and their developmental trends. As the ToTCoP is to be a comprehensive longitudinal twin study, it presents enormous possibilities to provide answer to many testable questions. The 'for twin' information leads to evidence-based support for nursing, dieting and educating infant twins by presenting relevant information about the causes of parenting stress and environmental effects on infant growth and development.

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Targeted population

As the name of this project indicates, the target population of ToTCoP is twins living in the Tokyo area which covers the Tokyo Metropolis and its three neighboring prefectures (Kanagawa, Chiba, and Saitama). There are 252 municipalities in this area, and the expected number of twin maternities is estimated to be 3500 pairs per year. The age of the targeted twins for this project is 0 to 2 years old at the time of entry.

Recruitment

Although the history of twin research is quite extensive in Japan (Ando, 1993), no population-based twin registry has been established as yet as the list of individual twin residential addresses, based upon complete birth records, is not accessible to researchers due to legal regulations. Japanese twin researchers have thus collected data mainly from name lists from social organizations for twin families or from special schools for twins. These datasets could be contaminated by sampling bias in terms of socioeconomic status or academic level, for example, and it has been difficult to evaluate the source and extent of these biases. A possibility for constructing a population-based twin registry exists in using the Basic Resident Register (BRR; nationwide census), which contains individual names, sex, mailing addresses, and dates of birth for all residents. Anyone with legitimate and plausible reasons can access these databases at city halls of municipalities. It is highly probable that individuals who share the same address and date of birth are members of a multiple birth set.

There are four serious practical problems, however, in constructing a 'complete' population-based twin registry from BRR data. The first and most serious problem is the cost. It costs about $400,000 USD to obtain candidate data from the databases of the entire targeted regions. The second is that the residential data are provided not electronically but in printed form. Therefore, the data of probable twins need to be identified by human inspection and manually transcribed. The third is the recent change in legal regulation regarding privacy protection policy, which occurred at the start of this project. The *Private Information Protection Law* has been more strictly applied since April 2005, and some municipalities have changed the conditions of access to the BRR. In some cases, access to the data was denied in the first instance, and in other cases, the printed order of the list was randomized in order to hide the family information making it impossible to identify twins. The last is that, as newborn children do not appear on the registry in the first 2 or 3 months after birth, it is impossible to attain a perfectly 'complete' sampling. As the records are usually renewed every 3, 4, or even 6 months, the relevant data after renewal are not obtained.

The first problem has been resolved by sufficient research funding by the JST. The second problem has been also resolved by this funding, and by the recruitment of excellent staff who identify and transcribe the individual residential data of probable twins. The third and fourth problems cannot be resolved. We were obliged to skip some municipalities as a result of the regulation. Selected staff visited the city halls of all the remaining municipalities between November 2004 and March 2006. All probable multiple birth data

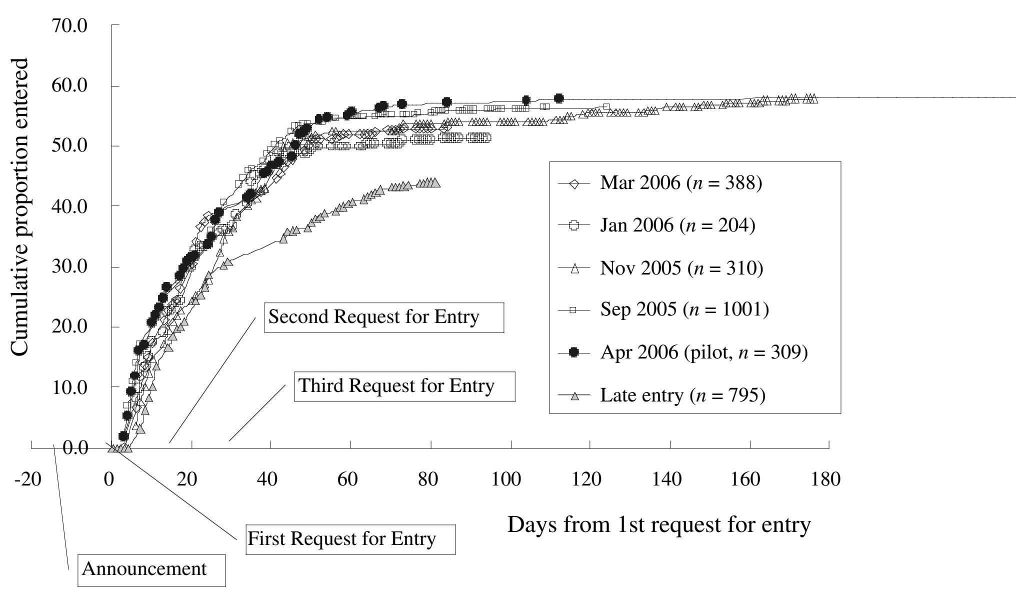

Figure 1

Response to request for participation.

Table 1

Number of Multiple Births in the Registry

Birth Year	Twins					Triplets						Quadruplets					
	MM	FF	MF[a]	UK[b]	Total	MMM	MFF	MMF	FFF	UK[b]	Total	MMMM	MMFF	MFFF MMMF	FFFF	UK[b]	Total
2004–2006	1202	1184	1046	1	3433	12	16	15	14	2	59						0
2000–2003	3144	3140	2427		8711	32	49	51	29		161		1	1			2
1990–1999	6386	6412	3836	2	16,636	70	108	108	63		349	2	3	6	1	6	18
1980–1989	4592	4891	1959		11,442	29	16	23	40		108		2	1	1	2	6
1970–1979	1918	1875	782		4575	1	6	4	10		21						0
1960–1969	465	349	220		1034			1			1						0
1950–1959	142	84	104		330						0						0
1940–1949	68	57	152		277						0						0
–1939	19	40	121		180						0						0
Unknown				17	17												
Total	17,936	18,032	10,647	20	46,635	144	195	202	156	2	699	2	6	8	2	8	26

Note: [a] probably including couples who have the same date of birth in older cohorts; [b] unknown.

were identified and transcribed, that is, individuals who had the same addresses and dates of birth (not only twins but also triplets and quadruplets of all ages). The information was available for 218 out of 252 municipalities. The total number of multiple births extracted from the BRR (twins, triplets, quadruplets) is shown in Table 1.

Findings at recruiting stage

We conducted a pilot study from mid-March, 2005, to establish the procedure for participant recruitment. The outline of the pilot study has been described elsewhere (Ando et al., 2006), and 178 pairs of the recruited twins at the ages of 9 to 14 months (58% out of 309 pairs) did not indicate any serious sampling biases in terms of variables such as parental age, family size, and residential region. As the population-based recruitment of twin families was unprecedented in Japan, some experiences during the pilot study merited more detailed description. The first step was to mail a flier introducing the project 2 weeks prior to the request for participation in the project. When the entry questionnaire, which included questions on birth/current weight, questions for zygosity diagnosis, milk intake, sleep regularities, and so forth, was not returned, second and third requests were made by mail within 2-week intervals. As an incentive for parent participation, we attached cards with hints for rearing twin children, and sent a magnet sheet, as a token of appreciation. Figure 1 shows the cumulative proportion of responders to the request for participation: more than 50% responded within 50 days of the first request, and 58% had agreed to participate 4 months after the first request. About 8 months after the first approach, a re-approach was made with a fourth request for participation for the nonresponders (n = 131), and a further five pairs participated (4%), resulting in a final participation rate of 59%. Further gain by the fourth request was limited.

This procedure for participant recruitment was repeated in the main study and, as Figure 1 shows, the response curves were mostly reproduced from the pilot study, for the four waves from September 2005 to March 2006. It is worth noting that the response rate was significantly lower for another group (noted as 'late entry' in the figure) consisting of twins of the same age as the pilot group, but that had not been transcribed from the BRR at the time of the pilot study. This group was thus first approached at an age 8 months older than the pilot group, namely 17 to 22 months of age. The reason of this difference in response is not clear, but the burden of rearing children after they have started walking may have inhibited the willingness of participation in these parents.

The entry questionnaire has been delivered to 3070 applicants and 1619 families have registered so far. Although a 60% level of participation has been attained in the whole population, it is essential for the longitudinal cohort study to minimize the attrition of participants in future investigations. In the pilot study, a booklet of full-scale questionnaires was mailed to the population, and about 80% of the families returned them, which corresponds to about 45% of the registered population of mothers. A series of questionnaires are currently being designed for the main study and will be administered at the ages of 9, 12, 15, 18, 24+, 36, 42, 48, and 54 months. Efforts to raise participation and to reduce attrition are ongoing.

Research Plan

This project consists of three major data sources:

1. Questionnaire: the first entry questionnaire sheet and nine age-specific questionnaire booklets administered at 9, 12, 15, 18, 24+, 36, 42, 48, and 54 months. The contents of each month-specific booklet are shown in Table 2.
2. Home visiting: home visiting planned for a subgroup of the participants at the ages of 12, 18, 24, 36 and 48 months. In addition to the observation of mother–twins' play, the following tasks are planned: Bayley Infant Scales of Development (Bayley, 1993) at 12, 18 and 24 months of age, Early Social Communication Scales (Mundy et al., 2003) at 12 and 18 months of age, Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983), Picture Vocabulary Test (Ueno et al., 1978), and other language acquisition tasks (Byrne et al., 2002) at 42 and 54 months of age.
3. Brain imaging study: near-infrared spectroscopy measurement (optical topography or NIRS) of language lateralization and social cognition; mismatch negativity, a type of event-related potentials, under the presentation of speech phoneme.

Initial Findings

The first entry phase was almost completed by March 2006 with 1619 pairs returning entry questionnaire

Table 2

Timeline of Investigation Tools in Questionnaires

	Months								
	9 months	12 months	15 months	18 months	24–30 months	36 months	42 months	48 months	54 months
Children's characteristics									
Body sizes	x	x	x	x	x	x		x	
Stressful life events	x	x	x		x	x		x	
Zygosity			x		x	x			
Laterality	x	x	x		x	x			x
Motor development	DenverII				DenverII				
Temperament		IBQ-R							
		R-ITQ			ECBQ		CBQ		PTCI
Autisitic symptoms	M-CHAT		Yale	M-CHAT	Yale				
Social behavior			Screener		Screener				
Sleeping behavior			BISQ		BISQ MEQ		BISQ	MEQ	
Problem behavior						SDQ		SDQ	
Nutrition	x	CFQ		x			x		
Parenting behavior/environment									
Attachment	MAI		MAI						
Cultural/educational environment				x			x		x
Parental behavior	x		x				x		x
Home environment	EES			EES					
Twin situation	x		x		x			x	
Parening stress									
Depressive symptom		SDS		SDS		SDS		SDS	
Parental stress	PSI		PSI						
Social support	x	x	x		x	x		x	

Note: Bayley (Bayley Scales of Infant Development; Bayley, 1993); BISQ (Brief Infant Sleep Questionnaire; Sadeh, 2004); CBQ (Children's Behavior Questionnaire; Ahadi et al., 1993), CDI (MacArthur Communicative Developmental Inventories; Fenson et al., 1993); CFQ (Child Feeding Questionnaire; Birsh, 2001), Denver II (Frankenburg et al., 1992); ECBQ (Early Childhood Behavior Questionnaire; Putnum et al., 2002), EES (Evaluation of Environmental Stimulation; Anme, 1997); ESCS (Early Social Communication Scales; Mundy et al., 2003); MAI (Maternal Attachment Inventory; Müller, 1994); IBQ-R (Infant Behavior Questionnaire-Revised; Gartstein & Rothbart, 2003; Nakagawa & Sukigara, 2005); MEQ (Morningness-Eveningness Questionnaire; Horne & Ostberg, 1976), M-CHAT(Modified Checklist for Autism in Toddlers; Baron-Cohen et al., 1992); PSI (Parenting Stress Inventory; Abidin et al., 1995), PTCI (Preschool Temperament and Character Inventory; Constantino et al., 2002); SDQ (Strength and Difficulty Questionnaire; Goodman, 1999), SDS (Self-Rated Depression Scale; Zung, 1965).

Table 3

Descriptive Statistics of Parental and Children's Variables for Sex/Zygosity Groups

	MZM			MZF			DZM			DZF			DZOS						Total[a]		
	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*
Parental characteristics																					
Paternal age	33.8	5.5	216	34.1	5.3	208	34.8	4.9	281	34.8	5.1	245	35.5	5.0	487				34.7	5.2	1530
Maternal age	31.3	4.9	222	31.5	4.6	210	32.9	4.0	281	32.8	4.2	245	33.1	3.9	488				32.5	4.3	1540
Placentation	1.23	0.42	150	1.23	0.42	134	1.79	0.41	201	1.85	0.35	191	1.96	0.19	327				1.68	0.46	1062
Parity	0.60	0.73	205	0.62	0.79	194	0.38	0.62	264	0.36	0.58	239	0.41	0.65	453				0.47	0.69	1441
Gestation	36.0	1.9	228	36.0	1.8	218	36.1	2.0	295	35.8	2.4	256	36.1	2.2	506				36.0	2.1	1606
Maternal weight	52.0	7.2	203	51.3	7.9	190	52.5	7.8	253	51.7	7.6	238	52.4	7.7	438				52.0	7.6	1406
Parenting stress	3.55	1.07	203	3.41	1.00	193	3.50	1.01	261	3.35	0.99	232	3.58	1.74	448				3.50	1.29	1420
Children's characteristics														(Boys)			(Girls)				
At birth																					
WT (weight)	2290.6	389.2	462	2206.2	392.4	438	2332.3	430.9	590	2171.4	450.7	510	2306.6	457.0	509	2232.6	416.8	510	2259.3	428.7	3019
HT (height)	45.5	2.6	443	44.8	2.9	419	45.7	2.8	568	44.7	3.5	490	45.5	3.3	492	45.0	3.0	494	45.2	3.0	2906
CC (chest)	28.9	2.2	439	28.7	2.4	415	29.1	2.5	561	28.4	2.5	483	29.0	2.6	488	28.7	2.4	493	28.8	2.5	2879
HC (head)	31.7	1.9	438	31.2	1.9	417	31.9	2.0	562	31.5	2.0	484	31.8	2.2	488	31.4	2.2	492	31.6	2.1	2881
At 4 months																					
WT	6479.5	903.3	434	5943.1	876.1	414	6359.8	1047.5	558	5848.4	1072.5	488	6323.0	1061.7	485	5941.4	944.1	485	6153.5	1021.6	2864
HT	61.0	3.2	429	59.4	3.3	414	61.0	3.4	558	59.1	3.9	484	60.7	3.9	481	59.4	3.3	480	60.1	3.6	2846
CC	41.2	2.5	292	39.9	2.5	273	40.9	2.6	385	39.6	3.0	372	40.7	2.8	322	39.9	2.5	324	40.4	2.7	1968
HC	41.0	1.5	345	40.0	1.4	331	41.0	1.6	477	39.9	1.9	429	41.0	1.8	388	40.0	1.7	386	40.5	1.7	2356
At 10 months																					
WT	8825.8	1045.8	302	8026.7	938.9	248	8615.1	1063.0	375	8077.5	992.4	312	8629.4	988.1	315	8231.4	912.8	317	8418.7	1037.3	1869
HT	71.3	2.9	298	69.1	2.7	246	71.1	2.9	371	69.3	2.8	304	70.9	3.3	314	69.7	2.7	315	70.3	3.0	1848
CC	45.3	2.1	219	43.8	2.1	178	45.1	2.1	284	43.9	1.9	252	44.9	2.1	241	44.1	1.9	241	44.6	2.1	1415
HC	45.3	1.4	243	44.3	1.2	194	45.4	1.5	319	44.2	1.4	274	45.4	1.6	263	44.5	1.6	265	44.9	1.6	1558
Milk	4.26	0.79	460	4.23	0.78	434	4.15	0.87	592	4.11	0.91	507	4.22	0.84	504	4.18	0.83	506	4.19	0.84	3003
Sleeping																					
Time (min)	30.82	21.70	424	33.49	23.75	416	30.21	21.74	552	30.86	22.48	479	31.94	22.44	483	31.71	20.58	481	31.44	22.10	2835
Rhythmicity	3.88	0.79	463	3.83	0.86	440	3.90	0.81	593	3.92	0.72	514	3.86	0.81	508	3.87	0.80	510	3.88	0.80	3028
M-CHAT total	1.88	1.17	439	1.83	1.18	421	1.74	1.19	564	1.78	1.23	490	1.87	1.16	483	1.96	1.16	486	1.84	1.18	2883
Mimic	0.69	0.46	445	0.73	0.45	424	0.68	0.47	568	0.70	0.46	493	0.70	0.46	491	0.74	0.44	493	0.71	0.46	2914
Point gazing	0.45	0.50	444	0.44	0.50	426	0.41	0.49	571	0.44	0.50	495	0.45	0.50	491	0.49	0.50	493	0.45	0.50	2920
Joint attention	0.74	0.44	442	0.66	0.48	422	0.64	0.48	569	0.63	0.48	492	0.71	0.46	485	0.73	0.45	488	0.68	0.47	2898

Note: [a]Including 'zygosity unknown' individuals.

Table 4

Partial Correlation Between Parental and Children's Characteristics Controlled by Sex and Zygosity

	Paternal age	Maternal age	Placentation	Parity	Gestation	Age in days	Parenting stress
At birth							
Weight (WT)	.04	*.08*	.04	.12	***.74***	—	.05
Height (HT)	.05	*.09*	.06	.09	***.73***	—	***.08***
Chest (CC)	.03	.07	.05	.11	***.70***	—	.05
Head (HC)	.05	*.09*	.07	.07	***.68***	—	.07
At 4 months							
Weight (WT)	–.03	.03	.05	.02	***.50***	—	***.12***
Height (HT)	.01	*.08*	.07	.05	***.57***	—	***.11***
Chest (CC)	.00	.03	.04	–.01	***.47***	—	***.12***
Head (HC)	–.03	.01	.03	.03	***.45***	—	***.08***
At 10 months							
Weight (WT)	–.04	.03	.04	–.04	***.20***	—	***.11***
Height (HT)	.02	*.12*	.03	–.04	***.23***	—	***.12***
Chest (CC)	.00	.02	.01	–.01	***.16***	—	.06
Head (HC)	–.01	.03	–.01	–.04	.13	—	***.08***
Milk	.04	.03	.04	.06	***.10***	.02	.00
Sleeping							
Time (to fall asleep)	–.01	.03	–.03	*–.09*	–.01	–.07	.07
Rhythmicity	.04	.04	–.07	.04	.06	.09	***–.16***
M-CHAT	*–.08*	–.06	*.11*	.04	***.21***	***.57***	.07
Mimic	–.03	–.02	*.08*	.07	***.22***	***.30***	.06
Point gazing	*–.08*	*–.09*	.10	–.02	***.16***	***.61***	.06
Joint attention	–.06	–.01	.07	.05	***.12***	***.31***	.05

Note: Italic = $p < .05$; bold italic = $p < .01$.

sheets. The response rate was 52.7%. Major items of the entry questionnaire are the followings.

- Zygosity Diagnosis

  6-item questionnaire based upon parental cognition of twins' physical similarities and experiences of being mistaken for each other. (Ooki & Asaka, 2004).

- Parental characteristics

  (a) pregnancy: number of placenta, parity, gestation age, mother and fathers' ages at the birth of twins

  (b) mother's weight before pregnancy

  (c) self-reported parenting stress (5-point scale).

- Children's characteristics

  (a) body sizes: weight (WT), height (HT), chest circumference (CC) and head circumference (HC) at birth, 3 to 4 and 9 to 10 months of age. The parents recorded these figures in a health notebook which was measured in the official medical examination by medical staff.

  (b) Dietary: milk consumption (MILK) measured in 5-point Likert scale

  (c) Sleeping behavior: rhythmicity and time required to fall asleep.

  (d) Socialization: total score of three items from M-CHAT — mimic (*Does your child imitate you?*), point gazing (*Does your child ever use his/her index finger to point, to indicate interest in something?*) and joint attention (*If you point at a toy across the room, does your child look at it?*; Baron-Cohen et. al.,1992; each item is scored 1 for *yes*, 0 for *no*)

Zygosity and Sex

The weighted sum scores of zygosity diagnosis items (Ooki & Asaka, 2004) distinguished the estimated zygosity of the same-sex twins in two ways: stringent and loose. In a 'stringent' way, twin pairs who had borderline scores were categorized as 'unknown' whereas, in a 'loose' way, they were tentatively categorized as monozygotic (MZ) or dizygotic (DZ) based on a certain cut-off point. The numbers of pairs were 232/262 (stringent/loose) MZ boys (MZM), 220/252 MZ girls (MZF), 297/313 DZ boys (DZM), 257/278 DZ girls (DZF), 510 opposite-sex (DZOS) and 103/4 zygosity unknown pairs.

Descriptive Statistics of Parental and Children's Characteristics

Table 3 shows the means, standard deviations and sample sizes of parental and children's information in terms of sex and zygosity. For parental information,

Table 5

Genetic, Shared Environmental and Nonshared Environmental Contributions (Diagonal) and Correlation (Off Diagonal) for Boys (Lower) and Girls (Upper)

a) Genetic		Birth				4 Months				10 Months					Sleep		
		WT	HT	CC	HC	WT	HT	CC	HC	WT	HT	CC	HC	Milk	Time	Rhythmicity	M-CHAT
Birth Weight (WT)	***.24***	***.28***	.60	.93	.89	.49	.55	.25	.33	.52	.45	.24	.09	.12	.04	–.01	–.05
Height (HT)	.67	***.31***	***.12***	.75	.58	.54	.74	.35	.34	.62	.72	.23	.09	.13	.05	–.02	–.06
Chest (CC)	.93	.83	***.13***	***.13***	.87	.47	.65	.32	.46	.53	.54	.51	.18	.28	.25	–.07	–.19
Head (HC)	.81	.71	.81	***.21***	***.13***	.50	.65	.19	.53	.56	.60	.09	.56	.35	.20	–.18	–.35
4 Month Weight (WT)	.50	.54	.57	.46	***.34***	***.38***	.77	.87	.75	.99	.75	.60	.74	.41	–.14	.09	.13
Height (HT)	.58	.75	.67	.51	.86	***.21***	***.23***	.62	.69	.77	.97	.55	.47	.29	.03	.05	–.16
Chest (CC)	.18	.13	.28	.12	.84	.53	***.33***	***.22***	.71	.81	.54	.68	.65	.40	–.01	–.03	.08
Head (HC)	.47	.40	.53	.62	.66	.42	.48	***.23***	***.15***	.77	.67	.68	.94	.62	–.05	–.14	–.35
10 Month Weight (WT)	.46	.57	.58	.40	.92	.72	.80	.74	***.54***	***.64***	.77	.88	.68	.42	–.02	.00	.21
Height (HT)	.52	.81	.70	.39	.77	.93	.48	.40	.74	***.39***	***.40***	.46	.55	.34	.04	.00	.06
Chest (CC)	.26	.32	.59	.38	.83	.56	.79	.48	.93	.63	***.59***	***.56***	.44	.36	–.30	.12	.77
Head (HC)	.21	.23	.33	.54	.49	.46	.38	.83	.66	.53	.41	***.61***	***.44***	.47	–.11	–.23	.49
Milk	.20	.03	.13	.27	.45	.25	.43	.23	.35	.20	.24	.23	***.38***	***.37***	.06	–.07	.31
Sleep time	.19	.06	.31	.32	.05	.05	.02	–.08	–.05	.00	.12	–.11	–.04	***.30***	***.32***	–.37	.25
Rhythmicity	.04	.12	.02	–.12	–.13	–.04	–.13	–.11	–.07	.00	–.08	–.08	.14	–.41	***.18***	***.24***	.00
M-CHAT	.31	.41	.40	.03	.33	.41	.18	.09	.56	.51	.68	.19	.12	.40	–.04	***.08***	***.04***
	WT	HT	CC	HC	WT	HT	CC	HC	WT	HT	CC	HC	Milk	Time	Rhythmicity	M-CHAT	
		Birth				4 Months				10 Months				Sleep			

b) Shared environment		Birth				4 Months				10 Months					Sleep		
		WT	HT	CC	HC	WT	HT	CC	HC	WT	HT	CC	HC	Milk	Time	Rhythmicity	M-CHAT
Birth Weight (WT)	***.43***	***.49***	1.00	.79	.68	.51	.60	.52	.42	.09	.30	.39	.17	.06	–.06	.02	.14
Height (HT)	.90	***.42***	***.59***	.79	.68	.51	.60	.50	.42	.07	.30	.37	.06	.07	.03	–.01	.15
Chest (CC)	.75	.68	***.51***	***.52***	.20	.44	.48	.52	.34	.11	.25	.37	.10	.08	–.06	.00	.14
Head (HC)	.59	.49	.06	***.49***	***.51***	.37	.39	.43	.45	.01	.11	.29	.33	–.01	–.09	.07	.05
4 Month Weight (WT)	.51	.38	.39	.34	***.54***	***.48***	.88	.91	.80	.35	.37	.52	.08	.11	.10	.00	.06
Height (HT)	.57	.51	.39	.39	.86	***.69***	***.66***	.74	.72	.22	.39	.27	.02	.01	.03	.00	.09
Chest (CC)	.53	.45	.45	.47	.91	.78	***.51***	***.51***	.70	.48	.40	.55	–.02	.07	.02	.04	.03
Head (HC)	.42	.31	.33	.46	.85	.84	.83	***.57***	***.65***	.23	.18	.24	.43	–.01	–.05	.09	.12
10 Month Weight (WT)	.32	.24	.21	.11	.46	.41	.48	.35	***.37***	***.28***	.61	.29	.40	.04	.06	.00	–.09
Height (HT)	.32	.27	.21	.16	.39	.47	.43	.37	.74	***.51***	***.44***	.61	.18	.04	.10	–.09	.04
Chest (CC)	.26	.31	.15	.23	.19	.26	.35	.41	.35	.71	***.18***	***.24***	.41	.05	.32	–.03	–.19
Head (HC)	.25	.24	.08	.40	.30	.15	.24	.44	.44	.49	.81	***.19***	***.30***	–.16	.20	.09	–.08
	WT	HT	CC	HC	WT	HT	CC	HC	WT	HT	CC	HC	Milk	Time	Rhythmicity	M-CHAT	
		Birth				4 Months				10 Months				Sleep			

Table 5 (continued)

Genetic, Shared Environmental and Nonshared Environmental Contributions (Diagonal) and Correlation (Off Diagonal) for Boys (Lower) and Girls (Upper)

b) Shared environment		Birth				4 Months				10 Months					Sleep		
		WT	HT	CC	HC	WT	HT	CC	HC	WT	HT	CC	HC	Milk	Time	Rhythmicity	M-CHAT
Milk	.03	.04	.04	–.01	.08	.10	.07	.12	.20	.14	.19	.16	***.52***	***.55***	.03	–.10	.00
Sleep time	–.09	–.02	–.05	–.12	–.05	–.07	.03	–.06	–.05	–.02	–.09	.06	–.18	***.63***	***.60***	–.29	–.19
Rhythmicity	–.02	–.03	–.04	.05	.02	–.01	.03	.03	–.01	–.05	.00	.06	.12	–.24	***.77***	***.72***	.11
M-CHAT	.11	.07	.10	.04	.09	.09	.05	.10	–.07	–.04	–.16	–.11	–.09	–.17	.12	***.81***	***.87***
	WT	HT	CC	HC	WT	HT	CC	HC	WT	HT	CC	HC	Milk	Time	Rhythmicity	M-CHAT	
		Birth				4 Months				10 Months				Sleep			

b) Nonshared environment		Birth				4 Months				10 Months					Sleep		
		WT	HT	CC	HC	WT	HT	CC	HC	WT	HT	CC	HC	Milk	Time	Rhythmicity	M-CHAT
Birth Weight (WT)	***.31***	***.26***	.65	.70	.52	.76	.60	.55	.34	.58	.35	.32	.28	.14	–.05	.04	.02
Height (HT)	.74	***.26***	***.32***	.45	.36	.57	.49	.38	.27	.51	.29	.38	.28	.10	–.07	.06	–.07
Chest (CC)	.80	.63	***.34***	***.36***	.45	.57	.43	.44	.29	.36	.21	.26	.19	.07	–.02	.03	.07
Head (HC)	.67	.55	.50	***.30***	***.38***	.46	.30	.43	.41	.30	.08	.41	.17	.02	–.07	.02	.06
4 Month Weight (WT)	.82	.61	.64	.55	***.12***	***.12***	.65	.72	.48	.69	.40	.43	.27	.12	.04	.02	–.04
Height (HT)	.65	.45	.52	.41	.49	***.11***	***.10***	.51	.34	.44	.35	.20	.20	.25	–.09	–.02	–.01
Chest (CC)	.62	.53	.64	.58	.69	.47	***.16***	***.25***	.35	.64	.43	.46	.11	.08	.01	.01	–.01
Head (HC)	.30	.25	.27	.39	.42	.32	.23	***.21***	***.21***	.42	.20	.25	.49	–.01	.02	.05	.00
10 Month Weight (WT)	.70	.52	.53	.44	.83	.53	.65	.43	***.11***	***.09***	.54	.55	.41	.16	.01	.14	.05
Height (HT)	.50	.38	.37	.36	.54	.41	.54	.33	.67	***.14***	***.15***	.38	.36	.08	–.12	.16	–.01
Chest (CC)	.43	.34	.34	.29	.34	.25	.33	.16	.55	.33	***.23***	***.20***	.21	.01	.02	.03	–.11
Head (HC)	.39	.30	.26	.34	.43	.25	.34	.42	.50	.33	.36	***.20***	***.26***	.02	–.03	.14	–.05
Milk	–.01	.03	.03	–.03	–.03	.00	–.03	.10	.15	.12	.17	.11	***.09***	***.07***	.27	–.05	–.05
Sleep time	–.14	–.07	–.14	–.12	–.17	–.06	–.06	–.14	–.04	–.03	–.07	–.09	–.01	***.07***	***.08***	–.14	.04
Rhythmicity	.02	.00	.02	.06	.13	.08	.20	.13	.17	.17	.14	.11	.01	–.35	***.04***	***.04***	.04
M-CHAT	.09	–.02	.07	.08	.06	.04	.08	.05	.03	.16	–.24	.00	–.05	–.22	.02	***.10***	***.09***
	WT	HT	CC	HC	WT	HT	CC	HC	WT	HT	CC	HC	Milk	Time	Rhythmicity	M-CHAT	
		Birth				4 Months				10 Months				Sleep			

gestational age was available for almost all the participants (N = 1606), whereas the number of placenta was reported only by about two thirds of the participants as there were many parents who were not informed of this information by doctors or nurses. For the twin children's characteristics, height and weight at birth were available from over 95% of twin individuals. Data on twins' height and weight at birth were available for over 95% as medical staff routinely measure twins' height and weight at the time of birth. However, twins' chest and head circumferences at time points other than at birth were less reported: over 80% of those who reported twins' birthweight offered twins' head circumference data, and 82% at age 3 or 4 months and 83%, at age 9 or 10 months. Only 69% of those who reported twins' birthweight provided twins' chest circumference data at age 3 or 4 months, and 76%, at age 9 or 10 months. About 40% of the participating parents of twins did not report the body size measures when twins were 9 or 10 month old as their twins were younger than this when they returned the entry questionnaire.

Table 4 shows correlation matrices between parental and children's characteristics. The correlations between gestation age and twins' height, weight, and chest and head circumferences were substantial at birth ($r > .68$). However, the correlations become progressively smaller as the twins gets older ($r \approx .5$ at age 4 months, and $r \approx .2$ at age 10 months). Gestational age was also correlated with M-CHAT scores (r = .12–.22, $p < .01$). As the M-CHAT scores are characterized as part of social skills, they were highly correlated with twins' current age in days, estimated by the date of the informed consent signature given by parents. The correlations between parity and twins' height, weight, and chest circumference at birth were small but statistically significant ($p < .05$). The correlation of parity with head circumference at birth, however, did not attain statistical significance. The correlations between parity and twins' height, weight, and chest and head circumferences diminished to 0 at 4 months of age. Correlations between the parental stress variable and the twins' height, weight, and chest and head circumferences were positive, but generally modest (r = .05–.12) at all three time points (i.e., at birth, at 4 months, and at 10 months). Not unexpectedly, higher parental stress was significantly associated with the less regular sleeping time rhythmicity of the twins.

We estimated the relative and absolute contributions of genetic, and shared and nonshared environmental effects on various children's characteristics. Table 5 provides heritability estimates (panel a) and shared and nonshared environmental contributions (panel b and c) for the children's traits on diagonals and their correlations (off diagonals) for boys (lower) and girls (upper). To compute genetic, and shared and nonshared environmental correlations, we applied the Cholesky decomposition model to the twin data. Parameters for the Cholesky decomposition model were estimated using the maximum likelihood estimation procedure in Mx (Neale et al., 1999). Three things presented in the table are particularly noteworthy: the genetic contribution to body size increases as the infant grows, milk consumption correlates with body size more from a genetic than environmental perspective; and although heritability for social behavioral variable M-CHAT was small, it showed substantial genetic correlation with body size.

Future Direction

The initial findings reported here are preliminary and require further in depth analysis. However, they provide plausible results which show the validity of this sample. The ToTCoP should make every effort to encourage participation in order to take advantage of the population-based origins, as well as to obtain as much longitudinal follow-up data as possible for research questions on early human development.

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References

Abidin, R. R. (1995). *Parenting stress index: Professional manual*. Odessa, FL: Psychological Assessment Resources, Inc.

Ahadi, S. A., Rothbart, M. K., & Ye, R. (1993). Children's temperament in the US and China: Similarities and differences. *European Journal of Personality*, *7*, 359–377.

Ando, J. (1993). Twin studies in Japan. *Inquiries into Humans and Societies: Studies in Sociology, Psychology, and Education*, *38*, 9–23.

Ando, J., Nonaka, K., Kato, N., Ooki, S., Nakajima, R., & Hashimoto, E. (2006). A longitudinal study of twins in early childhood (1) (Tokyo Twin Cohort Project: ToTCoP): Outline and evaluation of pilot study [in Japanese with English Abstract]. *Inquiries into Humans and Societies: Studies in Sociology, Psychology, and Education, 31–49*.

Anme, T. (1997). 'Evaluation of Environmental Stimulation (EES)' as predictive method related to decrease of physical 3 years later. *International Disability*, *5*, 435–441.

Baron-Cohen, S., Allen, J., & Gillberg, C. (1992). Can autism be detected at 18 months? The needle, the haystack, and the CHAT. *British Journal of Psychiatry, 161,* 839–843.

Bayley, N. (1993). *Bayley Scales of Infant Development: Administering and scoring manual*. New York: Psychological Corporation.

Birsh, L. L., Fisher, J. O., Grimm-Thomas K, Markey, C. N., Sawyer, R., & Johnson, S. L. (2001). Confirmatory factor analysis of the Child Feeding Questionnaire: A measure of parental attitudes, beliefs and practices about child feeding and obesity proneness. *Appetite, 36,* 201–210.

Byrne, B., Deleland, C., Fieldling-Barnsley, R., Quain, P., Samuelson, S., Hoien, T., Corley, R., DeFries, J. C., Wadsworth, S., Willcutt, E., & Olson, R. K. (2002). Longitudinal twin study of early reading development in three countries: Preliminary results. *Annals of Dyslexia, 52,* 49–73.

Constantino, J. N., Cloninger, C. R., Clarke, A. R., & Hashemi, B. P. T. (2002). Application of the seven-factor model of personality to early childhood. *Psychiatry Research*, *109,* 229–244.

Fenson, L., Dale, P. S., Reznick, J. S., Thal, D., Bates, E., Hartung, J. P., Pethick, S., & Reilly, J. S. (1993). *The MacArthur Communicative Development Inventories: User's guide and technical manual*. San Diego: Singular Publishing Group.

Frankenburg, W. K., Dodds, J., Archer, P., Shapiro, H., & Bresnick, B. (1992). The Denver II: A major revision and restandardization of the Denver Developmental Screening Test. *Pediatrics, 89,* 91–97.

Gartstein, M. A., & Rothbart, M. K. (2003). Studying infant temperament via the Revised Infant Behavior Questionnaire. *Infant Behavior and Development, 26,* 64–86.

Goodman, R. (1999). The extended version of the Strengths and Difficulties Questionnaire as a guide to child psychiatric caseness and consequent burden. *Journal of Child Psychology and Psychiatry*, *40,* 791–801.

Horne, J. A., & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology*, *4,* 97–110.

Kaufman, A. S., & Kaufman, N. L. (1983). *K-ABC interpretative manual*. Circle Pines, MN: American Guidance Service.

Müller, M. E. (1994) A questionnaire to measure mother-to-infant attachment. *Journal of Nursing Measurement, 2*, 129–141.

Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). *A manual for the abridged Early Social Communication Scales (ESCS)*. Coral Gables, FL: University of Miami, Department of Psychology.

Nakagawa, A., & Sukigawa, M. (2005). How are cultural differences in the interpretation of infant behavior reflected in the Japanese Revised Infant Behavior Questionnaire? *Japanese Journal of Educational Psychology*, *53*, 491–503.

Neale, M. C., Boker, S. M., Xie, G., & Maes, H. H. (1999). *Mx: Statistical modeling* (5th ed.). Richmond, VA: Department of Psychiatry.

Ooki, S., & Asaka, A. (2004). Zygosity diagnosis in young twins by questionnaire for twins' mothers and twins' self-reports. *Twin Research*, *7*, 5–12.

Putman, S. P., Jones, L. B., & Rothbart, M. K. (2002). *The Early Childhood Behavior Questionnaire: Development, psychometrics, factor structure, and relations with behavior problems*. Poster presented at the Biennial Meetings of the International Conference on Infant Studies, Toronto, CA.

Sadeh, A. (2004). Findings for an internet sample. A brief screening questionnaire for infant sleep problems: Validation and findings for an internet sample. *Pediatrics*, *13,* 570–577.

Ueno, K., Nadeo, C., & Iinaga, K. (1978). *Picture Vocabulary Test.* Nihon Bunka Kagakusha, Tokyo.

Zung, W. W. K. (1965). A self-rating depression scale. *Archives of Genetic Psychiatry, 12,* 63–70.