Genetic and environmental influences on sleeptalking, half-sleeping, night terrors, and nocturnal enuresis in childhood
—A study of two Japanese twin samples—

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The purpose of this study was to clarify genetic contributions to the childhood behavioral phenomena of sleeptalking, half-sleeping, night terrors, and nocturnal enuresis using the two largest databases of Japanese twins. The subjects were children of members of several maternal associations for multiples, including 765 pairs ranged in age from 3 to 15 years with a mean age of 7.0 years, as well as school applicants, including 1,140 twin pairs 11–12 years of age. All data were gathered by questionnaire. Structural equation modeling showed that the proportion of total phenotypic variance attributable to genetic influences was 88–96% regarding sleeptalking, 62–91% regarding half-sleeping, and 70–91% regarding night terrors, which were higher in the school applicants group than in the maternal associations group. Age and gender difference was suggested to impact nocturnal enuresis. Moreover, co-occurrence of sleeptalking, half-sleeping, and night terrors were attributed partly to common genetic or environmental factors for these three traits.

Key words: twin children, genetic and environmental influences, sleeptalking, half-sleeping, night terrors, nocturnal enuresis

I Introduction

As pointed out by numerous studies, many habitual behaviors during sleep in childhood, for example sleeptalking (Abe and Shimakawa, 1966a; Abe et al., 1984a), nocturnal enuresis (Abe et al., 1967, 1984b; Bakwin, 1971), teeth-grinding (Abe and Shimakawa, 1966a), night terrors (Abe et al., 1993; Kales et al., 1980), sleepwalking (Abe and Shimakawa, 1966b; Abe et al., 1984a; Bakwin, 1970; Kales et al., 1980), are genetically controlled. Many of these studies were performed by classical methods of genetic analysis, for example family studies or twin studies of relatively small sample size. In many twin studies, the concordance rate was used as an index for the similarity of twin pairs; researchers did not use the information from unaffected concordant pairs for calculation. Recently, several studies using more sophisticated statistic analysis, namely, structural equation modeling, have been reported (Butler et al., 2001; Gregory et al., 2004; Hublin et al., 1997, 1998a, 1998b, 1998c, 1999a, 1999b, 2001). These studies were performed using population-based twin registries with several thousands of pairs.

In addition, currently more than 1% of all births are multiples in Japan. Under such circumstances, there is an increasing need to provide appropriate information to parents and nursing staff, including...
information on the behavioral characteristics of multiples. 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 behavioral characteristics. To resolve this situation, it is essential to obtain objective data on behavioral characteristics based on a large sample of Japanese twins.

In the present study the author analyzed four behavior characteristics often seen during sleep in childhood: namely, sleeptalking, half-sleeping (being half-asleep, doughy with sleep, or sleep drunkenness), night terrors, and nocturnal enuresis. These traits are usually, if anything, normal habits in the broad sense, rather than behavioral problems or disorders. The aim of present study was to clarify the prevalence of these habitual behaviors in twins, and the role of genetic and environmental factors in the origin of these traits. Moreover, the genetic and environmental background related to the co-occurrence of these traits was statistically confirmed. Two large-scale samples of normally developed Japanese twins were used in the present study so that results could be compared between different subject groups and to provide more information on the genetic contribution (heritability). Some of these traits have never been analyzed, at least not in a large Asian twin sample.

II Methods

1. Subjects

The present sample consisted of two independent groups of subjects. These databases were constructed for the purpose of maternal and child care of families with multiples and genetic epidemiologic twin family studies. The basic characteristics of the databases are reported in detail elsewhere (Ooki and Asaka, 2005, 2006; Ooki and Yokoyama, 2004).

The first group of subjects consisted of 951 mothers in several associations for the parents of multiples throughout Japan (maternal associations group). Not all of the subjects were analyzed, as the age of twins was too young. The occurrence of behavior traits in the present study is in general age-dependent. The author analyzed only 765 pairs, who were ranged in age from 3 to 15 years (792 males and 738 females, mean age 7.0, standard deviation (SD) 3.4 and median age 6.0) at the time of data collection. Their birth years ranged from 1986 to 2003 (mean 1995, SD 4 years).

The second subjects were a total of 1,140 twin pairs, consisting of 1,065 males and 1,215 females in the sixth grade of primary school, all of whom were applicants to the secondary education school attached to the faculty of education at the University of Tokyo from 1981 through 2005 (school applicants group). At the time of data collection, all the twins were either 11 or 12 years old. Their birth years ranged from 1968 to 1993 (mean 1979, SD 7 years).

2. Zygosity classification

The zygosity of the same–sex twins was determined primarily by a questionnaire (Ooki and Asaka, 2004) that has been used widely in Japan and that, in the present study, was completed by the mothers in maternal associations group, and was completed by the mothers and twins themselves in the school applicants group. The zygosity types were monozygotic (MZ), unclassified (UZ), and dizygotic (DZ), according to a similarity score, which was calculated using five questions regarding physical similarity and confusion of identity between the twins. For the school applicants group, zygosity was diagnosed also by the use of many genetic markers for those twin pairs who
were actually admitted to the school, prior to administration of the zygosity questionnaire.

In the present study, strict criteria of zygosity classification were used to clarify the genetic or environmental factors. When zygosity determination by DNA/genetic markers was regarded as the gold standard, the accuracy of the zygosity questionnaire was 98%, although about 9% of the pairs were unclassified. The accuracy was a trade-off according to the percentage of unclassified pairs.

The zygosity of the 765 pairs of maternal associations group was classified as follows: 348 MZ, consisting of 185 male–male and 163 female–female pairs; 372 DZ, consisting of 104 male–male, 108 female–female, 76 male–female, and 84 female–male pairs; and 45 UZ, consisting of 27 male–male and 18 female–female pairs.

The zygosity of the 1,140 pairs of school applicants group was classified as follows: 734 MZ, consisting of 329 male–male and 405 female–female pairs; 303 DZ, consisting of 91 male–male, 83 female–female, 72 male–female, and 57 female–male pairs; and 103 UZ, consisting of 48 male–male and 55 female–female pairs.

3. Data collection

Data were collected through mailed or hand-delivered questionnaires, which had nearly the same format between the two groups. The questions asked about family structure; obstetric findings on the mothers; the twins’ physical growth, motor, language, and mental development; the twins’ and parents’ medical histories; habitual behaviors and any behavioral problems the twins had had. 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, the author recommended that, in the questionnaire, they should not use incorrect answers merely to complete the questionnaire, but give a blank response.

These questionnaire surveys are now in progress. The response rates of the questionnaire were 100% for the school applicant group and approximately 70% for the maternal association group.

Of these questions, the author analyzed four items regarding habitual behavior during sleep, namely, sleeptalking, half-sleeping, night terrors, and nocturnal enuresis. Mothers were asked to think back over the entire lifetime of their twins, and choose one answer as to the frequency of these items from four categories, “often”, “sometimes”, “never”, or “don’t know”. As to nocturnal enuresis in the school applicants group, “often” and “sometimes” were not differentiated. The term “night terrors” was explained in easily understandable language as a sudden awakening with terror during sleep. No clear definition was given for the other three traits. Therefore, mothers answered questions about sleeptalking, half-sleeping and nocturnal enuresis based on what they think these traits are. One limitation of the questionnaire survey was that strict medical criteria regarding the definition of these items, such as those in DSM, were not used. It would have been difficult to obtain correct answers of events that happened for some subjects about years ago.

4. Statistical methods

Two subject groups were analyzed separately so their results could be compared and to provide more information concerning the genetic contribution. These two groups have differences in birth year range, age at the time of data collection.
and some obstetric characteristics (Ooki and Asaka, 2005) which may affect the genetic contribution to the targeted traits.

Data analyses were performed according to the standard twin study method. The prevalence of four traits was calculated according to sex or zygosity for each group. The effect of sex or zygosity on prevalence was tested using the $\chi^2$ test. These analyses were performed according to the birth order of the twins (first-born and second-born) to avoid the effects of within-pair similarity, which would make the significant difference detectable.

Next, genetic analysis was performed using MZ and DZ pairs with both twins’ complete data on frequency. Twin similarity for ordinal data can be estimated using concordance rate (McGue, 1992; Ooki, 2005a, 2005b, 2005c). In the calculation of concordance rates, the answers need to be summarized in the form of $2 \times 2$ contingency tables. Therefore, “often” and “sometimes” were included in one category. Casewise concordance rates were calculated as $2 \times \text{Conc.} / (2 \times \text{Conc.} + \text{Disconc.})$, where “Conc.” denotes the numbers of affected concordant pairs and “Disconc.” denotes the numbers of discordant pairs. Probandwise concordance rate is equal to the casewise concordance rate, if the ascertainment is complete (McGue, 1992). The difference in the concordance rate between same-sex MZ and DZ pairs was tested using the $\chi^2$ test.

When the number of unaffected twin pairs is known, a more sophisticated model can be used to estimate the contribution of genetic factors to the susceptibility to the target traits (Neale and Cardon, 1992; Ooki, 2005a, 2005b, 2005c). The polygenic multifactorial model assumes that a latent variable called liability to the traits is normally distributed. When a certain threshold of liability is reached, the traits becomes manifest. Both genes and environmental factors are assumed to contribute to the liability. Namely, the combination of many genes with small effects and a multitude of environmental factors cause the disorder to manifest. The correlation of liability was obtained as polychoric correlation (Neale and Cardon, 1992). This correlation of the latent liability was calculated directly from the $2 \times 2$ or $3 \times 3$ tables cross-classifying the affected status of the first and second twin in each twin pair.

The author used structural equation modeling techniques to estimate the variance components and to compare different genetic models by carrying out univariate genetic analysis (Neale and Cardon, 1992; Ooki, 2005a, 2005b, 2005c).

These models postulated four sources of variance in liability to the traits: (1) additive genetic factor (A); (2) non-additive genetic factor (D); (3) shared environmental factor (C); or (4) non-shared environmental factor (E). The proportion of the total variance in liability due to additive and non-additive genetic factors and shared and non-shared environmental factors were termed $a^2$, $d^2$, $c^2$ and $e^2$, respectively, where $a$, $d$, $c$, and $e$ denote each path coefficient from latent variables (A, D, C, E) to observed variables. The value of ‘A’ denotes narrow-sense heritability, and the value of ‘A’ plus ‘D’ denotes broad-sense heritability. It is possible to fit models based on the five different combinations of these four parameters: ACE, ADE, AE, CE and E. As the parameter E contains a random error factor, this parameter cannot be excluded.

As the data of opposite-sex DZ twin pairs were obtained, homogeneity and heterogeneity of the parameters effects on males and females could be compared directly. The male and female parameters are set to be equal in a homogeneity model (see Fig. 1). This restriction is not set in a heterogeneity model. In other words, each path coefficient, namely ‘a’, ‘d’, ‘c’, and ‘e,’ is set to be equal for males and females in the homogeneity model, whereas the path coefficient could be unequal.
across sex in the heterogeneity model.

The limitation is that the non-additive genetic effect (D) and the common environmental effect (C) cannot be simultaneously modeled with data from twins reared together (Neale and Cardon, 1992). The best fitting model was chosen using the information criteria of Akaike (AIC) (Akaike, 1987), the chi-square value minus twice the degree of freedom, which reflects both the goodness of fit and the parsimony of the model.

Next, phenotypic correlations of these four traits, namely, sleeptalking, half-sleeping, night terrors, and nocturnal enuresis were calculated as polychoric correlations. Test of independence was also performed using Fisher’s exact test. Finally, multivariate genetic analyses were performed. Three types of polychoric correlations were calculated according to zygosity and sex, and the results were summarized as correlation matrices. The correlation between different traits within the same individual, for example, the correlation between sleeptalking and half-sleeping within the same individual, is phenotypic correlation. The correlation of the same trait between twin pairs, for example the correlation of sleeptalking between first-born and second-born MZ/DZ twin pairs, reflects the genetic contribution for this trait. The correlation of different traits between twin pairs, for example, the correlation between sleeptalking in the first-born and half-sleeping in the second-born MZ/DZ twin pairs, reflects the common genetic contribution for the two targeted traits. If phenotypic correlations of the two traits are relatively high, and correlations of the same trait and different traits between MZ pairs are higher than those of DZ pairs, a common genetic influence for the two traits is strongly suggested. Both independent–pathway and common–pathway models (Neale and

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**Fig. 1** Two types of general sex–genotype interaction models

MZ: monozygotic twins, DZ: dizygotic twins,
A: additive genetic factors, C: common environmental factors, E: random environmental factors,
f: female, m: male.

Path diagram of ACE model is shown for DZ opposite–sex pairs.
Path diagrams for MZ male–male, MZ female–female, DZ male–male and DZ female–female pairs are drawn similarly. All five types of diagrams according to sex and zygosity combinations are analyzed simultaneously.
Latent variables are shown in the circle. Observed variables are shown in the square.
Cardon, 1992), were performed by taking the results of phenotypic correlations into consideration. Throughout all model-fitting analyses, a goodness of fit index (GFI) $>0.85$ was used as the criteria for model adoption.

Basic statistics were computed using PC SAS version 8 (SAS Institute INC, 1999). Structural equation modeling was performed by the Mx software package (Neale, 2000).

5. Ethical issues

The methods of informed consent vary according to the subjects. As to school applicant group, the statistical analysis of the data was clearly written in the application document, and the detailed explanations concerning data collection by questionnaire and interview, and blood sampling for zygosity examination and health check were added as another paper from 1999 on. Moreover, informed consent was obtained from each twin and his or her parents in writing from 2001 on as part of the application process. The data analysis was also permitted by the twin research committee of this school. When present study was performed, this school did not have ethical committee of twin study, which has been now under construction, including the author as one of the advisers. Zygosity diagnosis using DNA sample was permitted through ethical committee of Graduate School of Medicine, the University of Tokyo (Ooki, 2006).

All the mothers in the maternal association group cooperated voluntarily in this research, mainly through the presidents of their associations (Ooki, 2006).

These twin studies were also permitted by the ethical committee of the Ishikawa Prefectural Nursing University in 2004.

III Results

The prevalences of four traits are shown in Table 1. Significant sex difference was observed only for nocturnal enuresis in both groups, with males showing significantly higher frequencies. No traits were significantly related to zygosity according to birth order within twin pairs (data not shown).

Casewise concordance rates observed for these traits are given in Table 2. All casewise concordance rates of MZ were significantly greater than those observed in DZ pairs, except for nocturnal enuresis of females in the school applicants group. Based on the $2 \times 2$ contingency tables, tetrachoric correlations and their 95% confidence intervals were computed, which were also shown in Table 2. The correlations of MZ were greater than those of DZ pairs for almost all items.

The results of the univariate genetic analysis are shown in Table 3. In the maternal associations group, the homogeneity AE model was selected for sleeptalking, and the heterogeneity ACE model for half-sleeping and nocturnal enuresis, and the homogeneity ACE model for night terrors. In the school applicants group, the heterogeneity AE model was selected for sleeptalking, half-sleeping and night terrors, and the heterogeneity ACE model for nocturnal enuresis. The variance components of the best-fitting models are also shown in Table 3. The proportion of total phenotypic variance attributed to genetic influences ($A_m$ or $A_f$ in the table) was 88–96% regarding sleeptalking, 62–91% regarding half-sleeping, and 70–91% regarding night terrors, which were higher in the school applicants group than in the maternal associations group. Age and gender difference was suggested to impact nocturnal enuresis, with higher genetic influences in males.

Phenotypic correlations between all combinations of two traits, for example sleeptalking and half-sleeping, and so on, according to sex and birth order within twin pairs are summarized in Table 4.
Table 1  Frequencies of four habitual behaviors during sleep in childhood twins

<table>
<thead>
<tr>
<th>Behaviors</th>
<th>Maternal associations group</th>
<th>School applicants group</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>The first born</td>
<td>The second born</td>
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<tr>
<td></td>
<td>Males</td>
<td>Females</td>
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<tr>
<td></td>
<td>N (%)</td>
<td>N (%)</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Skeptalking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>24</td>
<td>6.4</td>
</tr>
<tr>
<td>Sometimes</td>
<td>206</td>
<td>54.5</td>
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<tr>
<td>Never</td>
<td>148</td>
<td>39.2</td>
</tr>
<tr>
<td>Missing value</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Half-sleeping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>15</td>
<td>4.0</td>
</tr>
<tr>
<td>Sometimes</td>
<td>120</td>
<td>31.8</td>
</tr>
<tr>
<td>Never</td>
<td>242</td>
<td>64.2</td>
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<tr>
<td>Missing value</td>
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<td>16</td>
</tr>
<tr>
<td>Night terrors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>7</td>
<td>1.9</td>
</tr>
<tr>
<td>Sometimes</td>
<td>52</td>
<td>13.9</td>
</tr>
<tr>
<td>Never</td>
<td>316</td>
<td>84.3</td>
</tr>
<tr>
<td>Missing value</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Nocturnal enuresis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>55</td>
<td>15.3</td>
</tr>
<tr>
<td>Sometimes</td>
<td>125</td>
<td>34.7</td>
</tr>
<tr>
<td>Never</td>
<td>180</td>
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</tr>
<tr>
<td>Missing value</td>
<td>32</td>
<td>26</td>
</tr>
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</table>

*aAs to nocturnal enuresis, the answers 'often' and 'sometimes' were combined.

Sex difference was tested by χ² test. *: p<0.05, **: p<0.01.
### Table 2  Casewise concordance rates and tetrachoric correlations with 95% CIs of four habitual behaviors during sleep based on 2×2 contingency tables

<table>
<thead>
<tr>
<th></th>
<th>MZ</th>
<th></th>
<th>DZ</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MM</td>
<td>FF</td>
<td>MM</td>
<td>FF</td>
</tr>
<tr>
<td><strong>Casewise concordance rate</strong></td>
<td><strong>p</strong></td>
<td></td>
<td><strong>p</strong></td>
<td></td>
</tr>
<tr>
<td>Sleepwalking</td>
<td>0.885 (200/226)</td>
<td>0.888 (182/205)</td>
<td>0.723 (86/119)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.697</td>
<td>0.885</td>
<td>0.732 (90/123)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.885</td>
<td>0.885</td>
<td>0.891</td>
<td><strong>p</strong></td>
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<tr>
<td></td>
<td>0.697</td>
<td>0.885</td>
<td>0.891</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td>Half-sleeping</td>
<td>0.811 (116/143)</td>
<td>0.767 (92/120)</td>
<td>0.667 (46/69)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.375</td>
<td>0.811</td>
<td>0.543 (38/70)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.375</td>
<td>0.811</td>
<td>0.543 (38/70)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td>Night terrors</td>
<td>0.735 (36/49)</td>
<td>0.714 (40/56)</td>
<td>0.375 (12/32)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.452</td>
<td>0.735</td>
<td>0.452 (28/62)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.452</td>
<td>0.735</td>
<td>0.452 (28/62)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td>Nocturnal enuresis</td>
<td>0.846 (148/175)</td>
<td>0.832 (104/125)</td>
<td>0.652 (58/89)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.525</td>
<td>0.846</td>
<td>0.569 (70/123)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.525</td>
<td>0.846</td>
<td>0.569 (70/123)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td><strong>Tetrachoric r with 95% CIs</strong></td>
<td><strong>r</strong></td>
<td><strong>95% CI</strong></td>
<td><strong>r</strong></td>
<td><strong>95% CI</strong></td>
</tr>
<tr>
<td>Sleepwalking</td>
<td>0.884 (N=178)</td>
<td>0.803–0.964</td>
<td>0.884 (N=159)</td>
<td>0.798–0.969</td>
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<tr>
<td></td>
<td>0.454</td>
<td>(N=98)</td>
<td>0.454</td>
<td>(N=98)</td>
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<td></td>
<td>0.719</td>
<td>(N=99)</td>
<td>0.719</td>
<td>(N=99)</td>
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<tr>
<td></td>
<td>0.913</td>
<td>(N=177)</td>
<td>0.775–0.987</td>
<td>(N=156)</td>
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<td></td>
<td>0.479</td>
<td>(N=97)</td>
<td>0.479</td>
<td>(N=97)</td>
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<td>0.950</td>
<td>(N=94)</td>
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<tr>
<td>Nocturnal enuresis</td>
<td>0.877 (N=169)</td>
<td>0.793–0.960</td>
<td>0.877 (N=154)</td>
<td>0.840–0.983</td>
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<td>0.510</td>
<td>(N=94)</td>
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<td>0.510</td>
<td>(N=94)</td>
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### School applicants group

<table>
<thead>
<tr>
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<th>DZ</th>
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<td>FF</td>
<td>MM</td>
<td>FF</td>
</tr>
<tr>
<td><strong>Casewise concordance rate</strong></td>
<td><strong>p</strong></td>
<td></td>
<td><strong>p</strong></td>
<td></td>
</tr>
<tr>
<td>Sleepwalking</td>
<td>0.914 (308/337)</td>
<td>0.899 (400/445)</td>
<td>0.687 (68/99)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.615 (48/78)</td>
<td>0.615</td>
<td>0.615 (48/78)</td>
<td><strong>p</strong></td>
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<td></td>
<td>0.615 (48/78)</td>
<td>0.615</td>
<td>0.615 (48/78)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td>Half-sleeping</td>
<td>0.675 (102/151)</td>
<td>0.771 (138/179)</td>
<td>0.465 (20/43)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.429 (18/42)</td>
<td>0.429</td>
<td>0.429 (18/42)</td>
<td><strong>p</strong></td>
</tr>
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<td></td>
<td>0.429 (18/42)</td>
<td>0.429</td>
<td>0.429 (18/42)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td>Night terrors</td>
<td>0.596 (28/62)</td>
<td>0.677 (42/62)</td>
<td>0.211 (4/19)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.182 (2/11)</td>
<td>0.182</td>
<td>0.182 (2/11)</td>
<td><strong>p</strong></td>
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<tr>
<td></td>
<td>0.182 (2/11)</td>
<td>0.182</td>
<td>0.182 (2/11)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td>Nocturnal enuresis</td>
<td>0.935 (290/310)</td>
<td>0.907 (282/311)</td>
<td>0.765 (52/68)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td></td>
<td>0.870 (60/69)</td>
<td>0.870</td>
<td>0.870 (60/69)</td>
<td><strong>p</strong></td>
</tr>
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<td></td>
<td>0.870 (60/69)</td>
<td>0.870</td>
<td>0.870 (60/69)</td>
<td><strong>p</strong></td>
</tr>
<tr>
<td><strong>Tetrachoric r with 95% CIs</strong></td>
<td><strong>r</strong></td>
<td><strong>95% CI</strong></td>
<td><strong>r</strong></td>
<td><strong>95% CI</strong></td>
</tr>
<tr>
<td>Sleepwalking</td>
<td>0.960 (N=318)</td>
<td>0.932–0.988</td>
<td>0.934 (N=391)</td>
<td>0.898–0.970</td>
</tr>
<tr>
<td></td>
<td>0.527 (N=88)</td>
<td>0.527</td>
<td>0.527 (N=88)</td>
<td>0.527</td>
</tr>
<tr>
<td></td>
<td>0.527 (N=88)</td>
<td>0.527</td>
<td>0.527 (N=88)</td>
<td>0.527</td>
</tr>
<tr>
<td>Half-sleeping</td>
<td>0.821 (N=316)</td>
<td>0.730–0.911</td>
<td>0.859 (N=389)</td>
<td>0.859–0.962</td>
</tr>
<tr>
<td></td>
<td>0.512 (N=86)</td>
<td>0.512</td>
<td>0.512 (N=86)</td>
<td>0.512</td>
</tr>
<tr>
<td></td>
<td>0.512 (N=86)</td>
<td>0.512</td>
<td>0.512 (N=86)</td>
<td>0.512</td>
</tr>
<tr>
<td>Night terrors</td>
<td>0.872 (N=317)</td>
<td>0.762–0.983</td>
<td>0.827–0.982</td>
<td>(N=387)</td>
</tr>
<tr>
<td></td>
<td>0.294 (N=87)</td>
<td>0.294</td>
<td>0.294 (N=87)</td>
<td>(N=387)</td>
</tr>
<tr>
<td></td>
<td>0.294 (N=87)</td>
<td>0.294</td>
<td>0.294 (N=87)</td>
<td>(N=387)</td>
</tr>
<tr>
<td>Nocturnal enuresis</td>
<td>0.980 (N=312)</td>
<td>0.963–0.997</td>
<td>0.973 (N=379)</td>
<td>0.953–0.992</td>
</tr>
<tr>
<td></td>
<td>0.839 (N=82)</td>
<td>0.839</td>
<td>0.839 (N=82)</td>
<td>(N=83)</td>
</tr>
<tr>
<td></td>
<td>0.839 (N=82)</td>
<td>0.839</td>
<td>0.839 (N=82)</td>
<td>(N=83)</td>
</tr>
</tbody>
</table>

**MZ** : monozygotic, **DZ** : dizygotic, **MM** : male=male, **FF** : female=female, **OS** : opposite-sex, **CI** : confidence interval.

The difference in the concordance rate between same-sex MZ and DZ pairs was tested using the χ² test. **ns** : not significant, * : p<0.05, ** : p<0.01, *** : p<0.001.
### Table 3  Path coefficients and variance components for the best-fitting models

<table>
<thead>
<tr>
<th>Model</th>
<th>AIC</th>
<th>Path coefficients</th>
<th>Variance component (%) with 95% CIs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$a_m$</td>
<td>$c_m$</td>
</tr>
<tr>
<td>Maternal associations group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep talking</td>
<td>$-3.506$</td>
<td>0.940</td>
<td>0.343</td>
</tr>
<tr>
<td>Half-sleeping</td>
<td>$-0.826$</td>
<td>0.834</td>
<td>0.457</td>
</tr>
<tr>
<td>Night terrors</td>
<td>$-2.188$</td>
<td>0.836</td>
<td>0.447</td>
</tr>
<tr>
<td>Nocturnal enuresis</td>
<td>$-1.461$</td>
<td>0.915</td>
<td>0.202</td>
</tr>
<tr>
<td>School applicants group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep talking</td>
<td>$-5.062$</td>
<td>0.980</td>
<td>0.200</td>
</tr>
<tr>
<td>Half-sleeping</td>
<td>4.855</td>
<td>0.908</td>
<td>0.420</td>
</tr>
<tr>
<td>Night terrors</td>
<td>1.869</td>
<td>0.940</td>
<td>0.341</td>
</tr>
<tr>
<td>Nocturnal enuresis</td>
<td>5.889</td>
<td>0.576</td>
<td>0.802</td>
</tr>
</tbody>
</table>

$m$: male, $f$: female, CI: confidence interval

Latent variable $A_m$ was calculated, for example, nocturnal enuresis in males, as $a_m^2/\left(a_m^2 + c_m^2 + e_m^2\right) \times 100$.

---

The results of the test of independence using Fisher's exact test were also shown in this table.
et al., 1998c). Prevalence of traits depends on the age of subjects at data collection, methods of measurement, demographics and other factors. As to night terrors, one possible caution is that night crying may have been misclassified into night terrors in younger age children. As shown in previous reports on the prevalence of these traits, summarized by Hublin et al. (1998a, 1998c, 1999a). Moreover, the following results of present study have been observed generally in singletons. First, sleeptalking, half-sleeping, and night terrors occurred in that order of frequency. Second, males showed higher frequencies as to nocturnal enuresis compared to females.

2. Univariate genetic analysis

As a zygosity effect on prevalence was not observed in the individual twins, the results of the following genetic analyses, i.e., the comparison of similarity in the twin pairs according to zygosity, could be interpreted rationally.

It was confirmed that most mothers of the same-sex twin pairs did not have much knowledge of their twins’ zygosity. Zygosity classification of same-sex twins in childhood has been very rare in Japan. Moreover, zygosity misclassification at birth by means of easy placental findings used to occur in about 25–30% of MZ twin pairs (Ooki et al., 2004). Therefore, mothers of same-sex twins often did not know the correct zygosity of their

Table 4 Phenotypic correlations between four habitual behaviors during sleep

<table>
<thead>
<tr>
<th></th>
<th>Maternal associations group</th>
<th>School applicants group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The first born</td>
<td>The second born</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td></td>
<td>N  r  p</td>
<td>N  r  p</td>
</tr>
<tr>
<td>Sleeptalking and Half-sleeping</td>
<td>376 0.579 0.000**</td>
<td>356 0.513 0.000**</td>
</tr>
<tr>
<td>Sleeptalking and Night terrors</td>
<td>373 0.318 0.000**</td>
<td>356 0.418 0.000**</td>
</tr>
<tr>
<td>Sleeptalking and Nocturnal enuresis</td>
<td>357 0.119 0.210</td>
<td>345 0.005 0.195</td>
</tr>
<tr>
<td>Half-sleeping and Night terrors</td>
<td>373 0.639 0.000**</td>
<td>354 0.540 0.000**</td>
</tr>
<tr>
<td>Half-sleeping and Nocturnal enuresis</td>
<td>357 0.101 0.335</td>
<td>341 0.031 0.496</td>
</tr>
<tr>
<td>Night terrors and Nocturnal enuresis</td>
<td>356 0.036 0.731</td>
<td>342 0.098 0.600</td>
</tr>
</tbody>
</table>

Polychoric correlations (r) more than 0.30 are shown in boldface type.
Test of independence was performed using Fisher’s exact test. *: p<0.05, **: p<0.01.
### Table 5  Polychoric correlation matrices for sleeptalking, half-sleeping and night terrors according to zygosity, sex and subject groups

<table>
<thead>
<tr>
<th>Maternal associations group (Male)</th>
<th>The first born</th>
<th>The second born</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MZ : 176 pairs, DZ : 97 pairs</strong></td>
<td>Sleep talking</td>
<td>Half-sleeping</td>
</tr>
<tr>
<td>The first born</td>
<td>1.0</td>
<td>0.5562</td>
</tr>
<tr>
<td>Sleep talking</td>
<td>0.5656</td>
<td>1.0</td>
</tr>
<tr>
<td>Half-sleeping</td>
<td>0.6546</td>
<td>0.7912</td>
</tr>
<tr>
<td>Night terrors</td>
<td><strong>0.8901</strong></td>
<td>0.4395</td>
</tr>
<tr>
<td>The second born</td>
<td>0.4676</td>
<td>0.8935</td>
</tr>
<tr>
<td>Sleep talking</td>
<td>0.4634</td>
<td>0.6374</td>
</tr>
<tr>
<td>Half-sleeping</td>
<td>0.5560</td>
<td>0.5343</td>
</tr>
<tr>
<td>Night terrors</td>
<td>0.6302</td>
<td>0.6317</td>
</tr>
<tr>
<td>School applicant group (Male)</td>
<td>The first born</td>
<td>Sleep talking</td>
</tr>
<tr>
<td><strong>MZ : 312 pairs, DZ : 86 pairs</strong></td>
<td>1.0</td>
<td>0.5674</td>
</tr>
<tr>
<td>The first born</td>
<td>0.4798</td>
<td>1.0</td>
</tr>
<tr>
<td>Sleep talking</td>
<td>0.3010</td>
<td>0.3727</td>
</tr>
<tr>
<td>Half-sleeping</td>
<td><strong>0.9583</strong></td>
<td>0.3410</td>
</tr>
<tr>
<td>Night terrors</td>
<td>0.4125</td>
<td><strong>0.8131</strong></td>
</tr>
<tr>
<td>The second born</td>
<td>0.2015</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

Maternal associations group (Female)  

<table>
<thead>
<tr>
<th><strong>MZ : 154 pairs, DZ : 102 pairs</strong></th>
<th>The first born</th>
<th>Sleep talking</th>
<th>Half-sleeping</th>
<th>Night terrors</th>
<th>Sleep talking</th>
<th>Half-sleeping</th>
<th>Night terrors</th>
</tr>
</thead>
<tbody>
<tr>
<td>The first born</td>
<td><strong>0.8867</strong></td>
<td>0.4998</td>
<td>0.2571</td>
<td><strong>1.0</strong></td>
<td>0.4981</td>
<td>0.2333</td>
<td></td>
</tr>
<tr>
<td>Sleep talking</td>
<td>0.4676</td>
<td><strong>0.8935</strong></td>
<td>0.5624</td>
<td>0.6323</td>
<td><strong>1.0</strong></td>
<td><strong>0.5434</strong></td>
<td></td>
</tr>
<tr>
<td>Half-sleeping</td>
<td>0.4634</td>
<td>0.6374</td>
<td><strong>0.9129</strong></td>
<td>0.4561</td>
<td>0.6998</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Night terrors</td>
<td><strong>0.5106</strong></td>
<td>0.4849</td>
<td>0.1296</td>
<td><strong>0.5118</strong></td>
<td>0.4849</td>
<td><strong>0.1296</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>School applicant group (Female)</th>
<th>The first born</th>
<th>Sleep talking</th>
<th>Half-sleeping</th>
<th>Night terrors</th>
<th>Sleep talking</th>
<th>Half-sleeping</th>
<th>Night terrors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MZ : 383 pairs, DZ : 82 pairs</strong></td>
<td>1.0</td>
<td>0.6955</td>
<td><strong>0.3653</strong></td>
<td><strong>0.4122</strong></td>
<td>0.5690</td>
<td><strong>0.2352</strong></td>
<td></td>
</tr>
<tr>
<td>The first born</td>
<td>0.5828</td>
<td>1.0</td>
<td><strong>0.3640</strong></td>
<td>0.2494</td>
<td><strong>0.3960</strong></td>
<td>0.3067</td>
<td></td>
</tr>
<tr>
<td>Sleep talking</td>
<td>0.1783</td>
<td>0.3917</td>
<td>1.0</td>
<td>0.3115</td>
<td>0.5590</td>
<td><strong>0.3537</strong></td>
<td></td>
</tr>
<tr>
<td>Half-sleeping</td>
<td><strong>0.9369</strong></td>
<td>0.5236</td>
<td>0.2614</td>
<td>1.0</td>
<td><strong>0.5679</strong></td>
<td>0.2979</td>
<td></td>
</tr>
<tr>
<td>Night terrors</td>
<td>0.5522</td>
<td><strong>0.9067</strong></td>
<td>0.2092</td>
<td>0.5409</td>
<td>1.0</td>
<td><strong>0.2216</strong></td>
<td></td>
</tr>
</tbody>
</table>

The correlations of MZ twins or twin pairs are shown below diagonal and the correlations of DZ twins or twin pairs are shown above diagonal in each correlations matrix. The correlations between different traits within the same individual (phenotypic correlations) are shown in italic font. The correlations of the same trait between twin pairs are shown in bold font. The others are the correlations of different traits between twin pairs (cross-correlations).

*aThe tetrachoric correlation was not calculated because blank cell exists in 2×2 contingency table.
children. On the other hand, the zygosity of the present samples was objective and considerably accurate. It is not likely that the similarity of twins was affected by the mothers’ knowledge of their children’s zygosity. Therefore, the higher concordance rates and polychoric correlations in MZ pairs than in DZ pairs strongly suggest the role of genetic background.

The results of univariate genetic model fitting showed that most of these traits were under substantial genetic control. The genetic contributions to sleeptalking (Abe and Shimakawa, 1966a; Abe et al., 1984a), night terrors (Abe et al., 1993; Kales et al, 1980), and nocturnal enuresis (Abe et al., 1967, 1984b; Bakwin, 1971) have been pointed out by classic genetic studies. Moreover, Hublin et al. recently revealed the genetic contribution to sleeptalking (Hublin et al., 1998c), sleep terrors (Hublin et al., 1999a), and nocturnal enuresis (Hublin et al., 1998a) by analyzing a large Finnish Twin Cohort. The present study supported these results. To my knowledge, no previous twin study of half-sleeping exists. Structural equation modeling showed that the proportion of total phenotypic variance attributed to genetic influences was 62–96% regarding sleeptalking, half-sleeping, and night terrors, which were higher in the school applicants group compared to the maternal associations group. Though classic studies for sleeptalking, night terrors and nocturnal enuresis have shown the genetic contributions, few of them considered gender difference because of small sample size and because only concordance rates were calculated. Including the information from opposite-sex DZ pairs in this study permitted direct detection of sex-specific effects by structural equation modeling. One advance of the present study was this direct estimation of sex-based difference by using opposite-sex DZ pairs.

As to nocturnal enuresis, the results were inconsistent between two groups. High genetic contribution was observed as to the maternal associations group, whereas no or small genetic contribution was observed as to school applicants group. The estimated genetic contribution (heritability) was 84% for males and 48% for females in the mater-
nal associations group, and 33% for males and 0% for females in the school applicants group. One possible reason for very low heritability of females in school applicants group was thought to be the frequency scale of the two categories (“often” and “sometimes” vs. “never”). The genetic effect in enuresis in childhood may be of more importance in males than in females. Butler et al. (2001) observed gender differences in genetic effects regarding enuresis in 2900 3-year-old twin pairs. The heritability of males was 33% whereas that for females was 10%. These results are relatively similar to those of the present study. On the other hand, the results of Hublin et al. (1998a) showed nearly the same heritability for males (44%) and females (45%) by retrospective reports from adulthood aged over 30 years.

The age of subjects was thought to be important in the genetic study of behavioral traits. For example, as the age of the subjects in the series of Finnish Twin studies above mentioned was 33–60 years, unexpected recall biases for the events in childhood that occurred several decades ago may exist.

Slightly lower heritability was observed in the maternal associations group for sleeptalking, half-sleeping, and night terrors. Common environmental factors were observed for half-sleeping and night terrors in the maternal associations group. On the other hand, lower heritability of nocturnal enuresis was observed in the school applicants group. The contribution of common environmental factors for nocturnal enuresis was observed for both groups, with a higher proportion in the school applicants group. The definite reasons for these results were unclear. Nevertheless, considering the fact that there will be very large confidence intervals around the estimated variance components shown in Table 3, an apparent difference of heritability may not be so meaningful as values themselves. One reason of this wide confidence interval was attributable to analyzing categorical data. Therefore, it needs caution in over-interpreting apparent differences across samples.

3. Co-occurrence of habitual sleep behaviors

Sleeptalking, half-sleeping and night terrors were more likely to co-occur irrespective of the subjects group. The author did not give clear definitions of sleeptalking, half-sleeping and enuresis, because these traits are common and seen often in childhood. If mothers had difficulty distinguishing between these traits, phenotypic correlations between the traits may be present.

Twin studies will be a very powerful tool to analyze genetic contributions to the phenotypic correlations or comorbidity of many behaviors, including problem behaviors in childhood (Schmitz and Mrazek, 2001). As to maternal associations group, the independent-pathway ACE model showed the best fit. As for sleeptalking, the effects of trait-specific genetic factors were relatively high compared to those of common genetic factors. On the other hand, the effects of common genetic factors on half-sleeping were relatively high, and trait-specific genetic factors were not observed.

The genetic background of this co-occurrence according to sex was not necessarily made clear in the school applicants group. The possible reasons were as follows. Cross-variable correlations were still not stabilized in the present sample size, especially for DZ pairs. The multivariate genetic model for sleeptalking, half-sleeping and night terrors used fifteen correlations for both MZ and DZ pairs. If all of these correlations cannot explain the assumed models rationally, the model did not fit well. This restriction made multivariate model fitting much harder than univariate model fitting. Moreover, the present four traits were measured...
as qualitative variables for which there is less information than quantitative variables such as height or weight. This restriction also made model fitting difficult.

The concept of half-sleeping may be unique to Japanese. This word means the situation of “half asleep”, “doughy with sleep”, or “sleep drunkenness.” It is of interest to clarify what constitutes this trait to understand the co-occurrence of behaviors during sleep in more detail. Further research with a larger sample size will clarify the genetic background of these three traits during sleep. The co-occurrence between traits during sleep has been pointed out decades ago by Kales et al. (1980), and was ascertained by the recent study of Hublin et al. (2001) using a large Finnish Twin Cohort. In their study sleeptalking and sleepwalking, sleeptalking and nightmares, and sleeptalking and bruxism showed phenotypic correlations. Nocturnal enuresis did not show strong associations with sleeptalking or night terrors. These results were in good accordance with those of the present study. The etiology of nocturnal enuresis may be different from that of sleeptalking, half-sleeping, and night terrors. Recently, the association between childhood sleep and behavioral problems in later life were pointed out by Gregory et al. (2004).

Further systematic twin study should be performed regarding a wide range of phenotypic correlations including childhood behavior during sleep.

4. Limitations

The limitations of this study are as follows. First, the present study consisted of two separate analyses for the two independent samples. Therefore, the results of both samples may not be linked directly. As heritability could vary widely depending on the sample population, it is desirable to estimate and compare this parameter using many different populations.

Second, the age effect was not directly taken into consideration. Since behavior characteristics in childhood vary with age, it is desirable to examine longitudinal study to obtain information as to the duration in the occurrence of each trait. The age of twins in the maternal associations group varied, and not all of them had reached the stage of childhood at which the target behavior completes its course. The author also performed sub-analyses stratified by age group; for example, below and above the eight-year-old group, no marked difference of heritability was observed. Moreover, although structural equation modeling, which contained the age at which the data was collected as an independent variable, was performed, no direct age effect was observed. These findings suggested that the age effect, even if it exists, is not large, a finding that definitely changes the total results. A very large sample size is needed for slight changes of genetic effects according to age to be detected.

The twins in the school applicants group was 11 or 12 years old at the time of data collection, and had mostly already moved beyond the target behaviors of childhood. Therefore, the author used this group to analyze total genetic effects throughout childhood.

Third, the selection biases for the school applicants group were as follows: 1. Both twins are alive and have shown no marked growth disturbance through age 11 or 12. 2. The subjects are all applicants to an entrance examination for a university-affiliated school. These features may have an advantage regarding intrauterine growth, though the direct effect of these positive selection biases on the behavior traits is difficult to specify.

The total MZ/DZ ratio of the school applicants group was 2.42 (734/303), and that of the maternal associations group was 0.94 (348/372). The recent Japanese MZ/DZ ratio ranges roughly from 1.00 to 2.00 (Imaizumi and Nonaka, 1997). The ratio of
MZ was higher in the school applicants group, reflecting selection biases based on the sampling process.

Finally, the traits during sleep of one twin may affect the traits during sleep of their cotwin. There was no direct information on this point, for example, whether the twins sleep in the same bedroom or not.

V Conclusion

The present study supported the hypothesis of significant genetic effects on the occurrence of habitual behaviors during sleep in children. The genetic contribution toward various behavior characteristics during sleep and their co-occurrence in childhood was clarified by using two large sets of Japanese twin samples.

Acknowledgment

The author would like to gratefully acknowledge the help of Toshimi Ooma in the data analysis.

References

Abe K, Oda N, Ikenaga K et al. (1993) : Twin study on night terrors, fears and some physiological and behavioral characteristics in childhood, Psychiatr Genet, 3, 39–43
Abe K and Shimakawa M (1966a) : Genetic and developmental aspects of sleep talking and teeth-grinding, Acta Paedopsychiatr, 33, 339–344
Abe K and Shimakawa M (1966b) : Predisposition to sleep-walking, Psychiatr Neurol, 152, 306–312
Hublin C, Kaprio J, Partinen M et al. (1998a) : Nocturnal enuresis in a nationwide twin cohort, Sleep, 21, 579–585
Hublin C, Kaprio J, Partinen M et al. (1998c) : Sleep talking in twins : Epidemiology and psychiatric comorbidity, Behav Genet, 28, 289–298
McGue M (1992) : When assessing twin concordance, use the probandwise not the pairwise rate, Schizophr Bull, 18, 171–176
Neale MC (2000) : Statistical Modelling with Mx. Richmond, VA : Department of Psychiatry, Medical College of Virginia (Richmond)
Ooki S (2005a) : Genetic and environmental influences
on stuttering and tics in Japanese twin children, Twin Res Hum Genet, 8, 69–75


Ooki S (2005c) : Genetic and environmental influences on the handedness and footedness in Japanese twin children, Twin Res Hum Genet, 8, 649–656


Ooki S and Asaka A (2005) : Comparison of obstetric and birthweight characteristics between the two largest databases of Japanese twins measured in childhood, Twin Res Hum Genet, 8, 63–68

Ooki S and Asaka A (2006) : Twin database of the secondary school attached to the faculty of education of the university of Tokyo, Twin Res Hum Genet, 9, 827–831


SAS Institute Inc (1999) : SAS/STAT user’s guide, version 8, Cary (NC)

(Received 11.16.2007 ; Accepted 3.5.2008)