Prevalence of birth defects and parental work in Singapore live births from 1994 to 1998: a population-based study

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The aims of the study were to assess the prevalence of birth defects (BDs) among different occupational groups and non-working parents, and to identify possible risk factors associated with BDs in Singapore live births born between 1 January 1994 and 31 December 1998. To do this, information on live births (from the Singapore National Registry of Births and Deaths) and BD cases [from the National Birth Defects Register (NBDR)] was obtained from 1 January 1994 to 31 December 1998. There were a total of 237,755 live births in Singapore between 1 January 1994 and 31 December 1998. Over the same period, 3293 cases of BDs were reported to the NBDR, giving an overall rate of 13.9 per 1000 live births. A downward trend with time was noted. Of the live born with BDs in this series, 36.7% presented with multiple anomalies. The overall occurrence of malformation (per 1000 live births) among working versus non-working mothers was 13.4 versus 14.2, respectively, and 13.8 for working fathers compared with 16.8 for non-working fathers. Parents in the occupational group ‘Legislators, Senior Officers & Managers’ had the lowest prevalence rates of congenital anomalies (9.4 per 1000 for mothers and 10.3 per 1000 for fathers), while the ‘Agricultural & Fishery Workers’ had the highest rates (40.0 per 1000 for mothers and 23.4 per 1000 for fathers). However, the very small number of workers in this latter group makes the rate unreliable. The prevalence of BDs in Singapore is comparable to those in other countries. Parental work per se is not correlated with BDs.

Key words: Birth defects; demographic characteristics; parental occupations/industries; prevalence.

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Introduction

Birth defects (BDs) constitute the leading cause of infant death among all racial/ethnic groups, and command extensive personal and societal resources [1,2]. With a great reduction in childhood mortality due to infection, the proportion of deaths in children attributable to genetic causes has increased considerably [3].

The concept ‘birth defect’ is not strictly defined [4]. A broad definition would include functional and metabolic disorders that, although present, may not necessarily be recognizable at birth, but are determined only when the child is older [5].

There is no one classification of congenital anomalies used throughout the world. The two most commonly used classification systems are: (i) the BD classification according to the International Classification of Diseases...
[6,7]; and (ii) the International Clearing-house for Birth Defects Monitoring System (ICHBD) [8].

Worldwide surveys have shown that the frequency of BDs varies greatly from country to country. The frequency depends on the time of observation after birth, the types of malformation included, and the differences in reporting and statistical procedures [9].

In a multiracial and heterogeneous population like that of Singapore, it is important to know the significance of various BDs and their possible associated factors. The number of females who are working in Singapore is also on the rise. In 1996 there were 747,400 females in the workforce. As of 1999, the number had increased to 837,400. It is vital to ascertain the epidemiology of BDs, as a BD can be a significant medical, psychological and socio-economic burden on both the family and the community.

In order to obtain reliable knowledge on the pattern of various BDs, a national investigation was carried out. This enabled us to compare our agreement and/or specific findings with those of the major BD registries around the world and offer valuable experience for BD monitoring. With the findings, we can provide more accurate and comprehensive information for counselling. The aims of this study were to investigate the association between the prevalence of BDs among working and non-working parents, and to identify possible risk factors associated with BDs in Singapore live births born between 1 January 1994 and 31 December 1998.

Subjects and methods

Subjects

The subjects included all live births born of Singaporean parents between 1 January 1994 and 31 December 1998, who were registered at the Singapore National Registry of Births and Deaths (SNRBD).

Birth defects eligible to be included in the study were all live births with the presence of one or more BD during the data collection period. The inclusive criteria were based on the classification of cases according to the National Birth Defects Registry (NBDR).

Data collection

Information on live births and BD cases obtained from the relevant government agencies included the mother’s date of birth, ethnic group and highest educational qualification, the occupation of the mother and father, and, if employed, the industrial sector involved. The Singapore Standard Occupational Classification [10] and the Singapore Standard Industrial Classification [11] were used for coding of occupation and industry. The occupational and industrial codes held by the parents 1 year prior to the date of birth of the infants were used for the analysis.

All live births in Singapore are registered with the Ministry of Home Affairs’ Registry of Births under the Registration of Births and Deaths Act. On 1 January 1993, the Ministry of Health set up the NBDR. All physicians are required to notify the NBDR through a standard notification form when they diagnose any infants with congenital malformation as prescribed in the NBDR’s list. This list of BDs is based on that of the ICHBD [8]. The coding of the BDs is based on the International Classification of Diseases (9th revision) [6]. All notification data were verified correct by a team of trained nurses from the NBDR, who would visit the notification physician to clarify and confirm the information that had been received.

The analyses in this paper cover births from 1 January 1994 to 31 December 1998. All the live births that fulfilled the inclusive criteria were enrolled in the analysis.

Data processing and statistical analysis

Before being added to the final database, all the raw data from the different sources were checked and merged to produce a unique record number for each subject. The entire database was then re-examined to identify and resolve any discrepancies. New variables were created from the basic information in the raw data. The final dataset comprised a comprehensive list of variables that included an array of potential risk factors as well as socio-demographic information.

Statistical analyses were performed with standard contingency tables using the SPSS program, version 10.0, on a personal computer [12].

Results

Occurrence of BDs

During the 5 year period (1994–1998) covered by this study, there were 3293 cases with one or more congenital defects retrieved from the records of the NBDR among a total of 237,755 registered live newborns in Singapore. The overall rate of BDs was 13.9 per 1000 live births. The occurrence of congenital defects (per 1000 live births) across the period was 16.6 in 1994, 16.4 in 1995, 11.6 in 1996, 11.2 in 1997 and 13.2 in 1998—showing a downward trend from 1994 to 1997, with a slight rise in 1998.

Distribution and diagnosis of BDs

Among the live born with congenital defects in this study, 36.7% had multiple anomalies. The commonest single BD was ‘bulbus cordis anomalies and anomalies of cardiac septal’, which accounted for 9.6% of all malformations (Table 1).
**Epidemiological information about the demographic characters**

**Maternal delivery age**

The mean maternal delivery age was 30.3 ± 4.7 years (mean ± SD) for all live births, with 30.3 ± 4.7 years for non-defects and 30.7 ± 5.0 years for defects.

There was a J-shaped distribution of the defect rates and maternal delivery age (Figure 1).

**Maternal ethnic background**

The mothers of 68.0% of the live births were Chinese, 19.8% Malay, 7.5% Indian and 4.7% others. The occurrences of BDs among ethnic groups was lowest (5.5 per 1000) in the ‘others’ group, which includes Eurasians and Caucasians. This was followed by the ‘Chinese’ (13.4 per 1000) and ‘Malay’ groups (15.9 per 1000). The ‘Indian’ group had the highest rate, at 18.2 per 1000 live births.

**Maternal education qualification**

The distribution of maternal education qualification is shown in Figure 2. ‘Upper secondary’ had the largest proportion, at 34.95%. This was followed by ‘Diploma’, ‘Primary’, ‘No formal education’ and ‘Tertiary’, ranging from 18.15 to 12.51%. ‘Lower secondary’ accounted for <3%.

The highest qualification group, ‘University degree’, had the lowest occurrence of congenital defects, at 11.0 per 1000 live births, compared with the highest rate of 16.9 per 1000 live births in ‘No qualification/incomplete primary’ (Figure 2).

**Child’s birth order**

The birth order profiles showed that first- and second-born children constituted more than three-quarters of all live births. The number of occurrences of BDs increased with birth order (Figure 3).

**Parental occupation and employer’s industry**

**Distribution of BDs by parental occupation**

In total, 44.8% of mothers reported not working; 20% held a clerical occupation; 10% worked in a ‘Technicians & Associate Professionals’ position; and another 10% were employed as ‘Service Workers & Shop & Market Sales Workers’; the remainder accounted for <5% in each of the remaining occupational categories.

In contrast to the large group of non-working mothers, only 0.8% of fathers were unemployed. The most com-

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**Table 1.** The distribution and diagnosis of the major congenital defects conforming to the list of the ICHBD, shown by descending frequency: Singapore 1994–1998

<table>
<thead>
<tr>
<th>Types of BD</th>
<th>Occurrence (per 10 000 live births)</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple congenital anomalies</td>
<td>50.89</td>
<td>36.74</td>
</tr>
<tr>
<td>Bulbus cordis anomalies and anomalies of cardiac septal</td>
<td>13.29</td>
<td>9.60</td>
</tr>
<tr>
<td>Congenital anomalies of urinary system</td>
<td>9.84</td>
<td>7.11</td>
</tr>
<tr>
<td>Cleft palate and cleft lip</td>
<td>8.66</td>
<td>6.26</td>
</tr>
<tr>
<td>Certain congenital musculoskeletal deformities</td>
<td>8.37</td>
<td>6.04</td>
</tr>
<tr>
<td>Chromosomal anomalies</td>
<td>8.29</td>
<td>5.98</td>
</tr>
<tr>
<td>Other congenital anomalies of limbs</td>
<td>6.56</td>
<td>4.74</td>
</tr>
<tr>
<td>Other congenital anomalies of circulatory system</td>
<td>6.48</td>
<td>4.68</td>
</tr>
<tr>
<td>Other congenital anomalies of digestive system</td>
<td>5.05</td>
<td>3.64</td>
</tr>
<tr>
<td>Congenital anomalies of genital organs</td>
<td>4.80</td>
<td>3.46</td>
</tr>
<tr>
<td>Other congenital anomalies of nervous system</td>
<td>3.74</td>
<td>2.70</td>
</tr>
<tr>
<td>Other congenital musculoskeletal anomalies</td>
<td>3.24</td>
<td>2.34</td>
</tr>
<tr>
<td>Other congenital anomalies of heart</td>
<td>2.90</td>
<td>2.10</td>
</tr>
<tr>
<td>Other and unspecified congenital anomalies</td>
<td>1.09</td>
<td>0.79</td>
</tr>
<tr>
<td>Congenital anomalies of eye</td>
<td>0.93</td>
<td>0.67</td>
</tr>
<tr>
<td>Congenital anomalies of the integument</td>
<td>0.84</td>
<td>0.61</td>
</tr>
<tr>
<td>Congenital anomalies of ear, face and neck</td>
<td>0.76</td>
<td>0.55</td>
</tr>
<tr>
<td>Spina bifida</td>
<td>0.72</td>
<td>0.52</td>
</tr>
<tr>
<td>Anencephalus and similar anomalies</td>
<td>0.50</td>
<td>0.36</td>
</tr>
<tr>
<td>Congenital anomalies of respiratory system</td>
<td>0.50</td>
<td>0.36</td>
</tr>
<tr>
<td>Other congenital anomalies of upper alimentary tract</td>
<td>0.34</td>
<td>0.24</td>
</tr>
<tr>
<td>Fetus or newborn affected by maternal conditions which may be unrelated to present pregnancy</td>
<td>0.17</td>
<td>0.12</td>
</tr>
<tr>
<td>Others</td>
<td>0.55</td>
<td>0.39</td>
</tr>
<tr>
<td>Total</td>
<td>138.50</td>
<td>100.00</td>
</tr>
</tbody>
</table>
mon employment groups were ‘Service Workers & Shop & Market Sales Workers’ and ‘Production Craftsmen & Related Workers’, each accounting for ~20% of fathers, followed by ‘Technicians & Associate Professionals’, which accounted for 15.4%. The proportions of the fathers in other occupations ranged from 8.6 to 0.1%.

The overall malformation occurrences (per 1000 live births) of working mothers versus non-working mothers were 13.4 versus 14.2, and 13.8 for working fathers compared with 16.8 for non-working fathers. A maternal occupation of ‘Legislators, Senior Officers & Managers’ had the lowest defect occurrence (9.4 per 1000 live births), while the ‘Agricultural & Fishery Workers’ group had the highest occurrence (40.0 per 1000 live births). Similar findings were observed in paternal occupational classification: the lowest defect rate of 10.3 per 1000 was recorded for ‘Legislators, Senior Officers & Managers’, while the highest rate of 23.4 per 1000 was found for ‘Agricultural & Fishery Workers’ (Figure 4). It must be stressed that the ‘Agricultural & Fishery Workers’ group comprised very few individuals: over the period of the study (1994–1998), there were only 25 women and 171 men in this occupation. As such, the rate of BDs in this occupation is unreliable.

Occurrences of BDs across parental employers’ industries

The distribution of the BD occurrences by parental employer’s industry is shown in Figure 5.

Among maternal employer’s industries, ‘Manufacturing’, ‘Commerce’ and ‘Financial, Insurance, Real Estate and Business Service’ each accounted for 10%, while the remaining industries each comprised <7%.

For paternal industrial classifications, the largest proportion was ‘Manufacturing’, which accounted for 19.32% of fathers. This was followed by ‘Commerce’, with 16.9%. ‘Financial, Insurance, Real Estate and Business Services’, ‘Community, Social and Personnel Service’ and ‘Transport, Storage and Communication’ together accounted for about one-third, in almost equal proportions. Twenty per cent of fathers in our data set did not have information about their employer’s industry.

There was no apparent difference for occurrences of BDs across the parental employers’ industries, except for the category of maternal ‘Mining and Quarrying’ industry (Figure 5). Over the period of the study (1994–1998), there were only 125 women and 362 men in this industry, so the rate of BD in this industry cannot be taken as stable.

Discussion

The strengths of the present study included the use of national-based registries, a large sample size, diagnosis of congenital anomalies by clinical professionals, and classification based on standard occupational and industrial classification. The participation of the national registries ensured the complete coverage of health care services through which all the newborns with or without BDs are identified.

The frequency of ‘unknown’ answers obtained for the study variables was very low, and the proportion of values missing in our dataset is <1/10 000, except for the industrial information. There was 100% completeness for the information on parental occupations, and 16 and
20% available information for maternal and paternal employers’ industries in our dataset, respectively.

Some potential confounding variables in the maternal lifestyle and medical history (medical and obstetric history; infections and drug treatment; tobacco and alcohol consumption; hobbies; initiation of prenatal care; fever during early pregnancy; pregnancies of diabetics; nutrition; family history of disease; etc.) could not be taken into account in the analyses since information on these variables was not available in the NBDR and SNRBD. Previous studies have suggested an association between these non-occupational risk factors and adverse reproductive outcomes [9]. Father’s smoking, drinking and coffee consumption were not available. These variables could be potential confounders, which may over- or underestimate the associations of fathers’ occupations and BDs. However, most reported studies did not show any consistent evidence between fathers’ social habits and BDs [13].

We found the prevalence of overall congenital anomalies (13.9 per 1000) in our study to be generally similar to that of other studies. According to the Finnish register
of BDs, the prevalence of BDs among newborns in Finland varied from 13 to 20 per 1000 in 1963–1980, and the mean for the period was 14 per 1000 [9]. Not many studies have reported national BD rates. Most published data are based on hospital births over a period of time, and are not population based. Dryden [14] studied the rate of BDs in 10 000 babies born consecutively in a general hospital in Papua New Guinea and reported an overall prevalence of congenital defects of 11.6 per 1000. Riley et al. [15] reported that 32 per 1000 babies had at least one malformation during a 13 year study period (1983–1995) in Victoria, Australia. However, the study included 25 231 infants (born at 20 weeks or more) and 1566 terminations of pregnancy before 20 weeks’ gestation. Between January 1992 and January 1995, a total of 24 233 babies born consecutively in Corniche Hospital, which is the only maternity hospital in Abu Dhabi, United Arab Emirates, were surveyed for the presence of major congenital malformations. A total of 401 infants (16.6 per 1000) had a major defect [16].

The time trend during our 5 year study indicated that, in the first 4 years, the overall occurrence of BDs in live births decreased. A number of studies have noted a decline in the birth prevalence of certain congenital anomalies over the last decades, particularly neural tube defects [17–21] and Down’s syndrome [22]. Meanwhile, increasingly sophisticated prenatal diagnostic procedures have been developed to detect congenital defects in utero. The detection of serious congenital anomalies earlier in pregnancy and with greater accuracy has led to a corresponding increase in elective terminations of affected pregnancies [23,24]. The high percentage of prenatal abortions reduces the live-born cases [25]. Progress in the prevention and prenatal detection of BDs has led to a relative increase in the number of interruptions of pregnancies associated with chromosomal abnormalities [26–28]. This may be the main reason for the decline in prevalence of chromosomal anomalies in our series.

Among the major maternal ethnic groups, a diversity of occurrence rates of BD has been observed, with the lowest in the Chinese, intermediate in the Malays and highest in the Indians.

There is some evidence from previous studies that ethnic origin has a significant influence on the pattern of some specific congenital defects, such as heart defects [29], dislocation of the hip [30] and gastrointestinal malformations [31], and on the mortality associated with congenital abnormality [32]. The extent of impairment varies with country of origin. Some of the reasons implicated include different gene frequencies and mating patterns, age/parity distribution and use of preventive services [33]. There were also considerable variations in the distribution of different malformations [34].

The inverse relationship between maternal educational qualification and the occurrence rate of BDs might not indicate that the education level itself was a potential risk factor for BDs. The educational qualification most probably determined the socio-economic level and/or occupation. It is conceivable that education might affect the occurrence indirectly. The higher the education level, the more likely it is that the mother would have better knowledge of prenatal care. Likewise, the better-educated mothers may have access to better screening tests during pregnancy. Therefore, a malformed fetus may be terminated before birth [28,35,36]. This hypothesis could also provide an explanation for the decreased occurrence of live-born malformations in the higher maternal education qualification groups in our study.

From Figure 3, we can see that the occurrence rate of BDs increased with birth order. But this phenomenon might be explained by other factors rather than birth order itself. One of the possible reasons is the higher the birth order, the older the mother’s delivery age. From our study, the malformation rate was J-shaped along the maternal age axis.

There is also diversity in the overall BD occurrences across the parental occupations and employers’ industries, the occupation of ‘Agricultural & Fishery Workers’ having the highest rates of 23.4 per 1000 for fathers and 40.0 per 1000 for mothers. (The industry category ‘Mining and Quarrying’ actually had the highest BD rate of 43.5 per 1000 live births for mothers, but, as noted earlier, given the small sample size in this particular occupation and industry, any further inference would be premature.) These results highlight the need to conduct a more detailed study to identify the possible associations between parental occupations/industries and BDs.

In summary, the prevalence of BDs in Singapore is comparable to those in other countries. Parental work per se is not associated with BDs.

References