THE EPIDEMIOLOGY OF CEREBRAL PALSY IN BRITISH COLUMBIA

by

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The Epidemiology of Cerebral Palsy in British Columbia

Introduction: Cerebral palsy (CP) is a childhood condition related to a significant deficit in health for many individuals. Information provided by this research will assist health planners throughout British Columbia (BC) as resources are allocated for the treatment and care of children with CP.

Objective: To quantify the incidence of CP in BC within a four-year birth cohort.

Methods: The study is a population-based record linkage study of a birth cohort of BC children born between April 1, 1991 and March 31, 1995. Cases will be identified by the presence of the International Classification of Diseases, Version 9 (ICD-9) diagnostic code "343" recorded at three years of age or older, by having the ICD-9 diagnostic code "343" recorded prior to the third birthday with two confirmatory diagnoses within the first three years of life, through a record search of the BC Medical Services Plan billing files for the fiscal years 1991/92, 1992/93, 1993/94, 1994/95. These data were linked longitudinally to all further BC Medical Services Plan activity until March 31, 2001.

Results/Conclusion: This research has provided an estimate of the incidence of cerebral palsy in the four-year birth cohort 1991-1995 in British Columbia. An aggregate incidence rate of cerebral palsy was measured as 2.68 per 1000 live births, and a congenital rate was measured at 2.57 for the same population. Birth weight demonstrated a significant relationship with the development of cerebral palsy. As gestational age is highly correlated with birth weight, it may also have a significant relationship with the development of cerebral palsy. A significant relationship was not found between gender and area of residence (rural versus urban) and the development of cerebral palsy. Much research remains to be conducted in the epidemiology of cerebral palsy.

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CHAPTER 1 - INTRODUCTION

Preamble

Cerebral palsy is considered to be the most common, most disabling chronic childhood disorder. It has been defined as an umbrella-like term referring to a group of chronic conditions characterized by non-progressive, but often changing impairments in the structure of the central nervous system that result in variable impairments in the development of a child's motor and postural capabilities. Cerebral palsy is related to a significant deficit in health for many individuals. People with cerebral palsy also utilize a considerable number of health services. Limited research has been conducted in Canada regarding the epidemiology of cerebral palsy or health resource utilization for this population.

Purpose(s) of the Study

The purpose of this research is to describe the epidemiology of cerebral palsy in British Columbia.

Rationale for the Study

The epidemiology of cerebral palsy has not been measured in British Columbia, based on a lack of published evidence to the contrary. The information provided by this research will assist health planners throughout this province in terms of how resources are allocated for the treatment and care of children with cerebral palsy. The population-based approach will allow health planners to make decisions based on the most comprehensive data available in British Columbia.

Objective of the Study

The objective sought by this research is to quantify the incidence of cerebral palsy in British Columbia for a four-year birth cohort, dating from April 1, 1991 to March 30, 1995.

Research Questions

This research will attempt to answer three primary questions. First, is it possible to measure the incidence of cerebral palsy in a four-year birth cohort using linked health data? Second, what is the incidence of cerebral palsy in the four-year birth cohort from 1991-1995 in British Columbia? Third, are there any statistical differences among birth weight, gestational age and geographic area of residence with the occurrence of cerebral palsy?

CHAPTER 2 – LITERATURE REVIEW

This literature review provides an overview of the definitions of cerebral palsy and explores the aetiological, epidemiological and prognostic information related to cerebral palsy in the current literature.

What is Cerebral Palsy?

Cerebral palsy is not a single disorder with a single cause, but includes several different types of injury to a variety of areas of the developing brain (Goldstein, 2004).

There have been and continue to be a number of definitions of cerebral palsy. Each definition is similar, but not exact.

Cerebral palsy has been defined as an umbrella-like term referring to a group of chronic conditions characterized by non-progressive, but often changing impairments in the structure of the central nervous system that result in variable impairments in the development of a child's motor and postural capabilities. These impairments are often secondary to lesions or anomalies of the brain arising in the early stages of its development (Mutch, Alberman, Hagberg, Kodama, & Velickovic Perat, 1992; Murphy, Allsopp, Decoufle & Drews, 1993; and Koman, Smith & Shilt, 2004). It has also been simply defined as a disorder of movement and posture due to a defect or lesion of the immature brain (Suzuki & Ito, 2002).

A group calling itself the Surveillance of Cerebral Palsy in Europe (2000, p. 818-819), which constitutes a collaboration of 14 cerebral palsy surveys and registers, suggested that because of the variation in definitions, that it would be difficult to reach a consensual definition of what constitutes cerebral palsy. Rather they believe that any definition of cerebral palsy should include the following criteria: "(1) cerebral palsy is a group of disorders; (2) it is permanent but not unchanging; (3) it involves a disorder of movement and/or posture and motor function; (4) it is due to a non-progressive interference/lesion/abnormality; and (5) this interference/lesion/abnormality is in the developing/immature brain." Jacobsson and Hagberg (2004) concur and suggest cerebral palsy should be thought of as a symptom complex rather than a disease.

Cerebral palsy is also classified by subtype. While these subtypes have been relatively well defined throughout the years, some terms have been used synonymously. These subtypes follow the guidelines suggested by Hagberg, Hagberg and Olow (1993), and are defined as follows, according to the terms adopted by the Surveillance of Cerebral Palsy in Europe (2000):

- Bilateral spastic cerebral palsy (a.k.a. *quadriplegia, tetraplegia*): an abnormal pattern of posture and/or movement; increased muscle tone; an increase in pathological reflexes affecting limbs on both sides of the body.
- Spastic hemiplegic cerebral palsy: an abnormal pattern of posture and/or movement; increased muscle tone; an increase in the pathological reflexes affecting one side of the body.

- Ataxic cerebral palsy: an abnormal pattern of posture and/or movement; a loss of orderly muscular coordination so that movements are performed with abnormal force, rhythm and accuracy.
- Dyskinetic cerebral palsy: an abnormal pattern of posture and/or movement with involuntary, uncontrolled, recurring and occasionally stereotyped movements; may be either dystonic (reduced muscle activity with stiff movements and increased muscle tone) or choreo-athetotic (increased muscle activity with stormy movement and decreased muscle tone).
- Unclassifiable: other.

Some researchers have also attempted to classify cerebral palsy based on the level of severity (Grether, Cummins & Nelson, 1992; Colver, Gibson, Hey, Jarvis, Mackie, & Richmond, 2000; Parkes, Dolk, Hill & Pattenden, 2001). These levels include very mild, mild, moderate and severe. However, there does not appear to be consensus on what constitutes these levels.

Jacobsson and Hagberg (2004) believe that cerebral palsy should be classified or defined by the topographical distribution of the motor disorder (hemiplegia, diplegia, etc.) and the possible site of the lesion.

Cerebral palsy occurs congenitally due to a variety of prenatal or perinatal risk factors, or it may be acquired during the post-natal period, i.e. 28 days or more after birth (Stanley et al., 2000; and Cans, McManus, Crowley, Guillem, Platt, Johnson, and Arnaud, 2004).

According to Palmer (2004), cerebral palsy is a disorder of movement and postural control that results in functional limitations, and it is these functional limitations and their effects on daily activities that become the disability that is cerebral palsy.

The Epidemiology of Cerebral Palsy

Cerebral palsy is considered to be one of the most common, most disabling chronic childhood disorders (Colver et al., 2000; and Uldall, Michelsen, Topp and Madsen, 2001). It causes heavy demands on health, education and social service programs, as well as on families and the children themselves (Robertson, Svenson & Joffres, 1998; SCPE, 2000; and Uldall, Michelson, Topp and Madsen, 2001).

The majority of studies cited in this paper report the prevalence of cerebral palsy as the number of cases per 1000 live births/neonatal survivors. The majority of research into the epidemiology of cerebral palsy has been based on cerebral palsy registries (Uldall et al., 2001). Only one study has used a population-based record linkage (Robertson et al., 1998). Two studies reported the incidence of cerebral palsy (Nottidge and Okogbo, 1991; and Meberg and Broch, 1995).

Nottidge and Okogbo (1991) examined the number of referrals to a child neurology clinic in Ibadan, Nigeria from April 1980 to March 1983. They reported that 413 of 2053 referrals had a diagnosis of cerebral palsy. This yielded a percentage of 20.01% of all cases being referred to the clinic as having cerebral palsy. However, the authors inclusion criteria for what constituted cerebral palsy was very broad and these figures must be interpreted cautiously.

Sciberras and Spencer (1999) measured the period prevalence of cerebral palsy in Malta over the ten-year period from January 1, 1981 to December 31, 1990. Potential children with cerebral palsy were identified using various population-health registers and education registers. In total, 134 children met their case definition of cerebral palsy. The period prevalence rate for cerebral palsy for the Maltese population was 2.4 per 1000 (Sciberras and Spencer, 1999).

In 1995, Meberg and Broch published a study that traced a 20-year declining trend for cerebral palsy in Norway from 1970-89. They based their study on epidemiological data from the County of Vestfold, Norway for the period 1970-1989. Meberg and Broch (1995) split the group into two cohorts of children born during the 10-year periods 1970-79 and 1980-89. They then attempted to extrapolate the total incidence of cerebral palsy. The authors determined the total incidence of cerebral palsy during this 20-year period to be 2.4 per 1000. They also noted that there was a steady decline in cerebral palsy births from 2.8 per 1000 in the first five-year period of this study (1970-74) to 2.0 per 1000 in the final five-year period (1985-89), but the decline did not achieve statistical significance. Meberg and Broch (2004) recently updated this study, extending the period investigated to 30 years, from 1970-1999. They identified 166 cases of cerebral palsy registered among 70, 824 children, arriving at a prevalence rate of 2.3 per 1000 live births. The prevalence of cerebral palsy was found to be 15 times higher in low birth weight infants than in normal birth weight infants (p.436).

In a similar study, Kavcic and Velickovic Perat (1998) examined the prevalence of cerebral palsy in Slovenia during the birth years 1981 to 1990. Over the course of the study, 768 children with cerebral palsy were identified from Slovenia's National Cerebral Palsy Register. The authors found a significant decreasing trend in cerebral palsy during the period 1981 to 1990 from 3.3 per 1000 live births in 1981 to 2.3 per 1000 live births in 1990. These figures are very similar to the study by Meberg and Broch (1995) in Norway.

Bottos, Granato, Allibrio, Gioachin, and Puato (1999), in a study of the prevalence of cerebral palsy in two northeast Italian provinces, found that the prevalence of cerebral palsy increased from the mid-1960s to the mid-1980s, and then decreased between 1985-89. The authors identified 610 children with a diagnosis of cerebral palsy who were born in the provinces of Padua and Rovigo between 1965 and 1989. Bottos et al. (1999) recorded a crude prevalence rate for cerebral palsy of 1.82 per 1000 live births. They noted that this rate appeared to fluctuate from one year to the next during the study period. This study reported the prevalence rates in graphical form and expected the reader to extrapolate the information from the graphs provided. Thus, if one is to interpret the graphical information, the prevalence of cerebral palsy from 1965 to 1969 was about 1.5 per 1000 live births, from 1970 to 1974 was approximately 2.0 per 1000 live births, from 1975 to 1979 showed a sharp increase to roughly 2.7 per 1000 live births, and from 1980 to 1984 was equal to about 3.5 per 1000 live births. This rate then began to decrease in 1985 to 1989 to approximately 2.5 per 1000 live births. This was probably due to improved perinatal/neonatal care practices.

Suzuki and Ito (2002) conducted a study looking at the overall prevalence of six-year old children with cerebral palsy in Shiga Prefecture, Japan. They identified 325 cases of six-year old children with cerebral palsy from 1977 to 1991. Suzuki and Ito (2002) found an overall prevalence of cerebral palsy of 1.34 per 1000 six-year old children. The authors chose to use the age of six to identify the study population, as it is the mandatory age at which children must begin elementary school in Japan. This may be due to the fact that early diagnosis of cerebral palsy is sometimes difficult to confirm prior to the age of three.

Many epidemiological studies have been performed in the United Kingdom. All of these studies have been based on population-based registers of individuals with cerebral palsy. In 1995, MacGillivray and Campbell examined the changing pattern of cerebral palsy in the Avon area of southwest England during the 20-year period from 1969 to 1988. They identified 489 cases of cerebral palsy during this time period, all of which were registered with the Avon Handicap Register. The authors recorded a relatively constant prevalence rate of cerebral palsy varying between 1.93 and 2.27 per 1000 births between 1969 and 1988. This yielded an overall prevalence rate for cerebral palsy of 2.06 per 1000 (MacGillivray and Campbell, 1995).

Pharoah, Platt and Cooke (1996) disagree with MacGillivray and Campbell (1995) that the prevalence rate of cerebral palsy is constant. In fact, Pharoah et al. (1996) believe that there was a sharp rise in the prevalence of cerebral palsy over the 25-year period between 1966 and 1989. The authors attributed this rise in the

prevalence of cerebral palsy as being directly proportional to decreasing birth weights. Pharoah et al. (1996) agreed that the prevalence of cerebral palsy among children weighing greater than 2500 grams has remained steady at about 1.0-1.4 per 1000 neonatal survivors. However, for children born between 1500-2499 grams, there was an apparent threefold increase from approximately 4 per 1000 in the late 1960s to approximately 12 per 1000 neonatal survivors in the late 1970s. Coincidentally, children weighing less than 1500 grams also showed a threefold increase in the prevalence of cerebral palsy from 30 per 1000 to 90 per 1000 neonatal survivors during the 1970s. The prevalence of cerebral palsy during the 1980s for this group (1000-1499 grams) remained constant. This study took place in the counties of Merseyside and Cheshire, England. The size of the study population for this 25-year period was 1612 cases of cerebral palsy, all of who were identified using a population-based register. However, Pharoah et al. do not cite an overall prevalence of cerebral palsy for this study.

In a study conducted by Sinha, Corry, Subesinghe, Wild and Levene (1997), the prevalence of cerebral palsy was measured in an Asian community that was predominantly Pakistani Muslim, in the northeast of England. Cases of cerebral palsy were identified using the Yorkshire Regional Cerebral Palsy Register. Birth registrations were also recorded by ethnic subgroups, allowing Sinha et al. (1997) to determine the prevalence of cerebral palsy in both the Asian and the non-Asian population within the Bradford District Health Authority (BDHA). The study was conducted between 1985 and 1987. Sinha et al. (1997) recorded an overall prevalence of cerebral palsy of 3.87 per 1000 in the entire cohort within the Bradford District Health Authority. The researchers found that the Asian group

had a higher incidence of cerebral palsy (between 5.48 and 6.42 per 1000) as compared to the non-Asian group (3.18 per 1000).

In 1998, Pharoah, Cooke, Johnson, King and Mutch, looked at the epidemiology of cerebral palsy in the Mersey and Oxford regions of England and in Scotland. All cases of cerebral palsy born between 1984 and 1989 were included in the study. These cases were identified using the Mersey Cerebral Palsy Register, the Oxford Region Register of Early Childhood Impairments, and the Scottish Register of Children with a Motor Deficit of Central Origin. Pharoah et al. (1998) located 1649 cases of cerebral palsy born between 1984 and 1989. They calculated a cerebral palsy prevalence of 2.1 per 1000 neonatal survivors. These results contradict that of Pharoah et al. (1996), and are similar to those of MacGillivray and Campbell (1995).

Using data from the North of England Collaborative Cerebral Palsy Survey, Colver et al. (2000) ascertained 584 cases of cerebral palsy from all births between 1964 and 1993. The researchers analyzed the data in 5-year cohorts. They found a steadily increasing prevalence rate of cerebral palsy, rising from 1.68 per 1000 neonatal survivors in 1964-1968 to 2.45 per 1000 neonatal survivors in 1989-1993. Colver et al. (2000) attributed this increase in the overall rate of cerebral palsy to modern obstetric and neonatal care, citing the fact that many children born at < 2500 grams who would have died now survive with cerebral palsy.

The prevalence of cerebral palsy in Northern Ireland was examined by Parkes and colleagues in 2001. They explored the epidemiology of cerebral palsy in Northern Ireland between 1981 and 1993, based on 784 cases identified using the Northern Ireland Cerebral Palsy Register. Parkes et al. (2001) estimated an overall rate of cerebral palsy between 1981 and 1993 in Northern Ireland to be approximately 2.24 per 1000 live births. This rate is similar to other reported studies (Colver et al., 2000; Pharoah et al., 1998; MacGillivray and Campbell 1995).

Uldall, Topp and Langhoff-Roos (1997) reported an increase in the prevalence of cerebral palsy from 2.6 to 3.0 per 1000 from 1979-1982 to 1983-1986 in eastern Denmark. The data were gathered retrospectively from the Danish Cerebral Palsy Registry. In examining the data, Uldall et al. (1997) realized that the only rise in the rate of cerebral palsy was with those children born at less than 31 weeks gestation. The researchers concluded that the high prevalence rate of 3.0 per 1000 was due to broad inclusion criteria, higher completeness of registration, and possibly a higher risk for cerebral palsy in the Danish population.

In 2001, Topp, Uldall and Greisen published another study based in eastern Denmark. They found that the prevalence rate of cerebral palsy decreased from 3.0 per 1000 in the birth year period 1983-1986 to 2.4 per 1000 live births in the birth year period 1987-1990. The study population was again based upon children registered with the Danish Cerebral Palsy Register. Topp et al. (2001) identified 299 children with cerebral palsy during the study period. The researchers observed that between 1987-1990, the prevalence of cerebral palsy decreased by

approximately 35% in infants born at less than 38 weeks gestation. Thus, the rate of cerebral palsy in Denmark is similar to that in the United Kingdom.

A number of studies related to the prevalence of cerebral palsy have been reported from Sweden. In 1989, Hagberg, Hagberg and Zetterstrom expressed concern that the risk of cerebral palsy increased with a decrease in birth weight. They reported a decrease in the prevalence of cerebral palsy from 2.3 to 1.4 per 1000 live births during 1954-1970, and a subsequent increase in the prevalence of cerebral palsy after that time. This culminated in a prevalence rate of 2.17 per 1000 live births in the latter part of the study spanning 1979-1982. This increase was attributed to an increase in the number of preterm births (Hagberg et al., 1989).

In a comparative study between southwest Germany and western Sweden covering a period from 1975 to 1986, the researchers found the prevalence of cerebral palsy per live births and per neonatal survivors did not differ significantly (Krageloh-Mann, Hagberg, Meisner, Schelp, Haas, Eeg-Olofsson, Selbmann, Hagberg and Michaelis, 1994).

A series of epidemiological studies were conducted in Sweden between 1993 and 2001 (Hagberg, Hagberg and Olow, 1993; Hagberg, Hagberg, Olow, and Wendt, 1996; and Hagberg, Hagberg, Beckung and Uvebrant, 2001). In the 1993 study, Hagberg et al. determined the prevalence of cerebral palsy to be 2.49 per 1000 live births for children born between 1983 and 1986. They reported this to represent an increase since 1970. In a follow-up study covering the period 1987-

1990, the prevalence decreased slightly to 2.36 per 1000 live births (Hagberg et al., 1996). The latest Swedish study reported a further decrease in the prevalence of cerebral palsy of 2.12 per 1000 live births during the period 1991-1994 (Hagberg et al., 2001). This steady decrease was attributed to better obstetric and neonatal care.

Two studies were found in the literature pertaining to the prevalence of cerebral palsy in the United States. In the first study, Grether, Cummins and Nelson (1992) reported on a population-based study of 192 children residing in four San Francisco Bay area counties between 1983 and 1985. These children had to be alive and residing in California at age 3 years. The authors reported a prevalence of 1.23 /1000 survivors at age 3. Inclusion criteria for this study were narrow in scope, which may explain the low prevalence rate.

The second American study examined the prevalence of cerebral palsy among 10-year old children in metropolitan Atlanta from 1985 through 1987 (Murphy, Yeargin-Allsopp, Decoufle and Drews, 1993). Murphy et al. (1993) used a record review approach to identify 204 10-year old children with cerebral palsy, resulting in a prevalence of 2.3 per 1000. Inclusion criteria was broader for this study than for other studies, as it included children who had either congenital cerebral palsy (1.9 per 1000) or acquired cerebral palsy (0.4 per 1000), i.e. the injury/ lesion/abnormality occurred after the neonatal period and was not due to a perinatal event.

Cerebral palsy prevalence has been recorded in Western Australia since 1956 to the present day using a cerebral palsy register (Stanley, Blair & Alberman, 2000). Rates of overall cerebral palsy have remained between 2.0-2.5 per 1000 live births (Stanley et al., 2000).

Cans et al. (2004), on behalf of the Surveillance of Cerebral Palsy in Europe (SCPE) collaborative group, reported the prevalence rate of cerebral palsy of post-neonatal origin to be 1.26 per 10,000 live births. This study identified 347 cases of cerebral palsy of post-neonatal origin in children born between 1976 and 1990 who were reported to the SCPE common database by seven different centres. Prevalence among the centres reporting ranged from 0.46 to 2.05 per 10,000.

In Canada, the epidemiology of cerebral palsy has not been well documented. Robertson et al. (1998) conducted a population-based record linkage study in the province of Alberta. They identified 248 children living in the province of Alberta who were born between April 1985 and March 1988 who were diagnosed with cerebral palsy. The researchers were able to link diagnostic codes for all fee-for-service physician claims, all hospital separations and individual birth data from the Department of Vital Statistics of the Government of Alberta in order to identify these children. This linkage enabled Robertson et al. (1998) to calculate a prevalence rate for cerebral palsy of 2.57 per 1000 in the province of Alberta. This study included both congenital and acquired cases of cerebral palsy. The authors also calculated a prevalence rate for congenital cerebral palsy of 2.37 per 1000.

In a report published by the CanChild Centre for Disability Research in Hamilton, Ontario, a projected prevalence rate for cerebral palsy in the province of Ontario is suggested to be approximately 2.5 per 1000 (Missiuna, Smits, Rosenbaum, Woodside, and Law, 2001). Methods for obtaining this figure were not explained.

Table 2.1 – Epidemiology of cerebral palsy by country

Author(s)	Country	Data Source	Study Years	Rate (per 1000)
Hagberg et al. (1989)	Sweden	Registry	1954-1970	2.17
Grether et al. (1992)	United States	Registry	1983-1985	1.23
Hagberg et al. (1993)	Sweden	Registry	1983-1986	2.49
Murphy et al. (1993)	United States	Registry	1985-1987	2.30
Meberg & Broch (1995)	Norway	Registry	1970-1984	2.40
MacGillivray & Campbell (1995)	United Kingdom	Registry	1969-1988	2.06
Hagberg et al. (1996)	Sweden	Registry	1987-1990	2.36
Sinha et al. (1997)	United Kingdom	Registry	1985-1987	3.87
Uldall et al. (1997)	Denmark	Registry	1979-1986	2.60-3.00
Kavcic & Velickovic Perat (1998)	Slovenia	Registry	1981-1990	2.30
Pharoah et al. (1998)	United Kingdom	Registry	1984-1989	2.10
Robertson et al. (1998)	Canada	Record linkage	1985-1988	2.57
Bottos et al. (1999)	Italy	Clinical record search	1965-1989	2.50
Colver et al. (2000)	United Kingdom	Registry	1964-1993	2.45
Stanley et al. (2000)	Australia	Registry	1956-2000	2.00-2.50
Hagberg et al. (2001)	Sweden	Registry	1991-1994	2.12
Parkes et al. (2001)	Northern Ireland	Registry	1981-1993	2.24
Topp et al. (2001)	Denmark	Registry	1983-1986	3.00
Topp et al. (2001)	Denmark	Registry	1987-1990	2.40
Suzuki & Ito (2002)	Japan	Registry	1977-1991	1.34
Meberg & Broch (2004)	Norway	Registry	1970-1999	2.30

In summary, the prevalence rate of cerebral palsy in developed and developing nations appears to be between 2-3 per 1000 live births/neonatal survivors (Table 2.1), with a few exceptions. There seems to be some disagreement among researchers as to whether congenital and acquired cases of cerebral palsy should be considered together when calculating prevalence rates for cerebral palsy. Cerebral palsy registers exist in most European countries and some American States, but do not appear to exist in Canada. Only one study (Robertson et al.,

1998) appeared to use data linkages in order to calculate a prevalence rate of cerebral palsy.

The Aetiology of Cerebral Palsy

The aetiology for the majority of cases of cerebral palsy has not been established (Coorssen, Msall, and Duffy, 1991; Stanley, Blair, Hockey, Petterson, and Watson, 1993; Ramin, 2000; Ramin and Gilstrap, 2000; Griffin, Fitch, and Griffin, 2002). It has been estimated that for approximately 75% of cases of cerebral palsy, a single causative factor cannot be elucidated (Pschirrer and Yeomans, 2000). Stanley et al. (2000) believe that cerebral palsy is caused by multiple factors that follow a causal pathway, and that these causal factors may occur at any time during the early stages of the brain's development. Di Tommaso and Tranquilli (2004) have developed a checklist to identify the origin of cerebral palsy, which if used appropriately they believe will reduce the number of cases ascribed to unknown aetiology.

In 1998, Badawi and colleagues undertook the challenge of defining what constitutes cerebral palsy. They found that the inclusion criteria for many of the cerebral palsy registers were different and attempted to standardize it. Badawi et al. (1998) were able to compose a list of some conditions that definitely do not meet with the definition of cerebral palsy mentioned earlier in this paper. These included neurodegenerative conditions, neuromuscular disorders, neural tube defects of the spine, and tumours. Some disorders which may be excluded as cerebral palsy also include hypotonia, some genetic syndromes that are easily recognizable such as Down syndrome, metabolic disorders that are progressive in

nature, and syndromes with progressive vascular defects (Badawi et al., 1998; Badawi, 2000; and Gupta and Appleton, 2001).

Until the late 1970s and early 1980s, cerebral palsy was thought to be primarily caused by asphyxia during the birthing process (Al-Rajeh, Bademosi, Awada, Ismail, Al-Shammasi, and Dawodu, 1991). Recent research has shown that asphyxia has been estimated to be responsible for only about 6% to 10% of all cases of cerebral palsy (Shields and Schifrin, 1988; Pschirrer and Yeomans, 2000; McDonald and McMenamin, 2001; Lawson and Badawi, 2003; and Shevell, Majnemer, and Morin, 2003). Pschirrer and Yeomans (2000) also concluded that the criteria needed to diagnose antepartum or intrapartum asphyxia are still imprecise. Moreover, they reported "most cases of perinatal asphyxia are not followed by cerebral palsy, and most cerebral palsy is not associated with severe intrapartum asphyxia" (p. 219). Contrarily, in a study conducted on children with a birth weight ≥2500 grams, intrauterine hypoxia/birth asphyxia was strongly associated with an increased risk of cerebral palsy in children with no congenital abnormalities (Dite, Bell, Reddihough, Bessell, Brennecke, and Sheedy, 1998). Shevell (2004) postulated "neonatal encephalopathy at a moderate or severe level is a necessary antecedent to later cerebral palsy if intrapartum asphyxia is causally responsible for the cerebral palsy" (p. 26). He concluded that cerebral palsy is but one possible outcome of intrapartum asphyxia.

Related to asphyxia is the use of Apgar scores. Apgar scores had been used in the past and, continue to be used today, as an indication of lack of oxygen during the birthing process. However, Apgar scores are not indicative of an outcome

resulting in cerebral palsy (MacLennan, 1999). It has been reported that 93% to 95% of infants with 5-minute Apgar scores of 0 to 3 (Normal 1-minute Apgar scores are 7-10) will not have cerebral palsy (Paneth, 2001).

Coorssen et al. (1991) attempted to identify the occurrence of multiple minor malformations as an indicator for the prenatal aetiology of cerebral palsy. The researchers identified 109 cases of cerebral palsy with a suspected prenatal origin and used a modified version of the Weighted Anomaly Score to examine for any birth anomalies in this group. This group was compared to a group of 28 children with a suspected postnatal cause of cerebral palsy. The results suggested that minor malformations/anomalies appeared to occur more often in children with an identified prenatal cause of cerebral palsy than in children with a postnatal cause (Coorssen et al., 1991).

Thrombophilia, which is the presence of thrombi in maternal or foetal circulation, has also been implicated as a possible cause of cerebral palsy (McDonald and McMenamin, 2001). However, in a recent population-based study examining the relationship between thrombophilia and hemiplegic cerebral palsy, no conclusive association was found (Smith, Skelton, Howard, and Levene, 2001). Conversely, other epidemiological research is accumulating evidence that links thrombosis to the development and possible cause of cerebral palsy, as recently noted by Gibson and colleagues (2003).

There have been a number of reports of the association between chorioamnionitis, an inflammation of the foetal membranes, and cerebral palsy

(Grether and Nelson, 1997; O'Shea, Klinepeter, and Dillard, 1998; Vigneswaran, 2000; Gilstrap III and Ramin, 2000; Wu and Colford, 2000; McDonald and McMenamin, 2001). Grether and Nelson (1997) reported that the presence of chorioamnionitis and a maternal fever of $\geq 38^{\circ}$ Celsius were associated with an increased risk of cerebral palsy in children with birth weights greater than 2500 grams. Children with birth weights under 2500 grams were not included in the study population. Wu and Colford Jr. (2000) performed a meta-analysis on previous studies reporting an association between the presence of chorioamnionitis and the occurrence of cerebral palsy or cystic periventricular leukomalacia. They concluded that their meta-analysis indicated that chorioamnionitis is a risk factor for both cerebral palsy and cystic periventricular leukomalacia. This association is further supported by Vigneswaran (2000) and Gilstrap III and Ramin (2000). Wu and her colleagues later supported their conclusion with a case-control study to clarify the relationship between chorioamnionitis and the risk of cerebral palsy. Using a study population of 231, 582 singleton infants born alive at greater than 36 weeks born between 1991-1998, the researchers were able to identify 109 children with severe spastic or dyskinetic cerebral palsy. Chorioamnionitis was diagnosed in 14% of theses children, representing an odds ratio of 3.8. According to the researchers, this indicates that clinical chorioamnionitis is an independent risk factor for cerebral palsy in term and near-term infants (Wu, Escobar, Grether, Croen, Greene, and Newman, 2003).

In a recent Swedish study, Jacobsson (2004) used a population-based series of 148 preterm infants with spastic cerebral palsy, born between 1983-1990, and

matched them with a control group in order to examine inflammatory mechanisms that contribute to the development of cerebral palsy. He reported an association between antenatal infection/inflammation and cerebral palsy.

Wheater and Rennie (2000) examined 69 very low birth weight infants with cerebral palsy at an 18-month follow up using cranial ultrasound in an attempt to detect brain abnormalities. They reported that 39 children had cranial ultrasound abnormalities while 30 children had normal cranial ultrasounds. Infection also appeared to play a prominent role in their findings, with the presence of sepsis increasing the risk of cerebral palsy fourfold (Wheater and Rennie, 2000).

There has been some question as to whether preeclampsia, a toxemia of late pregnancy, is associated with an increased risk of cerebral palsy or reduced risk of cerebral palsy (Spinillo, Capuzzo, Cavallini, Stronati, De Santolo, and Fazzi, 1997; Collins and Paneth, 1998; and Gray, Jones, and O'Callaghan, 2001). Collins and Paneth (1998) suggested that there is insufficient evidence to provide an explanation of the relationship between preeclampsia and cerebral palsy. Gray et al. (2001), studied a group of children born between 24 and 27 weeks' gestation over an 8-year period in order to determine obstetric risk factors for cerebral palsy. They found that maternal preeclampsia was not associated with a statistically significant reduction in the risk of cerebral palsy. However, Spinillo et al. (1997), in their investigation of the relationship between the presence of preeclampsia and cerebral palsy, indicated that preeclampsia provided a protective effect against the development of cerebral palsy in the preterm infant.

In 1997, Dammann and Leviton used annotated evidence to hypothesize that maternal bacterial vaginosis increased the risk of intrauterine infection. This, in turn, increased the risk of newborn white matter damage to the brain. As a result of this newborn white matter damage, Dammann and Leviton suggested that one could predict the development of cerebral palsy in children born before 37 completed weeks of gestation. This hypothesis remains to be tested.

Yoon and colleagues (2003) and Grether and colleagues (2003) recently examined the relationship of intrauterine infection and the development of cerebral palsy. Yoon et al. (2003) believe that intrauterine infection can cause a foetal inflammatory response that predisposes the foetus to develop cerebral palsy, but are quick to point out that it is unlikely that the infection or the inflammation is sufficient in itself to directly cause cerebral palsy. Grether et al. (2003), in a retrospective case-control study of 170 singleton children born between 1988 and 1994 with spastic cerebral palsy who weighed less than 1999 grams and survived to age 2 years, found that exposure to intrauterine infection was not an independent risk factor for cerebral palsy in very preterm infants when gestational age and other confounders were tightly controlled. This supports Yoon et al. (2003) in presuming that intrauterine infection does not of itself cause cerebral palsy.

Hughes and Newton (1992) reported that possibly as high as 2% of cases of cerebral palsy may have a genetic basis. They based this speculation on a review of the literature.

The use of dexamethasone to treat preterm infants with respiratory distress syndrome has been implicated by Shinwell and colleagues (2000) as a possible cause of cerebral palsy and developmental delay. Shinwell et al. (2000) conducted a randomized, double blind, placebo controlled study of early postnatal dexamethasone treatment for prevention of chronic lung disease. They found that a three-day course of dexamethasone treatment administered shortly after birth to preterm infants with respiratory distress syndrome was associated with a significantly increased incidence of cerebral palsy and developmental delay.

Because cerebral palsy is thought to be due to a lesion or abnormality in the developing brain (SCPE, 2000), some research has been conducted using magnetic resonance imaging (MRI) to retrospectively analyze the brain images of people with cerebral palsy (Sugimoto, Woo, Nishida, Araki, Hara, Yasuhara, Kobayashi, and Yamanouchi, 1995; and Okumura, Kato, Kuno, Hayakawa, and Watanabe, 1997). In their 1995 retrospective study of 70 children with cerebral palsy, Sugimoto et al. found that cerebral palsy of term infants was likely due to prenatal factors as indicated by MRI findings showing neuronal migration disorders and cerebral infarct. They did caution that MRI on its own does not always reveal when the brain damage occurred. Okumura et al. (1997) studied MRIs of the brain in 152 children aged 1 to 19 years who had spastic cerebral palsy. From these imaging studies, the researchers found the primary lesion responsible for diplegia (bilateral spastic cerebral palsy affecting two limbs) was periventricular leukomalacia. In children with quadriplegia (bilateral spastic cerebral palsy affecting four limbs), periventricular leukomalacia, term-type brain injury and brain anomalies were the main types of lesions. Okumura et al. (1997)

believe that "MRI of the brain is helpful in understanding the pathogenesis of cerebral palsy, although further study is necessary" (p.372). Accardo, Kammann, and Hoon (2004) noted that evidence from imaging studies show that children with spastic forms of cerebral palsy often demonstrate white matter injury, whereas children with extrapyramidal syndromes (dystonia, ataxia, etc.) frequently have damage to the basal ganglia, possibly caused by conditions such as genetic metabolic disorders, kernicterus, mitochondrial disorders or hypoxic ischemic encephalopathy.

A number of studies have also implicated multiple pregnancies as being a risk of developing cerebral palsy (Laplaza, Root, Tassanawipas, and Cervera, 1992; Pharoah and Cooke, 1997; O'Shea at al., 1998; and Pharoah, 2001). Laplaza et al. (1992) found that of the 1217 cases of cerebral palsy in their study, 86 or 7.1% were the result of a twin pregnancy. They reported that cerebral palsy was about six times more frequent among children born as a result of a twin pregnancy and was more likely to occur in monozygotic versus dizygotic pregnancies. Pharoah and Cooke (1997) proposed that spastic cerebral palsy of unknown aetiology might be the result of the death of a co-twin early in the pregnancy and may result in impairing the neurological development of the surviving twin throughout gestation. In 2001, Pharoah tested this hypothesis by analyzing the birth and death certificates for same sex and different sex twins in England and Wales for the period 1993-1995 where both twins were live births. Pharoah (2001) found that the neonatal death rate in same sex twins was 25.4 per 1000 live births and in different sex twins was 18.0 per 1000 live births. This was thought to be attributable to the higher proportion of same sex twins with low birth weight. Blair

and Stanley (2002) suggest that multiple pregnancies born pre-term and at term are 1-2 and 3 times, respectively, more likely to have cerebral palsy than single pregnancies born at the same times. Using annotated information, Blickstein (2004) noted that the association of cerebral palsy and multiple pregnancies has been observed worldwide, with the data indicating that the higher the number of the foetuses, the greater is the prevalence of cerebral palsy.

In a recent study from Denmark, Pinborg and colleagues (2004) found that twins born after assisted conception had a similar risk of neurological sequelae, including cerebral palsy, as naturally conceived twins and singleton births after in-vitro fertilization or intracytoplasmic sperm injection. The crude prevalence rates per 1000 for cerebral palsy in twins and singleton births after assisted conception and in naturally conceived twins were 3.2, 2.5 and 4.0 respectively.

It has been well documented in the literature that survival of newborn infants of low birth weight has increased the risk for the development of cerebral palsy (Skidmore, Rivers, and Hack, 1990; Stanley et al., 1993; Hagberg et al., 1993; Krageloh-Mann et al., 1995; Hagberg et al., 1996; Pharoah et al., 1996; O'Shea et al., 1998; Colver et al., 2000; Stanley et al., 2000; Dolk et al., 2001; and Hagberg et al., 2001). Hagberg et al. (1993) reported that the prevalence of cerebral palsy from 1983-1986 in Sweden was 49.8 per 1000 for a birth weight of <1500 grams compared to 14.4 for birth weight between 1500-2499 grams and 1.5 for birth weight ≥2500 grams. During the birth year period 1987-1990, Hagberg et al. (1996) found that infants with a birth weight <1000 grams had a cerebral palsy prevalence of 57 per 1000, 68 per 1000 for infants between 1000-1499 grams, 14

per 1000 for 1500-2499 grams and 1.4 per 1000 for birth weights ≥2500 grams. For the birth year period 1991-1994, the prevalence of cerebral palsy was 48.51 per 1000 for a birth weight <1000 grams, 80.97 for a birth weight of 1000-1499 grams, 11.42 for a birth weight of 1500-2499 grams, and 1.25 for a birth weight ≥2500 grams (Hagberg et al., 2001). Pharoah et al (1996) reported similar findings in the counties of Merseyside and Cheshire in England between 1966 and 1989, noting that the prevalence of cerebral palsy in low birth weight infants appeared to be increasing and that this apparent increase was also associated with an increase in the functional severities of the disability. Colver et al. (2000) ascertained that there was an increase in cerebral palsy in the north-east of England during the birth year period 1989-1993 for children with birth weights <1500 grams (29.8 to 74.2 per 1000 neonatal survivors) and between 1500-2499 grams (3.9 to 11.5 per 1000 neonatal survivors). Dolk et al. (2001) reported similar findings in Northern Ireland. The research indicates that because of improvements to obstetric and neonatal care over the past 30 years, children born at low and very low birth weights have an increased rate of survival, but may also have an increased risk of developing cerebral palsy (Skidmore et al., 1990; Hagberg et al., 1996; and Colver et al., 2000). It has also been estimated that very low birth weight neonates now constitute approximately 26% to 28% of all new cases of cerebral palsy (O'Shea et al., 1998).

The aetiology of congenital cerebral palsy remains largely speculative and is often not known. It would appear that the best indicator of risk for developing cerebral palsy is a newborn's birth weight. Unfortunately, there does not appear to be a good screening test for cerebral palsy that is highly predictive. However,

research is ongoing in the areas of surveillance and early identification of cerebral palsy (Morgan and Aldag, 1996; and Lindstrom and Bremberg, 1997). For example, a recent Australian case-control study was able to identify neonatal risk factors associated with the development of cerebral palsy for children born at term and preterm (Walstab, Bell, Reddihough, Brennecke, Bessell and Beischer, 2004). The researchers found that for children born at term 73% of cases and 2% of controls were likely to develop cerebral palsy if one of the following factors was present: seizures, congenital abnormalities of the brain and elsewhere, other lesions, abnormal muscle tone and meconium aspiration. For children born preterm, the likelihood of the development of cerebral palsy for 68% of cases and 26% of controls were identified by the following factors: seizures, intraventricular haemorrhage, periventricular leukomalacia, other lesions and abnormal muscle tone. Table 2.2 provides a summary of recognized risk factors for developing cerebral palsy.

Table 2.2 - Some recognized risk factors for cerebral palsy

Advanced maternal age	Multiple pregnancy
Assisted reproduction	Neonatal encephalopathy
Birth defects	Nutritional deficiencies
Catastrophic intrapartum events	Poor education
Child abuse	Poor hygiene
Chromosomal anomalies	Poor nutrition
Close child spacing	Poor obstetric history
Coagulation defects	Poverty
Consanguinity	Preterm or very preterm birth
Cystic white matter damage	Prolonged menstrual cycles
Delayed childbearing	Promiscuity
Difficult delivery	Recessive genetic defects
Domestic violence	Sexually transmitted disease
Environmental degradation	Social isolation
Genital tract infections	Stress
Infertility drugs	Substance abuse
Intrauterine growth restriction	Teenage motherhood
Maternal abdominal trauma	TORCH infections
Maternal mental retardation	Toxic exposures
Maternal thyroid disease	Unemployment

Reprinted with permission from Blair and Stanley (2002) (personal communication May 31, 2004)

The aetiology of cerebral palsy of post-neonatal origin is somewhat better understood, and is of interest to researchers due to it often being preventable (Cans et al., 2004). There seems to be little difference among developing and developed nations with reference to aetiology (Stanley et al., 2000). Table 2.3 provides a summary of conditions that have been known to cause cerebral palsy of post-neonatal origin (Stanley et al., 2000; and Cans et al., 2004).

Table 2.3 - Aetiology of cerebral palsy of post-neonatal origin

Infection
Meningitis or encephalitis
Reye's syndrome
Pertussis
Post diphtheria-tetanus-pertussis immunization
Gastroenteritis + dehydration
Head injury
Motor vehicle/road traffic accident
Falls
Traumatic head/brain injury
Non-accidental injury
Unspecified cause
Vascular episode
Post-heart surgery
Post-other surgery
Associated with congenital heart disease
Cerebrovascular accident
Miscellaneous
Apparently life-threatening event
Near-drowning
Status epilepticus
Suffocation
Malnutrition
Unknown
Other miscellaneous events

Adapted from Stanley et al. (2000) and Cans et al. (2004).

The Prognosis of Cerebral Palsy

When considering the prognosis of cerebral palsy, life expectancy, survival and mortality must be examined. However, there has been relatively little information published regarding the life expectancy, survival and mortality for persons with cerebral palsy (Hutton, Cooke, and Pharoah, 1994; Crichton, Mackinnon and White, 1995; and Strauss and Shavelle, 1998).

Hutton et al. (1994) reported on the survival of children with cerebral palsy born between 1966-1984 to mothers who were residents of the Mersey region of

England. They examined the effect of cognitive and motor disability, birth weight, and gestational age on life expectancy. The researchers found that the 20-year survival rate for the entire cohort was 89.3% for females and 86.9% for males. Subjects who were severely disabled had a 20-year survival of 50% as compared to those with no severe functional limitations (99%). Interestingly, Hutton et al. (1994) found that children with cerebral palsy who were of normal birth weight and who were of full term gestation were more likely to have a severe form of cerebral palsy and thus a reduced life expectancy, as compared to children with cerebral palsy who were of low birth weight and low gestational age. They also reported that birth weight and gestational age were less predictive of survival than the level of functional disability.

Crichton et al. (1995) supported Hutton and colleagues' suggestion stating that, "the most important factors influencing survival are the presence of severe mental disability and reduced mobility" (p. 567). Crichton et al. (1995) conducted a study in British Columbia on life expectancy of a cohort of all cases of cerebral palsy registered with the Health Surveillance Registry (now the Health Status Register, BC Department of Vital Statistics) who were born between 1952 and 1989. The researchers found that there was no apparent difference in the survival times between males and females, reporting a 30-year survival rate of approximately 87%. They found that there was an association of reduced survival time if the subject had profound mental retardation, a severe form of cerebral palsy, and epilepsy.

Strauss and Shavelle (1998) examined data on 24,768 individuals with cerebral palsy aged 15 years and over who received services in California between January 1980 and December 1995 to determine the predictors of mortality and life expectancy. The two most frequent risk predictors were lack of mobility and inability to feed oneself. They also found that the type, severity and location of cerebral palsy had a lesser effect on survival. Life expectancies for adults with high levels of functioning, i.e. full motor and feeding abilities, were approximately only 5 years less than those for the general population (Strauss and Shavelle, 1998).

Strauss, Shavelle and Anderson (1998) authored a second study that examined risk factors for mortality of young children with cerebral palsy. Their study consisted of a sample of 12,709 children between the ages of 6 months to 3 years, 6 months with cerebral palsy who had received services from the state of California between 1980 and 1985. They again reported that the children with the best prognosis for survival were those with good mobility and feeding skills. Strauss et al. (1998) reported that the survival rate for children with fair motor and eating skills approached 90 % or better for reaching adulthood. Children who were unable to lift their heads when lying on their stomachs had approximately 8 times greater mortality risk than children who were able to roll/sit and who were able to walk 10 feet or more unaided. The authors also found that children who were tube fed were at a much higher risk for mortality, ranging from 3.85 at 2-3 years to 5.15 at 1 year, than children who had some self-feeding skills. Like Hutton et al. (1994), Strauss et al. (1998) found that children with low birth

weight and gestation had better survival rates than those of normal birth weight and gestation.

In 1998, a study examining the trends in mortality and cerebral palsy in a geographically-based cohort of infants weighing between 500 grams to 1500 grams born in North Carolina between July 1982 through June 1994 was conducted (O'Shea, Preissner, Klinepeter, and Dillard, 1998). O'Shea et al. (1998) reported that mortality did not change significantly up to 1990, but then began to decrease between 1990 and 1994 for this group. They found that mortality decreased from approximately 37% from 1982 to approximately 14% in 1994. The prevalence of cerebral palsy among children of very low birth weight also decreased throughout the study period. The authors concluded that the decline in mortality among very low birth weight infants during the 1990s has not resulted in an increase in the prevalence of cerebral palsy as was reported from studies in Western Australia, England and Sweden (O'Shea et al., 1998).

Williams and Alberman (1998) examined the role of severity and diagnostic labels on survival in cerebral palsy in the southeast area of England from 1980 to 1986. They found that approximately 85% of children with severe four-limb cerebral palsy survived to 15 years of age, consistent with other studies (Hutton et al., 1994; Crichton et al., 1995; and Strauss et al., 1998). The authors concluded that 15% of children with severe cerebral palsy died in childhood, suggesting that children with bilateral spastic cerebral palsy involving all four limbs are at a higher risk of mortality before they reach adolescence.

Strauss, Cable and Shavelle (1999) reported on diseases that may be causally linked to excess mortality in persons with cerebral palsy. They used a sample of 45,292 individuals with cerebral palsy, 4028 of whom died during the study period from 1986 to 1995. The authors obtained a standardized mortality ratio for this population of 8.4 as compared to the general population. They found that breast cancer rates were three times that of the general population, and that brain cancer rates were 24 times that of the general population, particularly for children, suggesting poorer detection and/or treatment. Standardized mortality ratios were also higher for persons with cerebral palsy for respiratory diseases, circulatory diseases, digestive tract diseases, and deaths due to external causes such as drowning or being hit by motor vehicles (Strauss et al., 1999).

In a similar study, Maudsley, Hutton and Pharoah (1999) evaluated cause of death information in people known to have cerebral palsy who had died prior to June 30, 1998, and who were registered with the Mersey Cerebral Palsy Register, a register which serves the Merseyside and Cheshire regions of England. The authors recorded mortality information on 2102 registered cases. This information was obtained from the National Health Service Central Register that requires a four digit International Classification of Disease – 9th Revision (ICD-9) code related to cause of death. This ICD-9 code was then linked to the case in question. Cerebral palsy was listed as the underlying cause of death in approximately 34% of cases. Another 13% of cases had the underlying cause of death listed as pneumonia. Approximately 61% of cases had a severe form of cerebral palsy (Maudsley et al., 1999).

Hutton, Colver and Mackie (2000) investigated the effect of motor and cognitive disabilities on the survival of persons with cerebral palsy in the Northumberland, Newcastle and North Tyneside health districts of northeast England born between 1960 and 1990. The researchers found that approximately one-third of those with a severe disability died before the age of 30 and that one-third of the deaths were attributed to cerebral palsy on the death certificates. Similar to other studies (Hutton et al., 1994; and Crichton et al, 1995), people with a severe form of cerebral palsy, including severe mobility restrictions and cognitive limitations, have an increased risk of dying as compared to those with a less severe form of cerebral palsy, approximately 60% as compared to approximately 98% (Hutton et al., 2000). Hutton et al. (2000) also reported that persons with cerebral palsy who have severe manual disability have a risk of dying that is 25 times higher than those without. Survival was reported to be poorest for children born weighing approximately 3000 grams, was better for larger birth weights, and was best for infants weighing less than 2500 grams. Hutton et al. (2000) believed this was due to severely damaged premature infants being less likely to survive until diagnosis than full term infants.

Predictors and causes of death in persons with cerebral palsy were reported for a cohort of 2014 in Western Australia who were born between 1958 and 1994. There were 225 people who had died before May 31, 1997 (Blair, Watson, Badawi, and Stanley, 2001). Blair et al. (2001) estimated crude and standardized mortality rates for the sample. The crude mortality rate was 6.23 deaths per1000 person years. Standardized mortality rates ranged from 0 in persons over 40 to 45.27 for children between 5 and 10 years of age. The standardized mortality rates

were highest for children between 1 and 15, being between 4 and 5 times greater than for persons between 15 and 40. The underlying cause of death was listed as cerebral palsy in 78.8% of cases, with respiratory disease accounting for 59% of deaths (Blair et al., 2001). Blair et al. (2001) concurred with previous studies that severe motor impairment and intellectual disability contributed significantly to mortality (Hutton et al., 1994; Crichton et al., 1995; and Hutton et al., 2000). They also found that infants born after more than 32 weeks' gestation were at a significantly higher risk of mortality than children born very preterm (Blair et al., 2001). The researchers concluded, "with the exception of those with profound intellectual deficit, most persons with cerebral palsy survive to adulthood" (Blair et al., 2001, p. 514).

Reddihough, Baikie and Walstab (2001) conducted a similar study in Victoria, Australia, examining the causes of death and the characteristics of children with cerebral palsy who had died between 1970 and 1995. The authors identified 155 children who had died during this period and found the predominant cause of death to be pneumonia (61/155, or 39.4%). There was an unknown cause of death in approximately 41.9% of cases. Of the 155 children who died, 89.0% had severe cerebral palsy compared to 4.5% with moderate and 5.2% with mild cerebral palsy. Of the children who died, the majority had a birth weight >2500 grams and were born between 37-44 weeks gestation. Most of the children who died during the study period had severe bilateral spastic cerebral palsy affecting four limbs, intellectual disability, and epilepsy (Reddihough et al., 2001).

In 2002, Hutton and Pharoah published a study that attempted to quantify the effects of motor, cognitive and sensory disabilities, year of birth, birth weight, and gestational age on survival in cerebral palsy. They studied a cohort of 1942 children with cerebral palsy born between 1966 and 1989 to mothers who were resident of Merseyside and Cheshire, England. They found that severe motor disability was associated with a 30-year survival of 42% and that severe cognitive disability was associated with a 30-year survival of 62% (Hutton and Pharoah, 2002). Hutton and Pharoah (2002) also concluded that survival among children of low birth weight declined steadily from 1966 to 1989 after allowing for disability.

In a systematic literature review dealing with life expectancy in children with cerebral palsy, Katz (2003) concluded that life expectancy depended on presence and severity of cognitive impairment, severity of physical disability, tube feeding, incontinence, and presence and severity of seizures. He also noted that life expectancy for physically and mentally disabled persons has increased slightly with time, although this does not seem to be the result of improvements in medical care or as a result of de-institutionalization.

Strauss, Ojdana, Shavelle and Rosenbloom (2004) studied the decline in function and life expectancy of 904 subjects of age 60 with cerebral palsy. They found that the abilities of person at 60 were not markedly different than younger persons with cerebral palsy. However, they also point out that persons with the most severe disabilities associated with cerebral palsy rarely survive to age 60. Strauss et al. (2004) concluded that survival rates of ambulatory older adults were only moderately worse than the general population, but that survival was much

poorer among those older adults who had lost their mobility and the ability to dress themselves.

In summary, it appears that the best predictors of a poor prognosis for cerebral palsy are the presence of severe motor and cognitive impairments, a birth weight ≥2500 grams, and gestation between 37-44 weeks. Most children with cerebral palsy will survive until adulthood, although the death rate is higher than in children who do not have cerebral palsy (Liptak and Accardo, 2004).

Conclusion

This literature review has presented the epidemiology, aetiology and prognosis of cerebral palsy based on information available in the current literature. Cerebral palsy occurs in approximately 2-3 per 1000 live births/neonatal survivors. Its aetiology remains largely speculative and/or unknown. Persons with cerebral palsy are likely to survive until adulthood, but those with severe motor and intellectual impairments are at a greater risk of dying.

CHAPTER 3 – METHODS

Primary Objectives

This research was conducted in order to provide an overview of the epidemiology of cerebral palsy in British Columbia in a four-year birth cohort of children born between April 1, 1991 and March 31, 1995. The objective of this research was to quantify the incidence of cerebral palsy in the four-year birth cohort for children in British Columbia.

Choice of Study Design

This research was a population-based record linkage study of a birth cohort of British Columbian children born between April 1, 1991 and March 31, 1995. It employed the use of systematically collected health data, rather than using a survey or cohort approach. Systematically collected health data may be less prone to underreporting as the submission of health information has been traditionally linked to health funding. According to Robertson et al. (1998), population-based record linkage for the purpose of recording the epidemiology of cerebral palsy allows the researcher to avoid recall bias, to avoid the need for direct subject contact, to provide cost effective measurement and analysis, to generate a large sample size, and to allow for the results to be generalized to other studies of cerebral palsy. Systematic error was likely reduced as the majority of health-related services provided to persons with cerebral palsy are by specialist practitioners. Also, systematically recorded health data may identify some of the less severe cases that might not be identified by surveillance.

Study Population

Inclusion Criteria: Subjects were identified by documenting diagnostic codes used by physicians and hospitals during the years reviewed for this study. The diagnostic codes being used are from the International Classification of Diseases, Version 9 (ICD-9) (International Classification of Diseases, 1977) as this was the relevant source for diagnostic codes for the time of the cohort. Cases were identified by the presence of the ICD-9 diagnostic code "343" for cerebral palsy recorded at three years of age or older, or by having the ICD-9 diagnostic code "343" recorded prior to the third birthday with two confirmatory diagnoses within the first three years of life. Each child had a minimum of six years of post-birth follow-up information in order to confirm the presence of cerebral palsy. In addition to the above codes for cerebral palsy, the following codes were also used to clarify a child's diagnosis: congenital abnormalities of the nervous system (742), other congenital abnormalities, (743-757, 759), and progressive neurological disorders (330, 331, 334, 335, 340, 341).

The following codes were searched in order to determine whether children with cerebral palsy may have acquired the disorder: malignant neoplasms of the brain (191), inflammatory disease of the nervous system (320-326), other conditions of the brain and nervous system (348, 349), intracranial haemorrhage (430-432), aborted sudden infant death syndrome (798), fracture of the skull (800-840), other injuries (950-959, 990-995), intracranial injury excluding skull fracture (850-854), late effects of injuries (905-909), and poisoning (960-989). These additional codes were suggested by Robertson et al. (1998).

Exclusion Criteria: Children whose health insurance was not continuous of the six-year follow-up period were excluded. Also, children with the ICD-9 diagnostic codes identifying chromosomal abnormalities (758.x) and spina bifida (741.x) were not included in this research.

Based on the work of Robertson et al. (1998), who completed a similar study in Alberta, Canada, the estimated number of cases available for this four-year birth cohort should be approximately 450. This was based on the average yearly population during the study-subject birth years for British Columbia of 3.57 million (BC Statistics, 2004).

British Columbia Linked Health Database (BCLHD)

The BCLHD is housed at the Centre for Health Services and Policy Research (CHSPR) at the University of British Columbia. It is an extensive data resource for research concerning applied health services and population health (Centre for Health Services and Policy Research, 2004). If possible, the data located in each file is linkable at the individual level, allowing researchers to explore and apply population-based trends to groups of individuals over time. The information contained in the BCLHD covers the entire population of British Columbia with the data being derived from numerous sources related to health services utilization, as well as utilization of social services, health and socioeconomic status (CHSPR, 2004). The BCLHD is based on a public utility model, meaning that data are provided on a cost-recovery basis for any approved research project. All administrative data received at CHSPR are encrypted by the agencies providing it, ensuring that the privacy of the individual is protected. Upon

receiving the data, CHSPR checks the data and ensures that it is made linkable using probabilistic linkage. Each record in a data file is then assigned a linkage identifier ensuring that the records in the data files belonging to one individual can be traced across different files and through time (CHSPR, 2004).

Data Linkage

In order to identify cases, a record search of the British Columbia (BC) Medical Services Plan billing files and the BC Hospital Separation Abstracts for the fiscal years 1991/1992, 1992/1993, 1993/1994, and 1994/1995 was conducted. The data gathered from these sources was linked longitudinally at the individual level to all further BC Medical Service Plan activity continuing until March 31, 2001. These data were longitudinally linked to any subsequent inpatient treatment recorded in the BC Hospital Separation Abstracts for the same time period. Using information from BC Vital Statistics, the cohort was linked to birth and death records. The birth records provided information on birth weight and gestational age at delivery. The death records included causes and dates of death for any of the children in the four-year cohort. Co-morbid conditions, including congenital abnormalities/anomalies and common childhood diseases such as asthma or injury, were also tabulated.

Linked Databases

This research used four linked databases as follows: the BC Medical Services Plan (MSP), BC Hospital Separation Abstracts, Continuing Care, and BC Vital Statistics. Each database is briefly outlined below.

MSP

Information gathered from MSP was through the payment information master file. The master file provides information on the annual fiscal-year files of services provided to MSP-covered individuals by practitioners for which MSP was billed and have paid. As this is a payment file, it represents services that have been reimbursed during the fiscal year rather than services provided during the fiscal year. Those billing MSP are separated in three groups: physicians, supplementary benefit practitioners (physical therapist, massage therapists, etc), and out-of-province practitioners. In addition, ICD-9 diagnostic coding is available for the fiscal years 1991/1992 and beyond.

Hospital Separation Abstracts

A file of hospital separations such as discharges, transfers, and deaths of inpatients and day surgery patients from acute care hospitals in BC exists. Inclusive in this file are ICD-9 diagnostic and procedure codes.

Continuing Care

This file provides information on client assessment and service. It includes the number and types of services received, e.g. inpatient or outpatient care, homemaking services, in-home nursing care, etc.

Vital Statistics

Birth and death files are available within this database. The birth file includes information such as gender, birth weight and gestational age. The death file includes information such as cause and date of death.

Data Analysis

The incidence of cerebral palsy was calculated for each year of the birth cohort using the year-specific population of British Columbian children with health insurance registration of at least six (6) years active to infancy as the denominator. The numerator for each of the birth cohorts was the sum of the individuals in each cohort meeting the inclusion criteria for cerebral palsy who have at least six (6) years of continuous health insurance registration active to infancy. An aggregate incidence rate was calculated for congenital and acquired (post-neonatal) cerebral palsy. Finally, incidence rates were stratified by birth weight (0-999 grams, 1000-1499 grams; 1500-2499 grams; 2500-3999 grams and >4000 grams), gestational age (<32 weeks; 33-37 weeks, and >37 weeks) and geographic health region. The results were compared using the chi-square statistic, assuming a significance level of ≤ 0.05.

Incidence versus Prevalence

Prevalence is defined as the proportion of a given population experiencing a condition at a given time, and is measured as an aid to planning service provision. Incidence is the rate at which a condition arises in a population and is measured by those interested in aetiology and prevention. Prevalence can be estimated from incidence rates if mortality rates and duration of the disease are known (Stanley et al., 2000). Table 3.1 summarizes the differences between prevalence and incidence. Based on this information, and because this research is studying a birth cohort, incidence was the appropriate measure to use.

Table 3.1 – Cerebral palsy measures of occurrence

	Prevalence	*Incidence*
Definition	Existing/current cases in a population	New cases arising in a population
Used for	Service planning	Aetiological studies
Relationship	Prevalence is incidence minus mortality and migration	
How measured	Surveys to identify cases as a proportion of specific population	Follow up a birth cohort Register cases of cerebral palsy and relate these to their birth cohorts
Problems with Measure	Very large surveys required to establish precise estimates	True incidence of brain defect or damage likely to cause cerebral palsy is not measurable Delay in ascertainment (months or years from cerebral defect) Cases lost due to deaths, out migration and other losses from birth cohorts

Reprinted with permission from Stanley et al. (2000) (personal communication May 31, 2004).

Sample Size

This study assumed an incidence rate of cerebral palsy of 2% and an annual birth rate of 10 per 1000 population (British Columbia Vital Statistics Agency, 2002). The 95% confidence limits on this rate were ± 0.1% (Kahn and Sempos, 1989). Additionally, using this population, an incidence rate difference of 0.4% is detectable for analyses comparing those low birth weight and short gestational age to normative values (Kahn and Sempos, 1989).

Data Handling and Analysis

All data were entered into and analyzed using SPSS, Version 12.0 (SPSS Inc., 2003).

Ethical Considerations

Research ethics approval has been obtained from the UNBC Research Ethics Board. The research plan has also been approved by a committee with the Health Research Development Unit at UBC. All data gained through the record linkage process will be de-identified such that no individual can be found as a result of the data linkage. All data will be stored on a password-protected computer in a locked office.

CHAPTER 4 – RESULTS

Physician's Codes

On reviewing the physician's codes and the accompanying ICD-9 diagnostic code for cerebral palsy, it appeared that paediatricians were responsible for recording the diagnosis in 39.2% of cases and orthopaedic surgeons in 35.6 % of cases, whereas general practitioners recorded the diagnosis 18.3 % of the time (Table 4.1).

Table 4.1 - Physicians making the diagnosis of cerebral palsy

Specialty	# Making Diagnosis	Percentage
Anaesthesiologist	2	0.4
General Practitioner	91	18.3
General Surgeon	1	0.2
Neurologist	3	0.6
Neurosurgeon	1	0.2
Ophthalmologist	1	0.2
Orthopaedic Surgeon	177	35.6
Paediatrician	195	39.2
Physical Therapist	25	5
Podiatrist	1	0.2
Total	497	99.9

Description of Sample

The number and proportion of children diagnosed with cerebral palsy in each of the birth cohorts is recorded in Table 4.2. Cerebral palsy was diagnosed in 497 of the children over this four-year cohort, yielding an aggregate incidence rate of 2.68 per 1000 (Table 4.4). Although there appears to be a decreasing trend in incidence rates among the cohorts, chi-square analysis for trend was not significant ($\chi^2 = 0.200$, $df=1$, $p=0.6551$). Approximately two-fifths (41.0%) of the children were diagnosed before their third birthday (Table 4.3). Twelve children (2.4%) died prior to their tenth birthday. Twenty (4.1%) children of the 485

confirmed living cases up to their tenth birthday had a definite post-natal event that could be considered the probable cause of the cerebral palsy.

Table 4.2 - Number and proportion of children with cerebral palsy* by age at first recorded diagnosis

Cohort (birth year)	Children's Age at Diagnosis											Total Individuals Diagnosed
	0-1	1	2	3	4	5	6	7	8	9	10	
Cohort 1 (1991-1992)	8	21	20	18	12	12	16	9	2	9	5	132
Cohort 2 (1992-1993)	13	26	10	21	14	15	9	9	10	1	0	128
Cohort 3 (1993-1994)	20	25	14	23	17	16	6	3	2	0	0	126
Cohort 4 (1994-1995)	25	12	8	21	19	14	7	5	0	0	0	111
Total	66	84	52	88	62	57	38	26	14	10	5	497
% of Total	13.3	16.9	10.5	16.7	12.5	11.5	7.6	5.2	2.8	2	1	100

* includes 20 children with cerebral palsy of probable post-natal cause

Table 4.3 - Number and percentage of children diagnosed with cerebral palsy by 3 years of age

Age at Diagnosis	Number	Percentage
Below age 3 years	204	41
Greater than age 3 years	293	59
Total	497	100

The probable causes for motor disorder of post-natal origin were determined from the ICD-9 codes. These included traumatic brain injury (3), meningitis (2), malignant neoplasm of the brain (2), acquired paralysis (1), acquired hemiparesis (1), progressive neurological disorder (2), anomalies of the circulatory system (1), occlusion of the cerebral artery (1), and other condition of the brain and nervous system (7).

Incidence of Cerebral Palsy in British Columbia

An aggregate (congenital and acquired cases) incidence rate for cerebral palsy in this four-year birth cohort was calculated to be 2.68 per 1000 (95 % CI = 2.44, 2.92). Using chi-square analysis, no significant statistical difference was found

amongst the cohorts ($\chi^2 = 2.68$, $df = 3$), although the number of children diagnosed with cerebral palsy varied among the cohorts. The incidence rate of congenital cerebral palsy for this birth cohort was 2.57 per 1000 (95% CI = 2.34, 2.80). Approximately 44% of the children diagnosed with cerebral palsy were female, and approximately 56 % were male.

Table 4.4 - Incidence of childhood cerebral palsy* by cohort in British Columbia

Cohort (birth year)	Number of Cases	Number in Cohort	Incidence	95% CI
Cohort 1 (1991-1992)	132	46,064	2.87	2.38, 3.36
Cohort 2 (1992-1993)	128	46,175	2.77	2.29, 3.25
Cohort 3 (1993-1994)	126	46,296	2.72	2.25, 3.19
Cohort 4 (1994-1995)	111	47,211	2.35	1.91, 2.78
Total	497	185,746	2.68	2.44. 2.92

*includes 20 children with probable acquired cerebral palsy.
CI = confidence interval

Upon reviewing the ICD-9 codes for all contacts with the 477 children with congenital cerebral palsy, 25 (5.2%) demonstrated the code "742" for other congenital anomalies. Code "742" details conditions such as encephalocele, reduction deformities of the brain, congenital hydrocephalus, other specific abnormalities of the brain, spinal cord or nervous system, and unspecified anomalies of the brain spinal cord or nervous system (ICD-9, 1977). Fourteen children (2.9%) had one or more codes identifying other congenital anomalies, codes 743-747 and 759. Therefore, 39 children (8.2%) diagnosed with cerebral palsy thought to have occurred congenitally were coded as demonstrating congenital anomalies. Of those children with cerebral palsy thought to be due to a post-natal cause, 4 (20 %) coded 742, while 2 (10%) coded 743-747 or 759. Children with the diagnoses spina bifida (code 741) or chromosomal

abnormalities (code 758) were excluded from this cohort, and were therefore not identified.

Incidence of Cerebral Palsy by Birth Weight

The occurrence of congenital cerebral palsy in British Columbia for the period 1991-1995 falls within the range of previously published reports (Hagberg, 1993; Hagberg et al., 1996; Pharoah et al., 1996; Colver et al., 2000; Dolk at al., 2001; and Hagberg et al., 2001). Table 4.5 illustrates the number and proportion of children with congenital cerebral palsy in this cohort by birth weight. Children born with a birth weight of less than 1000 grams in this study had an incidence rate of 66.5 per 1000 for this cohort. Children with a birth weight between 1000-1499 grams had an incidence of 53.1 per 1000, while those weighing between 1500-2499 grams had an incidence rate of 10.0 per 1000. For children with birth weights greater than 2500 grams, the incidence was calculated as 1.79 per 1000. Chi-square analysis was statistically significant ($\chi^2 = 895.92$, $df = 4$) demonstrating the likelihood of being born with cerebral palsy may have a causal relationship with low birth weight.

Table 4.5 – Number and proportion of children with cerebral palsy in the cohort by birth weight*

Birth Weight Groups (grams)	Cohort Size	Number of Children with Congenital Cerebral Palsy	Incidence by Birth Weight in the Cohort Group per 1000	95% CI
0-999	617	41	66.5	46.8, 86.2
1000-1499	829	44	53.1	37.8, 68.4
1500-2499	7,782	78	10.0	7.8, 12.2
2500-3999	150,470	273	1.81	1.61, 2.01
>4000	25,409	41	1.61	1.11, 2.11

*639 children had an unknown birth weight

Incidence of Cerebral Palsy by Gestational Age

The number and proportion of children with congenital cerebral palsy are recorded in Table 4.6. These numbers are similar to those found in other published reports mentioned previously in this thesis. Children born at less than 26 weeks (extremely premature) in this study had an incidence rate of congenital cerebral palsy of 52.3 per 1000 in this cohort. Those born between 26-30 weeks (very premature) had the highest incidence of cerebral palsy, measured at 67.5 per 1000. The incidence rate decreased in subsequent gestational periods from 10.8 for children born between 31-35 weeks (premature), to 1.84 for children born between 36-40 weeks (normal gestation), to 1.75 for children born after 41 weeks gestation (longer than expected gestation). Chi-square analysis was statistically significant (χ^2=1,912.22, df= 4) illustrating that gestational age may be causally related to the development of cerebral palsy.

Table 4.6 - Number and proportion of children with cerebral palsy by gestational age*

Gestational Age (weeks)	Cohort Size	Number of Children with Congenital Cerebral Palsy	incidence Rate by Gestational Age per 1000 in Cohort	95% CI
<26	382	20	52.3	30.0, 74.6
26-30	992	67	67.5	51.9, 83.1
31-35	5,470	59	10.8	8.1, 13.5
36-40	142,188	262	1.84	1.62, 2.06
>41	37,529	66	1.75	1.33, 2.17
Total	186,561	474	2.54	2.31, 2.87

*3 cases had an unknown gestational period

Incidence of Cerebral Palsy per Health Region

Table 4.7 reports the number and proportion of children with cerebral palsy in British Columbia in each health region. The Interior Health Region recorded the lowest incidence rate of 2.14 per 1000 (95% CI = 1.60, 2.68), while the Fraser Health Region recorded the highest incidence rate of 2.89 per 1000 (95% CI = 2.48, 3.30) in this four-year birth cohort. No statistically significant difference was found among the health regions using the chi-square statistic (χ^2=4.97, *df*=5). Therefore, no differences in the proportion of children with cerebral palsy were observed among geographic regions in the province of British Columbia.

Table 4.7 - Number and proportion of children with cerebral palsy by British Columbian health region (1991-1995)*

Health Region	Number of Cases of Cerebral Palsy per Health Region	Number of Births per Region in Cohort	Incidence of Cerebral Palsy per Region	95% CI
Interior	60	28,054	2.14	1.60, 2.68
Fraser	191	65,989	2.89	2.48, 3.30
Vancouver Coastal	108	42,046	2.57	2.09, 3.05
Vancouver Island	82	29,412	2.79	2.48, 3.10
Northern	53	18,640	2.84	2.45, 3.23
Unknown	3	638	4.7	-0.6, 10.0

* 967 British Columbian residents were born out-of-province

CHAPTER 5 – DISCUSSION

This thesis has presented a population-based record linkage study from administrative data, similar to that of Robertson et al. (1998). It has provided epidemiological information on cerebral palsy for children born in the early 1990s, which can be compared to other epidemiological studies conducted in different geographic areas throughout the world (Al-Rajeh et al., 1991; Nottidge and Okogbo, 1991; Grether et al., 1992; Hagberg et al., 1993; Murphy et al., 1993; Krageloh-Mann et al., 1994; MacGillivray and Campbell, 1995; Meberg and Broch, 1995; Hagberg et al., 1996; Pharoah et al., 1996; Sinha et al., 1997; Topp et al., 1997; Kavcic and Perat, 1998; Pharoah et al., 1998; Robertson et al., 1998; Bottos et al., 1999; Sciberras and Spencer, 1999; Colver et al., 2000; Stanley et al., 2000; Surveillance of Cerebral Palsy in Europe, 2000; Hagberg et al., 2001; Parkes et al., 2001; Topp et al., 2001; Suzuki and Ito, 2002; and Cans et al., 2004), although it's specific focus is British Columbia, Canada.

Physician's Diagnosing Cerebral Palsy

In contrast to Robertson et al. (1998), the number of general practitioners making or confirming the diagnosis of cerebral palsy in this study was quite high (18.3% versus 1.1%). This could occur for a number of reasons. Unlike in Alberta (Robertson et al., 1998), children with cerebral palsy are not normally referred to a tertiary care centre for a multidisciplinary assessment due to distance to the tertiary care facilities and cost involved for travel. Therefore, it is difficult for the diagnosis of cerebral palsy to be made by specialists such as developmental paediatricians, paediatric neurologists, or paediatric neurosurgeons unless children and their families live in Vancouver or Victoria where the tertiary care centres are

located. Rather, it is more common to have multidisciplinary rehabilitation assessments for children with cerebral palsy conducted by rehabilitation professionals through a Child Development Centre, located in many communities throughout British Columbia, or at one of the tertiary care facilities. In 57.5% of the cases in British Columbia, cerebral palsy has been diagnosed or confirmed by either a paediatrician or a general practitioner. Due to the complex geography of British Columbia, it is likely that these physicians are located in the local community, rather than a tertiary care facility. Interestingly, in over 35% of cases, paediatric orthopaedic surgeons either made or confirmed the diagnosis of cerebral palsy (Table 4.1). This did not occur in the study conducted by Robertson et al. (1998). These surgeons only practiced at the tertiary care facilities during the period of this study, and are likely confirming the diagnosis at the time of surgery, rather than initially identifying it.

Sample

The aggregate rate of cerebral palsy in British Columbian children born between 1991 and 1995 was measured at 2.68 per 1000. The congenital rate was measured at 2.57 per 1000 for the same cohort. These rates fall within the reported range of 2.0-3.0 per 1000 from previous studies throughout the world (Al-Rajeh et al., 1991; Nottidge and Okogbo, 1991; Grether et al., 1992; Hagberg et al., 1993; Murphy et al., 1993; Krageloh-Mann et al., 1994; MacGillivray and Campbell, 1995; Meberg and Broch, 1995; Hagberg et al., 1996; Pharoah et al., 1996; Sinha et al., 1997; Topp et al., 1997; Kavcic and Perat, 1998; Pharoah et al., 1998; Robertson et al., 1998; Bottos et al., 1999; Sciberras and Spencer, 1999; Colver et al., 2000; Stanley et al., 2000; Surveillance of Cerebral Palsy in Europe, 2000;

Hagberg et al., 2001; Parkes et al., 2001; Topp et al., 2001; Suzuki and Ito, 2002; and Cans et al., 2004).

The incidence rates reported for children with cerebral palsy in this cohort by birth weight (<1000 grams = 66.5, 1000-1499 grams = 53.1, and 1500-2499 grams = 10.0) were similar to those reported by Hagberg et al. (2001) who studied a cohort born between 1991 and 1994 in Sweden. More than 65% of children in this study had a birth weight of 2500 grams or greater, similar to that found in the other Canadian study (Robertson et al., 1998).

Population-Based Record Linkage

At the time of writing, this study was only the second one to use population-based record linkage to present epidemiological information about the incidence of childhood cerebral palsy (Robertson et al., 1998). It was also the second Canadian-based study to accomplish this. All previous studies were based on information gathered from cerebral palsy registries or exhaustive record searches (Al-Rajeh et al., 1991; Nottidge and Okogbo, 1991; Grether et al., 1992; Hagberg et al., 1993; Murphy et al., 1993; Krageloh-Mann et al., 1994; MacGillivray and Campbell, 1995; Meberg and Broch, 1995; Hagberg et al., 1996; Pharoah et al., 1996; Sinha et al., 1997; Topp et al., 1997; Kavcic and Perat, 1998; Pharoah et al., 1998; Robertson et al., 1998; Bottos et al., 1999; Sciberras and Spencer, 1999; Colver et al., 2000; Stanley et al., 2000; Surveillance of Cerebral Palsy in Europe, 2000; Hagberg et al., 2001; Parkes et al., 2001; Topp et al., 2001; Suzuki and Ito, 2002; and Cans et al., 2004).

The use of population-based record linkage has a number of advantages over the other methods. These include the ability to provide large sample sizes, reduce the likelihood of recall bias, allow researchers to use the data for various types of studies like outcomes research and cohort studies, and eliminate the need for direct subject contact. Record linkage of administrative data is also cost effective and permits the researcher to generalize results, as administrative databases encompass large groups of people(Roos, Nicol and Cageorge, 1987; Lohr, 1990; Roos, Sharp and Cohen, 1991; Romano, Roos, Luft, Jollis, Doliszny, 1994; Stanley, Croft, Gibbins and Read, 1994; Ellenbecker, Wagner, and Cloutterbuck, 1997; Steinwachs, Stuart, Scholle, Starfield, Fox, and Weiner, 1998; Fleming and Kohrs, 1998; Melfi, 2001; Best, Khuri, Phelan, Hur, Henderson, Demakis, and Daly, 2002; Iezzoni, 2002; and Price, Estrada, and Thompson, 2003).

Like all data sources, limitations also exist with record linkage of administrative data such as inaccurate coding of the diagnosis or procedures made by multiple physicians, underreporting of comorbid conditions, difficulty in recording the timing of events and causal inferences, and limited information about health status and clinical outcomes (Lloyd and Rissing, 1985; Roos et al., 1987; Iezzoni, 1990; Fisher, Baron, Malenka, Barrett, and Bubolz, 1990; Lohr, 1990; Deyo, Cherkin and Ciol, 1992; Fisher, Whaley, Krushat, Malenka, Fleming, Baron, and Hsia, 1992; Hannan, Kilburn, Lindsey, and Lewis, 1992; Quam, Ellis, Venus, Clouse, Taylor, and Leatherman, 1993; Iezzoni, Daley, Heeren, Foley, Hughes, Fisher, Duncan, and Coffman, 1994; Romano et al., 1994; Stanley et al., 1994; Cohen, Roos, DeCoster, Black and Decker, 1995; Ellenbecker et al., 1997; Hawker, Coyte, Wright, Paul and Bombardier, 1997; Iezzoni, 1997; Elixhauser,

Steiner, Harris and Coffey, 1998; Fleming and Kohrs, 1998; Steinwachs et al., 1998; Powell, Lim and Heller, 2001; Iezzoni, 2002; Twiggs, Fifield, Apter, Jackson and Cushman, 2002; Price, Estrada and Thompson, 2003; and Romano, 2003). This was avoided in this study by using a unique identifier for each case. These databases may not accurately reflect or record the prevalence or incidence of disease in a population (Cans, Surman, McManus, Coghlan, Hensey, and Johson, 2004b).

For this study, data on this childhood cohort was linked from the BC Vital Statistics database, the BC Medical Services Plan (MSP), and the BC Hospital Separation Abstracts. It is known that approximately 86% of the standard ICD-9 codes are covered in the MSP claims database, demonstrating that the information in the MSP database is relatively accurate and reliable. Also, greater than 96% of paid services and paid amounts to physicians are associated with the ICD-9 codes contained in the MSP database (Hu, 1996).

A population-based record linkage study on childhood cerebral palsy has been conducted before in Canada (Robertson et al., 1998), and is not without its difficulties. This study attempted to overcome such challenges as early diagnosis, early death of children, and the lack of universally accepted diagnostic criteria by ensuring that children in this cohort would be followed for six years, active to infancy, for any claims against their health insurance registration. This study was able to identify the physician's specialty via a unique identifier, allowing one to determine the number and percentage of physician's diagnosing cerebral palsy. In the same respect, by using the ICD-9 diagnostic code "343" for fee-for-service

physician visits and hospital separations, it was possible to identify children with cerebral palsy, in particular, children with more obvious forms of cerebral palsy as this population is more likely to receive the care of a physician. However, it is likely that the diagnosis could have been made at an earlier time, but was not recorded until the children were admitted to hospital, and subsequently discharged. This difficulty in affirming the diagnosis may have been averted if there existed in British Columbia a specific cerebral palsy register, with the aim of identifying all cases of cerebral palsy within the geographical population of British Columbia regardless of the need for hospital treatment (Cans et al., 2004b).

Implications of the Results and Recommendations for Future Research

Now that the incidence of cerebral palsy has been estimated for congenital cerebral palsy as 2.57 per 1000 live births and 2.68 for the aggregate rate in this cohort, important epidemiological evidence has been provided to add to the incidence and/or prevalence rates of this childhood disorder throughout Canada and the rest of North America. It is still evident that cerebral palsy affects a large number of children in the province of British Columbia, even with advances in neonatal and perinatal care. Neonatal intensive care units are located within regional and provincial health regions, yet the rate of cerebral palsy remains the same as it did 30 years ago.

This study can now be used to compare with other population-based record linkage studies in Canada and throughout other parts of the world. The results of this study can also contribute valuable information for future research. It has

provided a baseline from which one can now begin to conduct research such as measuring the use of continuing care services by children with cerebral palsy. It could also lead researchers to explore the relationship of variables such as maternal age, parity, gestational age, birth weight, rural residence, socioeconomic status, gender and maternal health status to the development of cerebral palsy. All of this information could be important to health planners throughout British Columbia in determining how to allocate health and social service funding for children with cerebral palsy.

This research has also provided a basis for the exploration of such things as measuring health and social outcomes of this population, specifically looking at quality of life issues, life expectancy and prognosis.

The information provided by this research may also lend credence to the establishment of a cerebral palsy register in the province of British Columbia. This would allow Canadian researchers the same advantages as those in Europe and the United Kingdom where cerebral palsy registers have been established for many years, specifically, the ability to investigate the origins of cerebral palsy using a case-control design because a register would provide an unbiased sample of cases from a geographically defined population (Cans et al., 2004b). A register would also allow researchers to monitor trends related to cerebral palsy, monitor quality of life of children with cerebral palsy, and provide longitudinal outcome data related to the costs of caring for children with cerebral palsy (Cans et al., 2004b; Liptak and Accardo, 2004: and Majnemer and Mazer, 2004). Alternatively, this information could be combined with that contained in the

British Columbia Health Status Registry to provide a more comprehensive report of the occurrence of cerebral palsy in British Columbia, as has already been done with other chronic childhood conditions such as Down syndrome and autism.

CHAPTER 6 – CONCLUSION

This research has provided an estimate of the incidence of cerebral palsy in the four-year birth cohort 1991-1995 in British Columbia. An aggregate incidence rate of cerebral palsy was measured as 2.68 per 1000 live births, and a congenital rate was measured at 2.57 for the same population. Birth weight demonstrated a significant relationship with the development of cerebral palsy. As gestational age is highly correlated with birth weight, it may also have a significant relationship with the development of cerebral palsy. A significant relationship was not found between gender and geographic area of residence and the development of cerebral palsy. Much research remains to be conducted in the epidemiology of cerebral palsy.

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