CHARTING BIRTH OUTCOME IN BRITISH COLUMBIA: DETERMINANTS OF OPTIMAL HEALTH AND ULTIMATE RISK – AN EXPANSION AND UPDATE

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Vital Statistics
British Columbia
Vital Statistics Agency

National Library of Canada Cataloguing in Publication Data

Main entry under title:

Charting birth outcome in British Columbia : determinants of optimal health and ultimate risk : an expansion and update.

Running title: Birth weight and gestational charts for British Columbia populations.

Originally published in 1993 by Ministry of Health, Division of Vital Statistics.

Also available on the Internet.

Includes bibliographical references: p.

ISBN 0-7726-5040-3

1. Childbirth - British Columbia - Statistics.
2. Infants - British Columbia - Statistics. 3. Birth weight - British Columbia - Statistics. 4. British Columbia – Statistics, Vital. I. Kierans, William, 1940- II. British Columbia Vital Statistics Agency. III. Title: Birth weight and gestational charts for British Columbia populations.

HB940.B7C42 2003 304.6’3’09711 C2003-960195-1

FOREWORD

As we have known for some time, birth weight and gestational age are two of the major determinants of mortality and/or disability in newborns. While charts showing the distribution of birth weights at each gestational age have been available since the 1920's they gained more widespread acceptance following the pioneering work of Dr. Lula Lubchenco and her colleagues in the early 1960's.

In 1993, the Vital Statistics Agency published a report that mapped birth weight and gestational age based on over 400,000 infants born in British Columbia between 1981 and 1990. The report contained nearly 80 tables and charts covering a variety of variables related to birth weight and gestational age.

I am pleased to introduce this new report, which is an update and expansion to the 1993 report. In total the work presented here includes over 880,000 records of births that occurred in British Columbia between 1981 and 2000. There are several new features in this report including a section that considers the effects of income on birth outcomes and a section that explores ethnic differences in birth outcomes in the province. The latter, in particular, highlights the need to measure First Nations births against their own standard rather than the provincial norm.

I hope the readers and users of this report will find it useful in their practice and research.

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ACKNOWLEDGEMENTS

The study was completed under the auspices of Mr. Ron Danderfer, Assistant Deputy Minister, Knowledge Management & Technology Division, British Columbia Ministries of Health Services and Health Planning (formerly Chief Executive Officer of British Columbia Vital Statistics Agency (BCVSA) whose administrative support and resource allocation made this project possible. In addition, Mr. Terry Tuk, Manager, Information and Resource Management, BCVSA, was always helpful with advice and supervised the completion of the final product. We are also indebted to the British Columbia Ministry of Children and Family Development for financial assistance and access to other resources.

The authors particularly wish to thank Mr. Brian McKee, Senior Project Officer at BCVSA for designing and formatting the final report as well for his particular contribution to the final appearance of the mortality grids.

Appreciation is extended to Weimin Hu PhD who kindly contributed to the design and programming of the initial analyses and to Zhong Cheng Luo, MB, PhD, Postdoctoral fellow, Montreal Children's Hospital Research Institute, McGill University for his supportive advice throughout the project. In addition, we thank the staff at Health and Human Services Library, Ministries of Health Planning and Health Services who conducted numerous literature searches and provided referenced reports.

We also wish to remember contributors to the 1993 report who made this update and expansion feasible: Ms. Julie Macdonald, Ms. Dallas Cobb, Mr. Mark Collison, Dr. Sam Sheps, and Dr. Greg Sherman.

Lastly, but by no means least, we wish to recognize the contribution of Dr. Perry Kendall, Provincial Health Officer of British Columbia, for his comments on and endorsement of the final product.

Although many contributed to the final product, any errors or omissions are wholly the responsibility of the authors.

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EXECUTIVE SUMMARY

This report is the culmination of a project that began with the publication of a birth weight chart in the 1989 Vital Statistics Annual Report followed by a comprehensive report of birth weight and gestational age statistics, including mortality, in 1993. This is an update and expansion of the previous report to include estimates related to socio-economic status and birth length and birth head circumference. This report reflects substantial changes that have occurred in birth outcomes in British Columbia and addresses the current needs of health care and other professionals.

Birth weight and gestational age are the two major determinants not only of disability and death among newborn infants but also of their subsequent health and well being. Charts showing the distribution of birth weights at each gestational age are used in British Columbia to evaluate every newborn and form part of the newborn record, which is completed after all hospital births. Charts presently in use in British Columbia need updating for the following reasons:

- The charts were based on births representing earlier populations and birth outcomes have changed considerably since then.
- The demographic and birthing characteristics of the base populations differed from current ones.
- Some charts in current use are modifications of charts produced elsewhere using different populations and different exclusion criteria.
- There was no accounting for differences according to socio-economic status, which is an important consideration in current practice.
- The samples that were selected for charting were further limited by certain exclusions that had an unknown impact on the output.

Project Objectives

The primary purpose of this project was to produce accurate, clear, and easily interpreted graphics that describe and summarise the birth outcomes of local populations in terms of birth weight and gestational age. The output charts are intended to provide reference data for health professionals to help evaluate the intrauterine growth environment, assist in making various delivery related decisions, and determine the need for special care.

Chart Description and Use

Published charts show the birth weight distributions at each week of gestation. These charts are usually presented in the form of "smoothed" line graphs showing measures of central tendency (median or mean) and dispersion (percentiles or standard deviations).

The following points summarise the uses of the charts in perinatal practice and public health in the province as well as the reasons for their production using vital event data.

- At birth the charts are used to identify infants in need of special care and for pre-term infants the charts can provide "ideal" or "target" weights to adjust feeding schedules and volumes.
- Charts are also used to identify infants that are small for gestational age (SGA), appropriate for gestational age (AGA), and large for gestational age (LGA) at each week of gestation.
- Charts based on British Columbia births provide reference data for local populations with our specific demographic mix, our local health care system, and many other factors that distinguish British Columbia births.

Mortality Grids

A series of mortality grids was also produced as part of this project. Mortality grids show the neonatal mortality rate for all British Columbia births and sub-groups across a range of birth weight and gestational age categories. They provide medical practitioners with important information when considering the possibility of postnatal problems, whether to induce delivery or prolong gestation, when to consider in-utero therapy, or the timing of a move to a higher care hospital. They are also useful educational tools because they graphically portray changes in risk in relation to intrauterine growth and gestational duration. They can also serve as a useful public health measure by comparing mortality patterns exhibited by different populations.

Methods

Study Population

The analyses were confined to data available from birth registrations, notices of birth, stillbirth registrations, and death registrations as recorded at British Columbia Vital Statistics Agency covering events to residents of British Columbia from 1981 to 2000. The output focused on live births except those with missing data (0.24%) but stillbirths were used for some additional analyses.

For each group listed below the following three statistical summaries are presented:

- a graphically smoothed line chart showing seven currently relevant percentiles of the birth weight distributions at 20 to 44 weeks of gestation,
- a table of descriptive statistics for the birth weight distributions at each week of gestation; and
- a grid showing percent neonatal mortality in 250 gram birth weight groups at each week of gestation.

The above summaries were produced for the following groups:

- all live births*,
- all males*,
- all females*,
- singleton males,
- singleton females,
- First Nations births*,
- congenital anomalies,
- multiple births
- single parity births,
- multiple parity births,
- neighbourhood income levels (quintiles) in five increments from lowest to highest *,
- five 4-year periods 1981 to 2000,
- births in each provincial Health Authority,
- births to immigrants of European origin*,
- births to immigrants of Chinese origin*, and
- births to immigrants of South Asian origin*.

* Mortality grids or mortality grid summaries were produced for these groups

Additional statistical summaries (e.g., charts for birth length and birth head circumference) related to current issues or needs in perinatal care and research are presented.

Results and Discussion

The following points highlight the results and discussion presented in this report:

- The full population charts and statistical summaries exhibited accelerating growth up to 37 weeks after which growth began to level off.
- Males weighed more than females and multiple births weighed less than single births at all gestational ages.
- Median birth weights for First Nations were consistently higher than those for the full population.
- As noted in the 1993 report and repeated this time, the differences in weight between first and subsequent births generally favoured subsequent births across the full gestational age spectrum.
- From 37 to 42 weeks gestation, median birth weights were clearly graded by neighbourhood income across the quintiles, with the highest weights in the richest quintiles, and the lowest weights in the poorest quintiles.
- The curves for five Health Authority regions were almost identical, confirming the efficacy of the full population chart as a provincial standard.
- Although the chart for babies born to European immigrants was similar to the full BC chart, those for babies of immigrants of Chinese and of South Asian origin showed lower birth weights at all gestational ages. These results have initiated a national collaboration on the use of birth weight standards for ethnic groups using British Columbia Vital Statistics Agency data.
- British Columbia Vital Statistics Agency began recording birth length and birth head circumference in 1995 so we are indeed fortunate to present the first population-based charts for those important measurements. The summary statistics presented here are commensurate with other smaller mostly hospital-based samples and further spin-off studies investigating the application of the data are nearing completion.
- The full population mortality grid showed a clear pattern of diminishing risk extending along a central path of increasing birth weight and gestational age, but greater risk accrued to increases or decreases in birth weight from that central path at each week of gestation.
- Regarding neonatal mortality, there was an optimal outcome category between 3,500 and 4,499 grams at 40 weeks.
- Compared to the previous report, the additional ten years of data permitted full mortality grids for males and females. Mortality was generally lower for females but there were provocative differences across the whole grid. For example the pattern of optimal births (see previous) was considerably larger for females.

Conclusion

This report presents a broad descriptive profile of current birth outcomes in British Columbia. The profile is done in terms of birth weight and gestational age charts for all residents and for numerous demographic sub-groups residing in the province. Despite demographic, socio-economic, cultural, geographic, and ethnic diversity in British Columbia the comparisons depicted relatively small yet consistent differences between sub-populations within the province. The picture that emerges is that of a healthy and sustained community requiring improvement in some specific areas.

1. INTRODUCTION

1.1. Background

Birth weight and gestational age are the two major determinants not only of disability and death among newborn infants but also of their subsequent health and well being. Charts showing the distribution of birth weights at each gestational age have appeared in the literature since the 1920's but they gained wide acceptance after Lubchenco et al.[1] presented " intra-uterine Growth Charts" in a now classic article and recommended their use in evaluating the nutritional status of newborns and the postnatal growth of premature infants.

Since then numerous charts have been published depicting various populations throughout the world, including British Columbia[2, 3] and Canada[4, 5], but in the last few years, there has been a proliferation of charts in recognition of their reference value when evaluating the progression of birth weights at each gestational age. British Columbia Vital Statistics Agency published the first chart specifically applicable to the birthing population of British Columbia in the 1989 Annual Report[2] and subsequently produced a comprehensive report[3] that showed charts for 24 demographic groups in the province and included birth weight and gestational age mortality grids. This report is an update to meet current needs of health and other professionals and expands the previous report by including estimates for socio-economic groups.

Charts based on the full spectrum of British Columbia births and specific sub-groups are presented and compared with those published elsewhere. In addition, mortality grids that show mortality risk in relation to birth weight and gestation are presented for selected resident groups.

1.2. Project Purpose and Rationale

The charts currently available and in use in the province need to be updated because:

- The charts were based on births representing earlier populations and birth outcomes have changed considerably since then.
- The demographic and birthing characteristics of the base populations differed from current ones.
- Some charts in current use are modifications of charts produced elsewhere using different populations and different exclusion criteria.
- There was no accounting for variations according to socio-economic status, which is an important consideration in current practice.
- The samples that were selected for charting were further limited by certain exclusions that had an unknown impact on the output.

All the above factors are reported in the literature as affecting birth weight charts and the production of up-to-date local versions is recommended.

Charts based on British Columbia births not only provide reference data for local populations with our specific demographic mix but they also portray birth outcomes in the context of the province's health care system, notably the degree of access to pre-natal care, the use of current medical technologies, almost universal access to physician care and hospital delivery, and many other factors which distinguish British Columbia births.

1.3. Project Objectives and Scope

The primary purposes of this project were:

- To produce accurate, clear and easily interpreted charts and graphics.
- Describe and summarise birth outcomes of local residents in terms of birth weight for gestational age.
- Provide reference data for perinatal health professionals to help evaluate the intrauterine growth environment, assist in making various "delivery related" decisions and determine the need for special care.

A secondary intent is to provide an up-to-date British Columbia perspective to the general literature on birth weight for gestational age and corresponding data analysis techniques.

1.4. Chart Description and Use

Published charts show the birth weight distributions for infants born at each week of gestation. They are usually graphically displayed in the form of smoothed line charts showing measures of central tendency (median or mean) and dispersion (centiles or standard deviations).

At birth the charts are used to identify infants who may require special care depending on how much they deviate from the norm established by those born previously at the same gestational age.

Charts are also used to classify newborns as small for gestational age (SGA), appropriate for gestational age (AGA), and large for gestational age (LGA), at each week of gestation. As originally defined by Battaglia and Lubchenco[6], SGA is below the 10th percentile, AGA is between the 10^{th} and 90^{th} percentiles and LGA is above the 90^{th} percentile at any specific gestational age. The classification system is widely used at birth to identify newborns at risk although there has been a recent disposition to use the 3^{rd} and 5^{th} percentiles and the 95^{th} and 97^{th} percentiles as additional cut-off points for SGA and LGA respectively (see sections 3.5 and 4.14 for an additional discussion of this point.). The system is widely used to further classify infants diagnosed with certain perinatal conditions by providing precise operational definitions of 'light for date' (SGA), 'heavy for date'(LGA), and intrauterine growth retardation (IUGR).

These charts are used after birth as well. For pre-term infants they can provide "ideal" or "target" weights. By comparing postnatal increases in the baby's weight to charted values, they can be used to judge appropriate weight gain and to adjust feeding schedules and volumes[1, 7].

1.5. Mortality Grids

In addition to birth weight charts, this report includes mortality grids that illustrate the mortality rate for sub-groups across the full birth weight and gestational age grid. The study of mortality in relation to weight and gestational age provides a measure of validity to the charts by indicating the degree of ultimate risk at the time of delivery and subsequently. Mortality grids provide medical practitioners with important information when considering the possibility of postnatal problems, whether to induce delivery or prolong gestation, when to consider in-utero therapy or the timing of a move to a higher care hospital. They also provide a useful educational tool, because they graphically portray changes in risk in relation to intrauterine growth and gestational duration. By comparing mortality patterns exhibited by different populations, they can provide a public health monitor.

Although mortality grids have been published for other populations, grids based specifically on British Columbia births were produced in the original report and updated in this one for the following reasons:

- Available grids included so few neonatal deaths (<28 days) that there was a need for considerable "data smoothing" across the full grid.
- The overall mortality rate in other studies was up to four times greater than the current rate in British Columbia. Such differences result in dissimilar mortality patterns across the grid.
- The production of a grid applicable to a provincial population is believed to be a first in Canada and could be considered a prototype for other jurisdictions.
- The mortality rate has decreased since the previous report and the change was expected to alter the pattern across the current grid.

1.6. Literature Review Summary

A computerized journal search conducted by the Health and Human Services Library uncovered numerous articles describing birth weight and gestational age charts from various populations all over the world. The Reference section shows a selection of those articles that have particular relevance to British Columbia births and this report.

The following points were summarized from the literature review and will serve as background for the remainder of this report.

- Charts that portrayed the birthing population at the University of Colorado Medical Centre, particularly those published by Lubchenco, are by far the most widely referenced although their current use is mainly confined to developing countries.
- Most of the studies cautioned against the use of charts as standards of intrauterine growth or to assess the quality of fetal growth because pre-term births were used and they might have had a different growth pattern from full term births that remained in utero at pre-term gestational ages. Accepting this shortcoming, they are still accepted as the best available estimators of intauterine growth.
- Each study in the review presented charts from samples of diverse populations with different demographic mixes that were further altered by various exclusions, but few of the studies investigated the impact of specific exclusions. The numerous charts presented here clarify the impact of such specificity.
- In addition to birth weight, many of the articles presented curves for birth length and birth head circumference. Those are critical measures to assess the quality of intrauterine growth, to diagnose potential pathological conditions and to determine the need for special care. The British Columbia Vital Statistics Agency has been recording both since 1995 and charts for births since then are presented here.
- The validity of neonatal risk inferred from the charts was refined with the publication of studies showing the changes in neonatal mortality risk across the birth weight/gestational age grid but the samples contained few deaths and a considerable amount of data "smoothing" was required.
- The neonatal mortality rate in the reviewed studies was usually over 10/1,000 live births. Comparison to B.C.'s usual rate of less than 5/1,000 would suggest a different pattern of deaths here and the need for local mortality grids.
- The results of the mortality studies suggested that there might be an abrupt change in mortality risk sometime between 30 and 35 weeks. However, the number of cases in previous studies was too small to clarify the possibility.

- The early series of charts attempted to portray optimal birth outcomes, so the original samples were reduced substantially by excluding infants showing various characteristics. That practice was modified in later studies because the authors wished to portray typical populations and therefore included the customary array of outcomes.
- An often mentioned flaw in the reviewed studies was the inaccurate calculation of gestational age, which exaggerated a naturally occurring positive skew in distributions of birth weight for gestational age. Several of the studies attempted to reduce the skew by excluding uncertain cases or by using alternate methods to double check the calculations.
- Even if the population diversity is taken into account, there was a definite increase in the average and median birth weights at each gestational age over the several decades covered by the studies.

2. METHODS

The output was confined to data available from birth registrations, notices of birth, and stillbirth registrations received at British Columbia Vital Statistics Agency (BCVSA) detailing events to British Columbia residents that occurred from January 1, 1981 to December 31, 2000. Events to British Columbia residents occurring in other provinces and the United States of America were included. Twenty years of data were considered sufficient to provide highly accurate and reliable summary statistics across most population groups in the analyses.

Stillbirth registration records for the same period formed part of the computer file for this study. Infant death (<365 days) registration records from the BCVSA death registry were linked and added to the birth records (including any infant deaths in 2001 that occurred to babies born in 2000). Links were deterministically based on the birth registration number that appears on the death record for infant deaths. In the case of infant deaths to former residents of British Columbia an inter-provincial agreement assured that the death record was available for linkage. The procedure resulted in a 98.9% linkage rate based on BCVSA infant death tables 1981-2000.[14]

2.1. Study Population

The data file contained 887,896 records including 6,241 stillbirths to residents of British Columbia. Analyses were restricted to live births between 20 and 44 completed weeks of gestation and weights less than 7,000 grams. In addition, records where the weight or gestational age was missing and four cases where the weight was greater than 5 standard deviations from the gestational age birth weight mean and not correctable by reference to original documents were excluded from the analyses.

This study was designed to provide reference charts that are representative of all live births that typically occur in British Columbia. For that reason, non-standard births, for example, those where there were complications, multiple deliveries, or infants with congenital anomalies were not excluded from the analyses. Exclusions were confined to cases where the quality of the data was affected rather than the quality of the delivery. For comparison, data and charts are presented pertaining to those groups often excluded from other studies.

2.2. Study Variables

A computer file was abstracted from the British Columbia Vital Statistics Agency master birth and death files specifically for these analyses and consisted of the following variables:

- year of birth,
- birth registration number,
- Health Region of mother's residence,
- child's gender,
- mother's birthplace,
- father's birthplace,
- kind of birth (plurality),
- birth order,
- weeks of gestation,
- number of live births to the mother,
- number of stillbirths to the mother,
- birth weight,
- marital status of parents,

- postal code of mother’s usual residence,
- standard geographic code of mother’s usual residence,
- place of birth – hospital,
- stillbirth flag,
- stillbirth cause (ICD Code),
- child’s abnormality – 1st ICD Code,
- child’s abnormality – 2nd ICD Code,
- child’s abnormality – 3rd ICD Code,
- apgar score at 1 minute,
- apgar score at 5 minutes,
- postal code of mother’s usual mailing address,
- hospital code,
- number of pregnancies to this mother,
- number of abortions to this mother,
- mode of delivery,
- complications of pregnancy/labour/delivery – 1st ICD Code,
- complications of pregnancy/labour/delivery – 2nd ICD Code,
- single parent flag,
- census tract,
- Local Health Area of mother’s residence,
- mother’s age,
- father’s age,
- birth head circumference,
- birth length,
- First Nation indicator (see text),
- infant mortality indicator,
- death date,
- cause of death – ICD code,
- nature of injury – ICD code, and
- age at death.

The Health Analysis and Measurement Group of Statistics Canada linked two additional variables to each birth record:

- the neighbourhood income quintile of mother’s usual residence (1985-2000); and
- the community size of the mother’s usual residence.

Pathological causes were coded using the International Classification of Diseases (ICD) codes Version 9 for events 1981 to 1999 and Version 10 for events in 2000 and 2001.

Some of the above variables were not needed for the primary analyses but were included for use in subsequent analyses that were suggested by the preliminary results.

2.3. Confidentiality

The confidentiality of BCVSA records was protected. Access to the data was restricted to one investigator (WJK) who prepared and ran all analysis programs and solely obtained the output. All programs and output were saved for review by BCVSA (author JM) and, further, all output was examined for unique identifiers, "small N cells", and personal, confidential, or sensitive information to insure observance of the privacy requirements of BCVSA. It was shared with others only after review. No unique identifiers were used in any analysis. Birth registration numbers were included in the computer file as links to original documents in case verification was required. Statistics Canada was provided a computer file consisting of registration numbers and postal codes, which were used to generate the neighbourhood income quintile and community size variables. This file was then returned, and the additional variables were added to the main file.

2.4. Data Analyses

The sub-groups were compared to the entire population. This report presents descriptive statistics only and no statistical comparisons (e.g. tests of significance) of the differences were intended. Visual comparisons of the curve shape and subjective interpretation of the overlap of confidence intervals may suggest further investigation.

Data were analysed using SAS-PC Release 8.2 leased and maintained by the British Columbia Ministry of Management Services and operated on the Microsoft Windows XP platform. Specialized graphic output was produced using Microsoft Excel software Version 2002.

2.4.1. Primary Analysis and Output

For each of the demographic groups described below, the following three statistical summaries were produced:

1. A graphically smoothed line chart showing the median (50^{th} percentile) of the birth weight distributions from 20 to 44 weeks. The 3^{rd}, 5^{th}, 10^{th}, 90^{th}, 95^{th}, and 97^{th} percentiles were also charted to show the dispersion. These are the familiar charts seen in recent published studies. Excel software was used to smooth random fluctuations in the line charts, using a third order polynomial least squares fit.
2. A table of descriptive statistics summarising the birth weight distributions at each gestational week. The descriptive statistics included:
   - number of cases,
   - mean birth weight,
   - upper and lower 95% confidence limits of the mean,
   - standard deviation of the birth weight distribution,
   - skewness, and
   - 3^{rd}, 5^{th}, 10^{th}, 50^{th}, 90^{th}, 95^{th}, and 97^{th} percentiles.

   Unsmoothed percentiles are presented in the tables; these may differ from the values in the charts due to the smoothing formulae. The skewness is a measure of the tendency of the deviations from the mean to be larger in one direction than in the other. For birth weight distributions, a positive skew value is an indication of the degree to which the distribution "leans" toward higher weights. These tables were produced mainly to provide statistical backup information for the charts, to estimate the reliability of other output and for research purposes.

3. A grid chart showing neonatal mortality risk related to weight and gestation. Neonatal mortality is death to a live born infant less than 28 days old. Mortality risk was calculated as percent mortality for 250g birth weight groups at each week of gestation. To compensate for random rate fluctuations in individual grid cells the following criteria were used to produce the final grid:
   a. Cells with fewer than five births were excluded from further calculations.
   b. The percent mortality in each remaining cell was averaged with the percents in the four cells immediately surrounding it.
   c. Where four cells were not available, for example on the edges of the grid, the mere exclusion of unavailable cells would produce a negative bias in the upper grid cells and a positive bias in the lower grid cells. In those cases the percents in each cell was averaged with the percents in the cell immediately to the left and below, and the percents in the cell immediately to the right and above the cell. This procedure was meant to balance a progressive reduction in mortality upward and to the right in the whole grid.

The above output was produced for each of the following sub-groups where frequencies warranted:

- All live births previously defined,
- Male births,
- Female births,
- Male singleton births,
- Female singleton births,
- Multiple births (considered as individual births not sets),
- First Nations births,
- Births in five neighbourhood income groups,
- Births with congenital anomalies, (ICD9 740 – 759, ICD10 P Series)
- Single parity births,
- Multiple parity births, and
- Births in each of five 4-year periods 1981 to 2000.

Neighbourhood income quintiles, First Nations and parity sub-groups were defined as follows.

- *Neighbourhood income quintiles* were defined according to methods developed at Statistics Canada, based on the postal code of the mother's usual place of residence, and then the quintile values were appended to each birth record.

  Postal codes were not present in machine-readable form on the records prior to 1985, so the following method was only used for births from 1985 through 2000. Using Statistics Canada postal code conversion software (PCCF+ Version 3J)[8], the postal code of the mother's usual residence was used to determine the 1996 census enumeration area of her place of residence. Additional "translation" files were used to determine the corresponding 1991, 1986 and 1981 census enumeration areas, based on nearest centroids of those areas with respect to the 1996 enumeration area centroids. As small-area income data from the 2001 census were not yet available at the time this work was done (early 2003), the 1996 enumeration area code was applied to all births from 1994 though 2000, and the neighbourhood income quintile for those years was based on 1996 census data. For births from 1989 through 1993, and from 1985 through 1988, the neighbourhood income quintile was based on data from the nearest census: 1991 or 1986, respectively.

For births for which the mother's residential postal code referred to a hospital or to a school or university residence, the neighbourhood income quintile was set to missing. Hospitals are unlikely to be the usual place of residence of the mother. School and university residences may be legitimate places of residence, but in such cases, although the geographic location is known with precision, the socio-economic characteristics of the neighbourhood of the school or university residence would not necessarily reflect the socio-economic characteristics of the mother.

Neighbourhood income quintiles were based on the average income per single-person equivalent (IPPE) in the enumeration area. IPPE uses the person-weights implicit in the Statistics Canada low-income cut-offs to derive "single-person equivalent" multipliers for each household size. For example, for 1996 a single-person household gets a multiplier of 1.0, and a two-person household got a multiplier of 1.25, and a three person household a multiplier of 1.55, since it generally costs less per person for two or more persons living together compared to one person living alone. The total income of the enumeration area (average household income times the number of households) was then divided by the total number of single person equivalents, yielding IPPE. This is a way of adjusting for household size, using the available data by enumeration area, since more sophisticated variables (such as the percentage of population under the low-income cut-off) are not available at the enumeration area level.

The IPPE quintiles of population were constructed within each CMACA (using SAS, PROC UNIVARIATE; BY CMACA), and then pooled across CMACAs. So one-fifth of the population of the Prince George census agglomeration was in each quintile, and one-fifth of the population of the Vancouver census metropolitan area was too. The reason for creating the quintiles within each CMACA is that housing costs vary enormously across Canada. Rents and house prices in some places (such as most of Quebec and the Atlantic provinces) have historically been much lower than those in Toronto or the lower mainland of British Columbia. Calculation of quintiles by CMACA (or city size within provinces) helps take that into account. Since we're dealing with relative (not absolute) income in any case, this helps to explain why quintiles calculated in this way (by CMACA) have in studies of mortality in urban Canada[9] revealed much greater disparities than have purely national quintiles (where 40% of the Atlantic provinces get classified into the poorest quintile, and 40% of Toronto into the richest quintile).

Note that for rural postal codes and urban postal codes for outlying suburban and rural areas, the same postal code is generally used for multiple enumeration areas, and the selection of a single EA for coding purposes is random, but with probabilities respecting the proportions of population with that postal code in each of the possible EA's. Thus, the coding is far less precise than for "ordinary" urban postal codes, which are usually only linked to a single EA.

- In recognition of current preferences we used the term *First Nations* to represent the following definition of those residents of British Columbia that we report here. Status Indians are one part of the broad group of First Nations people in British Columbia. There is considerable interest in the health status of First Nations people whether Status, Non-Status or Metis, but in most cases, relevant data exist only for Status Indians. A flag in the data set identified Status Indian births. The major source for this data flag was the British Columbia Vital Statistics Agency's statistical database of information extracted from birth registrations. Additional sources were the Indian Status Verification File (SVF) of the First Nations and Inuit Health Branch, Health Canada, originating from the Department of Indian Affairs and Northern Development and the Status Indian Entitlement files from the British Columbia Medical Services Plan. Using an extensive computer matching process, a birth was considered to be a First Nations birth if the individual was identified as First Nation in any of the three sources[10].

- *Parity* was defined here as the number of live-born and stillborn to date. It was chosen over the number of previous pregnancies (i.e., gravida) because it has been shown to have a higher correlation with birth weight[11] and was likely to be more accurately reported.

2.4.2. Secondary Analyses and Output

Primary analyses were intended to provide basic information for perinatal care and research. Additional analyses were done to provide more information on groups that might be expected to experience distinct birth outcomes, to make a contribution to the general field of birth weight for gestational age charting, and to aid interpretation of the primary output. These included:

- Geographic mapping of the variation of birth outcome throughout the province.
- Descriptive statistics, charts and mortality grids for infants where both parents had immigrated from three areas of the world that have a large cultural base in British Columbia: Chinese locations* (Hong Kong, Peoples Republic of China, Singapore, Taiwan and Vietnam); South Asia (Bangladesh, British India Ocean Territories, Sri Lanka, India, Nepal, Pakistan); and Europe (48 countries West of the Ural Mountains). We were fortunate that BCVSA records the birth place of the mother and the father so all births were identified here as 'Chinese', 'South Asian' or 'European' only if both parents were born in the specified locations.
- Twenty-year secular changes in birth outcomes other than birth weight for gestation.
- Investigation of the effect of using the 3rd, 5th, and 10th percentile to evaluate risk.
- Charts and descriptive statistics for birth length and birth head circumference for births since 1995.
- Other analyses suggested by the primary output.

* Note that locations from which immigrants to British Columbia were considered to be of Chinese origin were chosen after consultations with SUCCESS, the largest Chinese cultural support organisation in British Columbia. Immigrants from those countries are considered as sharing Chinese habits, culture, genetic heritage, and, most importantly, natality customs. In this report they are operationally defined as "Chinese" immigrants or "from Chinese locations" for brevity and ease of presentation.

3. RESULTS

3.1. Exclusions

The number of cases excluded from analysis and the reasons for their exclusion are presented below. The exclusions represent 0.24% of live births in the original computer file and were mostly due to incomplete computer records.

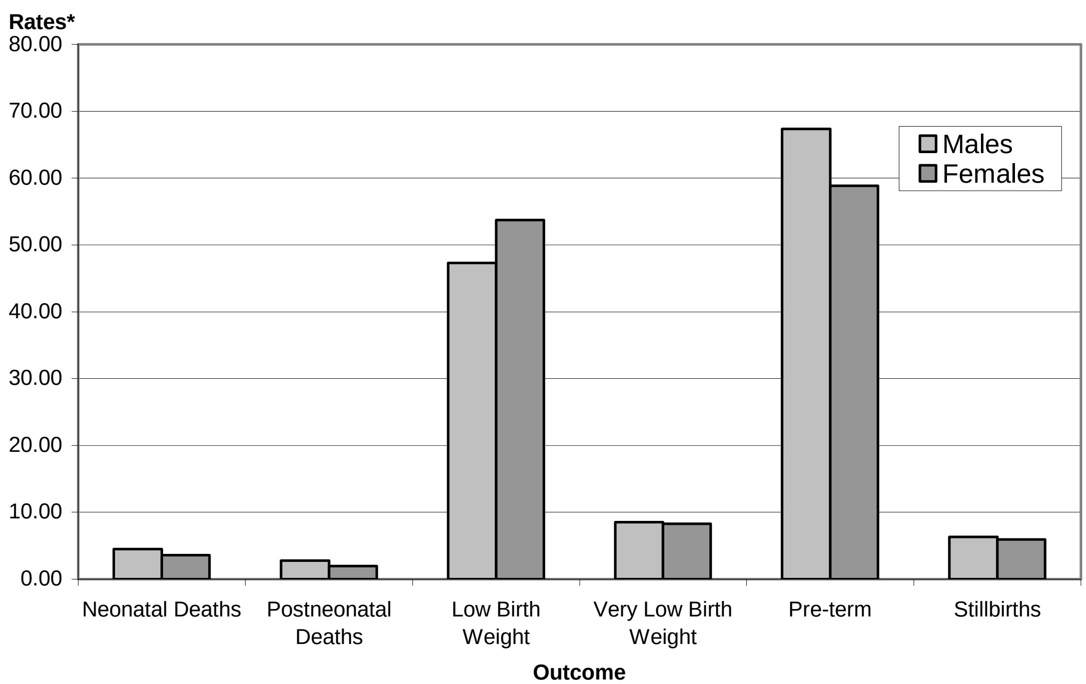
Table 1: Cases In Study Population

Number of Registrations 1981 to 2000		887,896
Cases < 20 Weeks	33	
Cases > 44 weeks	73	
Missing gestational age	1	
Only gestational age = 0	771	
Only birth weight = 0	198	
Birth weight and gestational age = 0	976	
Birth weight = 9999	51	
Invalid weight for gestational age*	4	
Stillbirths in study range	5,506	
Total exclusions		7,613
Number of live births for analysis		880,283

* Birth weight > 5 S.D. from mean and not correctable using original documents

Figure 1 shows the observed rates for selected birth outcome measures, comparing males versus females.

Figure 1: Rates for Selected Outcome Measures



* rates for stillbirths per 1,000 total births, others per 1,000 live births

3.2. Primary Analyses

Descriptive statistics at each week of gestation are shown for the full population in Table 6.1.1. The 3^{rd}, 5^{th}, 10^{th}, 50^{th} (median), 90^{th}, 95^{th}, and 97^{th} percentiles of the birth weight distributions are the raw values. Those charted in Figure 6.1.1 have been smoothed to compensate for chance fluctuations. Full-term deliveries (37 to 41 completed weeks) totalled 776,043 or 88.16% of the study sample. There were 55,637 pre-term births (6.32% prior to 37 weeks) and 48,603 post-term (5.52% after 41 weeks). Average weight for full-term infants was 3,469 grams. It was 2,367 grams for pre-term and 3,732 grams for post-term infants.

The equivalent statistics and charts for males, females, singleton males, singleton females, multiple births, First Nations, births with congenital anomalies, births to primiparae, births to multiparae, the five neighbourhood income quintiles, and each four-year period 1981 to 2000 are presented in Tables and Figures 6.1.2 to 6.1.20 respectively.

3.3. Secondary Analyses

Additional analyses were suggested by the primary output and the literature review. They are intended to provide more information on groups that might be expected to experience distinct birth outcome.

3.3.1. Geographic Location

Descriptive statistics were calculated for each of five main regions defined as British Columbia Health Authorities: Interior, Fraser, Vancouver Coastal, Vancouver Island, and Northern as shown in Tables 6.1.21to 6.1.25. The smoothed charts are shown in Figures 6.1.21 to 6.1.25. See Appendix 6.4 for maps of Health Service Delivery Areas and Local Health Areas included in each Health Authority.

3.3.2. Births to Immigrants

Birth weight is related to ethnic and cultural origin. To be more precise, previous studies at BCVSA have reported reliable birth weight differences among newborns of parents of Chinese[12] and South Asian[13] origin compared to provincial standards. British Columbia has substantial immigrant populations from those areas and from Europe so analyses were conducted using the foreign birthplace of the mother and father as the independent variable. Descriptive statistics and the chart for births to mothers and fathers from Chinese locations appear in Table and Figure 6.1.26. Those for mothers and fathers from South Asia appear in Table and Figure 6.1.27and those for mothers and fathers from Europe appear in Table and Figure 6.1.28. There were not enough European births at 20 weeks to provide meaningful statistics at that gestational age and caution is advised when interpreting statistics at other gestational ages.

There were 40,598 live births to Chinese immigrant parents, 38,592 to South Asian immigrant parents, and 19,078 to European immigrant parents during the twenty years covered in this study but cases were subject to exclusion from analyses because of the criteria mentioned previously.

3.3.3. Secular Trends in Selected Variables

Table 6.2.1 shows changes in selected outcome variables in each four-year period after stratification by gestational age. The variables were selected to further define the birthing population used to produce the charts and tables in this study. While they closely replicate statistics from other sources (e.g. British Columbia Vital Statistics Agency Annual Reports), the statistics in Table 6.2.1 apply only to births included in this study and not to all births in British Columbia.

3.4. Mortality Grids

There were 3,661 neonatal deaths in the BCVSA death file[14] for the period 1981 to 2000. The linking process described previously (see Methods) resulted in 3,656 (99.86%) neonatal deaths for analysis. There were 128 deaths excluded from the final grid because of the criteria reported in Section 2.4.1 and another 494 that had a birth weight under 500g so the final grid is based on 3,034 neonatal deaths.

Cross-classification by birth weight and gestational age produced a grid with 225 cells that met the criteria described previously. The coloured grid for all residents is shown in Figure 6.2.2. Percent mortality for each birth weight/gestational age crossing is shown as well as larger, coloured areas that depict relatively abrupt changes in percent mortality.

Percent mortality in all cells in the red area (extremely high mortality) of Figure 6.2.2 was greater than 45%. There were no cells between 35% and 45%. In the orange area (very high mortality) it ranged from 10% to 35%, in the yellow area (high mortality) from 2.0% to 9.9%, in the blue area (moderately high mortality) from 0.5% to 1.9%, in the dark green area (low mortality) from 0.10% to 0.49%, and in the light green area (very low mortality) the percentages were less than 0.10% (i.e. <1 per 1,000).

We were indeed fortunate to have the additional ten years of data, which enabled us to produce full mortality grids for males shown in Figure 6.2.3 and for females in Figure 6.2.4. The number of cells in the male and female grids was necessarily reduced because there were fewer male and female births included in each grid.

There were insufficient neonatal deaths in any of the other sub-groups to produce mortality grids with the narrow birth weight and gestational age groupings used in Figure 6.2.2. However, an alternative way of summarizing the data was devised whereby broader cell groupings could be used to provide reliable frequencies while maintaining a basis for comparison with the overall grid. Table and Figure 6.2.5 depict the percent mortality for all births within each of the coloured areas outlined in Figure 6.2.2. For clarity: 67.95% of the babies born in the red area (extremely high mortality) of Figure 6.2.5 died within 27 days, 17.23% of those in the orange area (very high mortality) died within 27 days, and so on.

Tables and Figures 6.2.6 to 6.2.8 show the percent mortality among male, female and First Nations births, within the equivalent coloured areas. The percent mortality among babies of mothers and fathers who were immigrants of Chinese origin is shown in Table and Figure 6.2.9 and for immigrants of South Asian origin, in Table and Figure 6.2.10. The percentages for neighbourhood income quintiles 1 (the lowest) to 5 (the highest) are shown in Tables and Figures 6.2.11 to 6.2.15.

Note that the percentages in Tables 6.2.3 through 6.2.15 refer to the proportion of babies born within each colour zone that died within 27 days so the percentages do not sum to 100%. As such the mortality rates can be considered statistically independent. Also, the coloured zones were determined by the pattern of abrupt changes in the full population grid; they should not be considered as constituted from independent grids for each of the sub-groups.

3.5. Effects of Socio-economic Status

Table 6.3.1 shows selected birth outcome indicators for the five neighbourhood income quintiles to provide additional information on the effects of socio-economic status.

3.6. Risk Evaluation Using 3^{rd}, 5^{th}, and 10^{th} Percentiles

Recent charts have included the 3^{rd} and 5^{th} percentiles as additional refinements for assessing risk at birth. To further investigate the risk implied by each percentile cut-off, birth outcome for babies below the 3^{rd}, 5^{th} and 10^{th} percentiles was analysed. Babies were grouped into one of the following categories: below the 3^{rd} percentile, from the 3^{rd} to below the 5^{th}, or from the 5^{th} to below the 10^{th}. Notice that each category was exclusive. Outcome measures are shown for each group in Tables 6.3.2.

3.7. Birth length and Birth Head Circumference

A shortcoming of the previous report was omission of British Columbia standards for birth length and birth head circumference, which were not available at that time. Those measurements have been included on the Notice of Birth since 1995 and BCVSA has been recording both since then. Because there were only five years of data for these measures, the descriptive statistics and smoothed charts begin at 23 weeks gestational age. Birth head circumference statistics and chart for the full population are shown in Table and Figure 6.1.29. The statistics and chart for birth length are shown in Table and Figure 6.1.30. In keeping with recent practice, descriptive statistics and the chart for birth head circumference of singleton males appear in Table and Figure 6.1.31 and of singleton females in Table and Figure 6.1.32. The corresponding statistics and charts for birth length of singleton males appear in Figure 6.1.33 and of singleton females in Table and Figure 6.1.34. Note that the tables and charts for birth length and head circumference are placed after the series of tables and charts for other groups for continuity.

3.8. Demographic Group Outcomes

Tables 6.3.3 and 6.3.4 show frequencies and rates for several outcome indicators for the main demographic groups in this study. The summaries provide basic comparisons and background information to aid understanding determinants of other output.

4. DISCUSSION

Birth weight charts are intended to be used to identify births that exhibit accelerated or retarded intrauterine growth in comparison to other infants in a comparable population. According to some schools of thought, an individual birth should be compared to other births in populations that have identical risk demographics, access to medical care, and other factors known to affect intrauterine growth and duration. Although national and provincial charts have been available for some years there is a recurrent need to improve and expand available charts based on ever-changing populations, advancing needs of health care and other professionals, as well as improvements in medical care and other health related services for infants. It is hoped that the data and charts presented here will address some of those needs by providing up to date reference standards for some of the diverse groups that make up British Columbia's newborn population and by providing a basis for comparison with other available charts.

Additional analyses, not reported in the results section, were carried out to clarify certain points warranted by the following discussion.

4.1. Full Study Population

The table and graph in 6.1.1 represent the full array of births that occurred in British Columbia. Earlier charts were designed to portray only "normal" births and therefore infants exhibiting selected deviations from "normal" were not included.

It is still debatable whether to use an overall chart as a reference or use a chart specifically dedicated to the various strata within the overall population. Should a unisex standard or a sex-specific standard be used? Do different ethnic groups require their own standard? The issues bear upon the risks inherent to the reference population. For example it would be ridiculous to produce charts dedicated to smokers and non-smokers because smoking is a behavioural risk in itself and differences have a pathological basis. Although a full discussion of those issues is beyond the scope of this report and a final consensus has not been reached, gender-specific charts are recommended[15] while ethnic-specific charts have been shown to be appropriate for some[27] but not for others[15]. A full population chart is presented here as well as demographic-group charts to demonstrate differences and encourage further research on these questions. (See section 4.10 for more discussion on this issue.)

Given the size of the full sample in this study it not surprising that the 95% confidence limits were close to the mean particularly after the first few weeks of gestation. However, the confidence limits will become meaningful when comparing sub-groups to the full population.

The most noticeable characteristic of Figure 6.1.1 was the accelerating growth up to about 37 weeks after which growth began to level off. Looking at the medians in Table 6.1.1 there was an ever-increasing simple weight gain each week (i.e., 75 grams in week 21 and 235 grams in week 37), after which the weekly gain was reduced in each successive week during term and post-term.

The positive skew in the distributions indicated by the smaller distance from the median to the lower percentiles compared to the distance to the upper percentiles was also noticeable. This was also confirmed by the consistently positive skewness measure in Table 6.1.1.

4.2. Gender Differences

At 20 and 21 weeks the median birth weights for boys were similar to those for girls (Tables 6.1.2 and 6.1.3), but thereafter, boys were heavier and the median difference steadily increased to 150 grams at term. The progressive differences shown here were virtually identical to the weight differences shown in the 1993 report[3]. According to these results boys weighed more than girls at virtually all gestational ages. Early studies reported that differences did not become apparent until at least 35 weeks but the lack of differences might have been due to the small numbers used in those studies. Canadian studies using large databases have consistently reported[3, 4, 5, 16] differences across the full spectrum of gestational ages.

As mentioned above current practice dictates separate charts for singleton males and singleton females[4, 5] since females are shown to be at lower risk despite lower birth weight[15]. The medians for singleton boys in Table and Figure 6.1.4 were a few grams heavier than all boys (Table and Figure 6.1.2) at early gestations and the differences generally increased during pre-term weeks but median weights were equal at term. The same pattern of differences between singleton and all births was also apparent for girls. The differences between pre-term and term were at least partially due to the exclusion of multiple births. By far most multiple births occurred during pre-term weeks so such births formed a larger proportion of all births during those weeks making the differences more apparent. Term births were dominated by singleton deliveries; hence the impact of multiple deliveries would have been small.

The potential overestimation of gestational age has been a question that has plagued birth weight by gestational age studies. It has been shown that the use of the mother's report of the onset of the last normal menstrual period (LNMP) can result in invalid estimates when compared to ultrasound dating[17]. A recent Canadian study[4] used a complex procedure where infants were excluded from further analysis based on the probability, derived from a maximum likelihood algorithm, that an alleged pre-term or post-term infant's true gestational age was 40 weeks. Data for singleton boys and girls were presented so it is appropriate to compare their results with Tables 6.1.4 and 6.1.5. Supplementary analyses (not shown here) indicated that both 90th percentiles, where errors would be most apparent, were remarkably similar before 26 and after 36 weeks. However, in the interim period the other study showed weights along the 90th percentile that were about 60 to 70 grams less than in this study. The same pattern was apparent for the median and 10th percentile but the differences were reduced. The same differences were apparent for girls. Although the possibility of an accelerated growth pattern during weeks 27 to 36 in British Columbia cannot be ruled out, the differences were commensurate with the correction strategy used in the other study. Considering the size of the differences between 27 and 36 weeks those results do not detract from the reference value of the British Columbia charts.

4.3. Plurality (Singleton Versus Multiple Births)

Because singleton births made up 98% of the full sample there was little difference between the singleton chart and the overall one so the former is not presented. However, the data for multiple births were lower at all gestational ages to the extent that, at term, the median for multiples closely matched the 10th percentile of the full sample, leading to the conclusion that fifty percent of the multiples have weights equal to and lower than ten percent of the predominantly singleton full sample. The multiple 90th is only 54 grams greater than the full sample median. Also the 10th, 50th and 90th percentiles for multiples in British Columbia closely matched those for Canadian twin births in 1986 but were slightly greater than the Canadian ones in 1972[18].

4.4. First Nations Births

As expected median and mean birth weight for First Nations infants were greater than the full population at all gestations, except 20 weeks. The prevalence of pre-term deliveries was 10.0% compared to only 6.2% for all births. These results confirm those of previous studies[3, 10]. Excessive weights are hypothesised due to a genetic endowment for fat storage and the relatively high prevalence of diabetes among First Nations people, in this case among First Nations mothers.

Notice that the First Nations 10^{th} percentile was consistently above the standard for the whole province (Table 6.1.1). If the provincial standard were used to classify First Nations babies, less than ten percent of them would be considered SGA. Further analyses were done to examine this issue. First Nations SGA babies were compared to non-First Nations babies using the overall provincial standard. First Nations SGA babies suffered higher rates of neonatal death (10.7 per 1,000 live births for First Nations versus 8.8 per 1,000 for the remainder) and higher rates of post neonatal death (12.5/1,000 versus 4.6/1,000).

The application of standard birth charts to First Nations births is being investigated and the results will be published shortly[27].

4.5. Births with Congenital Anomalies

There were 13,261 infants (1.5%) diagnosed with congenital anomalies. These conditions were more prevalent among very premature births, with 2.9% of infants born before 32 weeks and 1.6% born at or after 32 weeks so diagnosed.

The conditions, classified as congenital anomalies, are diverse and variously interact with birth weight and gestation so a birth weight chart representing their cumulative effect should not be considered a norm representing a singular effect. The main intent of our analysis of births with congenital anomalies was to show how the inclusion or exclusion of births with congenital anomalies from charted samples might have contributed to the final appearance of a standard chart. Rather than present a smoothed chart, Figure 6.1.8 compares the raw values of the three main percentiles for births with anomalies against those for the full British Columbia population. In spite of the fact that they form a small proportion of most samples, the deviations from the British Columbia norm shown in Figure 6.1.8 indicated that births with congenital anomalies might well alter the shape of an all-inclusive chart, but that alteration would not greatly affect the normative value of the chart.

It should be mentioned that the number of cases at each week of gestation in Table 6.1.8 caused concern over the reliability of the individual percentile values at each week. Although others have produced charts from smaller samples those samples had been modified in some way to enhance interpretation. For example, Kitchen et al.[20] and Keane and Pearse[21] supplemented the samples at lower gestational weeks, while Blinder[22] used a much narrower gestational age range.

Examining the edges of the distributions first, the 90^{th} percentile fluctuated considerably above the overall values up to 34 weeks, after which it stabilized and was similar to the overall through term. On the other hand the 10th percentile was reasonably close to the overall up to 30 weeks, after which it dropped considerably below the overall through term. Those patterns dictated the pattern of the median. The anomaly median was above the overall median up to 30 weeks where the two medians crossed and from then on the anomaly median remained below the overall.

Additional analyses failed to uncover any particular diagnostic categories that, either individually or in combination, could be responsible for those shifts. Although the shifts are considered reliable any further discussion based on these low frequencies would be very speculative. However, these data do suggest that infants born with congenital anomalies do have differently shaped birth weight charts and their exclusion from the charts in other studies would have had an effect, albeit minor because of low frequencies, on the output charts. It is hoped that their presentation here may suggest or encourage further research.

4.6. Parity of Mother

As noted in the 1993 report and repeated this time, the differences in birth weight between first and subsequent births (Tables 6.1.9 and 6.1.10) generally favoured subsequent births across the full gestational age spectrum, although the advantage was minor and not consistent until 35 weeks. Most studies have shown the biggest increase in weight between the first born and second born with succeeding births providing only marginal increases. For that reason parity was dichotomized for these analyses into primiparae or multiparae.

4.7. Income Quintiles

From 37 to 42 weeks gestation, median birth weights were clearly graded by neighbourhood income across the quintiles, with the highest weights in the richest quintiles, and the lowest weights in the poorest quintiles. At term, median birth weights for richest quintile babies were typically 60 to 70 grams heavier than for lowest quintile babies. At other gestational ages, there was either little difference across the quintiles (at 33-36 weeks), a reverse gradient (at 43-44 weeks), or no consistent pattern (at 20-32 weeks) by neighbourhood income. The 10th percentile birth weights were also clearly graded by neighbourhood income from 36 to 42 weeks gestation, and somewhat less clearly graded from 33 to 35 weeks, with no consistent pattern by income apparent prior to 33 weeks.

4.8. Longitudinal Comparisons

The medians in Tables and Figures 6.1.16 to 6.1.20 were almost identical during the pre-term period but at term there was a modest secular increase in each subsequent four-year period. The same pattern was apparent for the 10^{th} and 90^{th} percentiles although the increase was more modest.

In the last report there was an obvious skew in the 90^{th} percentiles in the two periods 1981 - 1982 and 1983 - 1984 but the skew was not apparent in the remaining three two-year periods. In other words the 90^{th} percentiles in 1981 to 1984 were skewed quite above those during the six subsequent years covered in that study. Informal contact with practitioners and obstetricians at the time of the last study revealed an apparent widespread practice of adjusting gestational age on the basis of ultrasound assessment usually performed in British Columbia at about 18 weeks. That practice combined with the facts that the main source of gestation data prior to 1993 was the notice of birth completed by the attending physician, rather than the birth registration completed by the mother, and since 1993 the notice of birth has been the sole source, may have contributed to greater accuracy. Also, it is well known that, in British Columbia and other Canadian jurisdictions, the use of ultrasound proliferated in the mid-1980s.

The above rationale for the increasing accuracy of gestational age data is admittedly speculative. However, when combined with the comparison to corrected data[4] mentioned in section 4.2 which indicated a minor dispersion, it is not unreasonable to conclude that these charts can be relied upon as a reference source.

4.9. Geographic Location

Little discussion is warranted about the variation in birth weight charts in different areas of the province. Although the values fluctuated there were no consistent differences across gestational weeks. It has been amply demonstrated that specific areas of the province vary in birth outcome[2, 14] but birth weight and gestational age charts are intended to portray standards not the details of birth outcomes.

Much has been written about the factors that affect intrauterine growth and duration such as stature, nutritional status, pre-natal care, cigarette smoking, access to medical care, etc. and there is little doubt that those factors vary across the regions. However, birth weight charts show the cumulative effect of all those factors so their similarity, as overall standards, not singular indicators, is not surprising.

Most importantly, the absence of discriminating differences confirms the efficacy of the overall and other charts as provincial standards.

4.10. Immigrant Births

Although The World Health Organization regularly publishes international data showing birth weights around the world, the differences are not presumed to be due to ethnic or cultural differences *per se*. There have also been many studies that reported the differences in weight among births to immigrant mothers compared to locally born populations. A study that has stood the test of time for repeated referencing was a study by Dawson and Jones[23] who compared birth outcomes for Punjabi and white European mothers and concluded that Caucasian standards should not be applied to all ethnic groups. In a review of the relationship between birth weight and ethnicity, Barron[24] cautions: “To compare ethnic groups for whatever purpose, the epidemiologist must negotiate a minefield of social variables, nutritional uncertainties and racial sensitivities.” With that caution in mind it should be adequate to say that the weights of babies of Chinese immigrant parents were generally higher than the provincial standard up to 31 weeks and then there was a crossover so that at term the babies of Chinese immigrants were smaller than the full population of babies. Babies of South Asian immigrant parents were slightly smaller than all babies during initial weeks and the difference increased in subsequent weeks. It is interesting to note that median values for babies of Chinese and South Asian immigrants were equal at 40 weeks – 167 grams less than the provincial standard. (It should be noted that the downward slopes of the 90th, 95th and 97th percentiles in the South Asian chart after term are potentially due to gestational age errors and should be interpreted with caution.) The medians for births to European immigrant parents fluctuated around, although mostly above, the median for the whole province in pre-term but consistently exceeded the provincial standard during term. The frequency of pre-term deliveries was limited so it may be an over-interpretation to presume that the babies of European immigrants are heavier than all British Columbia babies at all gestations, but the stability during term, where the numbers were adequate, strengthens that conclusion.

The decision to use an overall chart (e.g. the full population chart) as a reference for sub-groups within the overall population is admittedly debatable. There is evidence[15] that a specific standard is not warranted for Blacks in the United States. On the other hand, studies that compared fetal growth standards derived from different racial populations[25, 26] have recommended separate standards.

The evidence regarding the application of ethno-specific or overall charts for determining risk has not yet accumulated. The charts presented here for births to South Asian and Chinese immigrants will be enhanced by outcome measures based on the charts for each immigrant group compared to the overall British Columbia chart. Such an investigation is in progress and will be reported at a later date. Previous reports[12, 13] and the current work in progress[27] suggest that in British Columbia we are over-identifying newborns of Chinese and South Asian immigrant parents as “at risk” by applying the British Columbia standard to identify SGA infants.

4.11. Secular Outcome Trends in Selected Variables

Table 6.2.1 was prepared to augment the birth outcome data in other sections of this report. Some findings were particularly notable. As evidenced elsewhere[14] there was a clear and dramatic decrease in neonatal and post neonatal mortality particularly during the final four-year period.

Another clear change was the rate of post-term deliveries. Here the secular decrease can be seen in the percentage of live births occurring from 42 to 44 weeks. This had decreased across the ten years covered in the last study and that trend continued in the 1990's. The post-term decrease appears to have been taken up by equivalent increases in term births. Of more concern to the medical community is the rate of pre-term deliveries, but those rates fluctuated over the five 4-year periods studied here, so no clear trend was apparent.

Please note that Table 6.2.1 is intended for comparisons across yearly periods only and not across gestational periods. The outcome measures selected for presentation are variously and negatively correlated with gestational age so such comparisons could be misleading.

4.12. Mortality Grids

Compared to the 341 neonatal deaths charted by Lubchenco et al.[28] and the 252 charted by Koops et al.[29] the 3,656 deaths analysed in this study have permitted the extension of mortality percentages down to 21 weeks and have undoubtedly resulted in a more reliable grid. Although individual percentages were subject to chance variation, an emerging pattern was apparent in Figure 6.2.2: There was an unmistakable central path of diminished risk extending up and to the right across the whole grid but greater risk accrued to increases or decreases in birth weight from that central path even with advancing gestational age. Focusing on that central path there was an obvious advantage to be gained from increases in birth weight and gestational age. However, our results did not provide evidence as to which factor was independently more efficacious. Close inspection of the grid may suggest hypotheses amenable to more precise testing.

The next thing that was noticeable, and was particularly noticeable in the original raw percentage version, was that there were abrupt drops in the percents shown here by the colour changes. The most noticeable abrupt change of course was from the red to the orange area - there were no cells with between 35 and 45 percent deaths. And notice between the orange and the yellow areas the abrupt change was apparent and so on for the remaining coloured areas.

As expected the largest column in the light green area (the lowest risk area) was at 40 weeks between 3,500 to 4,499 grams. Although the percents fluctuated, there was a general increase in risk accruing to babies born with decreases or increases in weight or gestation in any direction from that optimal group. The last report presented data from 1981 to 1990 and the inclusion of data from 1991 to 2000 has enlarged the "Very Low" risk group (light green area) to include higher birth weights and into post-term.

A recent Canadian study[30] compared relative risk for early (0 to 6 days) and late (7 to 27 days) neonatal deaths in specific birth weight and gestational age categories in nine provinces and two territories. Risks were related to Quebec because Quebec had the largest number and lowest infant mortality rate among the provinces and territories studied. While British Columbia typically enjoyed one of the lowest risk levels in Canada the results for post-term and heavy weight babies are pertinent here. Although the post-term period extended to 47 weeks there was diminished risk in BC for early neonatal deaths but there was no increased risk for late neonatal deaths. Conversely, "heavy" babies showed increased risk for early but diminished risk for late neonatal deaths although a baby was considered heavy if its weight was between 4,000 and 6,999 grams. Given that we combined early and late neonatal deaths and narrower birth weight and gestational age categories in this study, our results confirm and refine the results of the earlier study.

The percents in the red area (extremely high mortality) might be considered low for such birth weights and gestational ages. It should be remembered that we were tracking neonatal deaths so some of those in greatest jeopardy, particularly those at low gestation and weight, may have succumbed after 27 days. Compared to the 1993 report, mortality in low birth weight and gestational age groups has decreased; no doubt improved medical technology has enhanced survival time for those in greatest jeopardy. In addition, underestimation of gestational age for just a few births in the red area may have enhanced apparent survival.

Turning to mortality among boys (Figure 6.2.3) and girls (Figure 6.2.4), our findings confirmed previous findings not only in British Columbia, [2,14] but worldwide, that males have higher neonatal mortality than females. However, the patterns of mortality across the birth weight and gestational age spectrum showed provocative differences.

First, a brief comparison of the male grid to the overall grid shows fewer cells in the light green area but the green, blue and yellow areas did not change substantially and the decrease in the light green area was taken up in the orange and red areas. Contrasting the female and overall grids, the size of the light green area for females was expanded in all directions and the actual percentages appeared lower in the whole area. Some of that expansion resulted in a reduction of the green and, to a lesser extent, the orange and red areas – in other words the expansion actually reduced the proportion of cells constituting the latter three areas.

There is a lot of current interest in mortality differences between males and females so those two grids will now be discussed based on additional analyses not shown here.

The cells constituting the central line of least risk were quite similar in the grids for each gender compared to the overall grid. Although the bracketing of the central line was just as apparent in the grids for each gender, the shape of the coloured areas was, of course, different. The most obvious difference in the grids for each gender was the size of the light green area where girls had a substantially larger number of cells. The proportion of cells in the green area for females was smaller than that for males. The proportions for each gender in the blue areas were the same. The proportion of cells in the yellow area was larger for females, and smaller in the orange and red areas. Although we concentrated on relative size differences, the shape of the coloured areas and distribution of percents should also be considered when reviewing the grids.

The three grids portray the changes in neonatal mortality in relation to birth weight and gestational age and the patterns are not simple ones. The important thing that has yet to be determined is whether the patterns represent physiological, pathological, or developmental factors underlying the differences and whether the differences are statistically reliable.

Turning to mortality among other groups there were insufficient sub-group births to produce full sub-group-specific mortality grids so, bearing in mind the cautions mentioned in section 3.4, these figures show mortality within the coloured areas of the full population grid.

The rates for First Nations (Figure 6.2.8) were generally higher for babies born prior to 34 weeks and/or less than 4,000 grams (i.e. in the red, orange, and yellow areas). On the other hand, neonatal mortality at higher gestational ages and weights (i.e. in the blue, green, and light green areas) either favoured First Nations births, or showed them at only a slight disadvantage.

The grid for First Nations was intended as a comparison to the mortality pattern exhibited by all residents and should not be construed as an independent pattern exhibited by First Nations. A full mortality grid for First Nations may show a somewhat different pattern, but a full grid was not possible due to insufficient numbers.

The mortality risk to babies born to immigrants of Chinese and South Asian origins was considerably less in all areas of the grid than the risk suffered by all babies. The rates for European immigrants were slightly lower than those for all British Columbians, but the low frequencies made further comparisons tentative.

It has been amply demonstrated[12, 31] that Chinese babies when compared to Caucasians have a lower mortality rate in spite of lower average birth weights. Those results were confirmed here but they are portrayed across the birth weight and gestational age spectrum. The factors that affect natality outcome in Caucasians and Chinese are myriad and differ in their degree of effect. The lower rates among Chinese have been attributed to reduced risk factors (e.g. smoking), beneficial pregnancy habits, the deference given to prospective and postnatal mothers ("mother warming"), and racial (i.e. genetic) heritage[12, 32].

The reduced perinatal mortality rate for expatriates from the Indian sub-continent has also been amply demonstrated in comparisons to Western indigenous populations[13, 23]. Here those favourable results are displayed in more detail and, when compared to the overall mortality pattern, babies born to South Asian immigrant parents enjoyed an advantage across the full spectrum.

It can be hypothesized that the low mortality among births to Chinese and South Asian immigrants is attributable to an immigration selection bias, i.e., immigrants are selected because they are healthy, well educated, and enjoy a high socio-economic status with the resulting better Chinese and South Asian birth outcomes. However, examination of the neighbourhood income quintiles of the mothers' residence reveals 61% of both the Chinese and South Asian immigrants fall into the lowest two quintiles compared to 43% for all other groups. Also, only 22% of Chinese and 17% of South Asian mothers lived in the two highest quintile areas versus 35% for all other groups. This evidence, although limited, refutes the "healthy immigrant" hypothesis, and should encourage a more rigorous investigation in future research.

4.13. Additional Outcomes by Neighbourhood Income Quintile

Because of the current interest in the effects of socio-economic factors on birth outcome Table 6.3.1 presents selected outcome rates for neighbourhood income quintiles based on household-size adjusted average income in the mother's neighbourhood of residence. There was a clear association between neighbourhood income environment and virtually all the outcomes. The strength, reliability, and degree of association would be dependent on the degree of variation within and between groups and would require statistical testing which was beyond the intent of this report. However, little doubt remains about the advantageous consequences associated with higher neighbourhood socio-economic status.

All of the summary measures of unfavourable birth outcomes were clearly graded by neighbourhood income quintile, with better outcomes in each successively higher income quintile. In such cases, the ratio of the rate for the poorest quintile divided by the rate for the richest quintile provides a good summary of the extent of the inequalities. The inter-quintile rate ratios were 1.52 for stillbirths, 1.30 for infant mortality (1.25 for neonatal mortality, 1.38 for post neonatal mortality), 1.31 for small for gestational age, 1.30 for low birth weight, 1.20 for very low birth weight, and 1.19 for pre-term birth.

4.14. Risk Evaluation Using 3^rd^, 5^th^, and 10^th^ Percentiles

In the last few years the popularity of SGA (<10th percentile) as a risk indicator has increased and there has been a recent disposition to report the 5th and/or the 3rd percentiles as additional standards for SGA. However, some questions have arisen from health care professionals about the degree and nature of risk associated with SGA – no matter what cut-off level is used. Health care administrators are asked to explain the medical, public health, and financial repercussions to justify regional differences in resource allocation[33]. To that end Table 6.3.2 shows outcome risks associated with the 3rd, 5th, and 10th percentiles of the British Columbia standard (Table and Figure 6.1.1).

The standard birth outcome indicators in Tables 6.3.2 are routinely used to show the different risks associated with various independent variables. It is not surprising that the risk for all these outcomes increased with descending percentile cut-offs. As a matter of fact, low birth weight (LBW) and very low birth weight are standard indicators, but have not been included because the percentile level is directly determined by birth weight. However, the variation in the degree of the increase is worth a closer look. Focusing on risks in the 10th to 5th group compared to risks in the other two groups, the risk for neonatal death was almost twice as great for babies between the 3rd and 5th percentiles and three times as great for babies under the 3rd. The risk of post neonatal death for babies between the 3rd and 5th was one and a half times as great and a little more than twice as great for babies under the 3rd percentile. It is clear that the greatest differentials between the groups were for stillbirths. Looking across all outcome measures the largest increase in risk was in the group of babies born under the 3rd percentile compared to those born between the 3rd and 5th but there was still a substantial difference between the latter group and those born between the 5th and 10th percentiles.

4.15. Birth length and Birth head circumference

Although birth length and birth head circumference are not as predictive of mortality as are birth weight and gestational age, the former two measures are used to diagnose pathologies at birth[34]. The additional measures are used to diagnose abnormalities in body proportions such as achondroplasia, hydrocephalus, and microcephalus[35].

In recognition of the importance of both measures and in response to comments about their 1993 birth chart report[3] BCVSA began recording birth length and birth head circumference in 1995 to provide population statistics and enable research on these two important outcome indicators. The number of observations is reaching a stage where reliable population statistics are feasible.

The actual measurement of birth length and to a lesser extent birth head circumference just after delivery can present difficulties[19] and requires a combination of skill, speed, and patience. As these are new measurement procedures we should initially look at the distributions in Tables 6.1.29 to 6.1.34 and compare them to other published data. As few jurisdictions collect population data concerning these anthropometric measurements, the reviews were confined to small-sample *ad hoc* studies.

A 1984 study sampled births at a Hamilton, Ontario hospital[22] and reported mean birth length at term of 52.0 cm for singleton boys and 51.3 cm for singleton girls, which compared favourably with the term values in Tables 6.1.33 and 6.1.34. At term, birth head circumference was 35.2 cm for singleton males and 34.4 cm for singleton females, which compare well with the values for term births shown in Tables 6.1.31 and 6.1.32.

A 1995 study[36] set in Manchester, England compared term births to British-Isles-born versus immigrant mothers. Singleton male babies of indigenous mothers had a mean birth length at term of 51.0 cm and singleton girls averaged 50.0 cm. Birth head circumference at term was 34.8 cm for singleton males and 34.2 cm for singleton females. The four estimates from England are comparable to the term data in this study.

There were few cases with measurements of birth head circumference and birth length at early gestational ages so the percentile values, particularly those on the edges of the distributions, should be viewed with caution. Nevertheless, stability of the estimates is suitably established at later stages. Few other studies have published measures at such low gestational ages but they are shown here to give an indication of the quality and availability of these data.

5. CONCLUSION

This report has presented a broad descriptive profile of current birth outcomes in British Columbia. That has been done in terms of birth weight and gestational age charts for all residents and for numerous population sub-groups living in the province. Despite demographic, socio-economic, cultural, geographic, and ethnic diversity in British Columbia the comparisons depicted relatively small yet consistent differences between sub-populations within the province.

The descriptive statistics provide a normative basis with which to compare individual births and make sound judgements about the condition of the newborn. These statistics should also provide a springboard from which to develop hypotheses amenable to testing with more refined statistical techniques.

The charts presented here address a recurring need for updated references to keep pace with a constantly evolving demographic profile and advancing medical technology in British Columbia. A comprehensive array of statistics has been offered to further define particular aspects of birth outcomes, notably socio-economic status and risk evaluation. The picture that emerges is that of a healthy and sustained community requiring improvement in some specific areas.