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ARTICLE

Estimation of the number of people with Down syndrome in Australia and New Zealand

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ABSTRACT

Purpose: Previous research estimated the effect of selective terminations on birth prevalence and population prevalence of people with Down syndrome (DS) in the United States and Europe. This study provides comparative data from Australia and New Zealand.
Method: The number of live births (LBs) with DS—in the absence of DS-related terminations of pregnancy—was estimated on the maternal age distribution in the general population. Actual LBs were modeled on registry data. We applied constructed survival curves to annual LBs to predict population numbers.
Results: For 2016-2020, we estimated 265 annual LBs with DS (1 in 1158) in Australia and 41 annual LBs (1 in 1450) in New Zealand. For this period, the reduction percentage—the net result of DS-related terminations on LB prevalence—was estimated at 66% for Australia, 71% for New Zealand, 62% for Europe (excluding the former East Bloc), and only 32% for the United States.
Conclusion: The total population of people with DS has been decreasing since 2000 in Europe (West Bloc) and 2011 in New Zealand owing, in large part, to increased selective terminations. By contrast, the population continues to increase, as of 2020, in Australia and the United States.

Introduction

Accurate estimates of the prevalence of chromosomal conditions such as Down syndrome (DS) provide the foundations for the development of effective public policy and service provision. However, in Australia, there is neither a national registry nor recent country-level data on DS live birth (LB) prevalence. Data collection on LBs with DS varies between state jurisdictions, and regional Australian surveillance data are scattered over diverse reports. For New Zealand, the New Zealand Birth Defects Registry (NZBDR) has collected DS LB prevalence information from 1980 onward. However, an estimation of population prevalence is lacking.

Access to accurate data is essential to provide a foundation for nongovernment and government initiatives within

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Australia and New Zealand, such as the National Disability Insurance Scheme (NDIS) in Australia, informing resource allocation and providing insights into accessibility. Comprehensive data are also essential to inform advocacy efforts to address health and social inequities faced by people living with DS and to help understand the implications of trends such as the increased life expectancy of people with DS and the wider use of noninvasive prenatal screening.

Increasingly, prospective parents are choosing noninvasive prenatal screening because they seek information about the likelihood their pregnancy has a chromosomal difference such as DS.[1] In Western Australia, 93% of prospective parents chose termination after diagnostic confirmation of a high chance screening result for DS during the period 1980-2013.[2] It is important to note that this rate of termination does not mean a reduction of births by 93% because there was (and still remains) a substantial group of prospective parents who chose to forgo prenatal screening or diagnostics for a variety of reasons.

Previous modeling estimated an overall reduction of babies born with DS as a consequence of selective terminations to be 30% in the United States as of 2010[3] and 54% in Europe as of 2011-2015.[4] This study provides a point of comparison for Australia and New Zealand. By establishing baseline data for DS LB prevalence and population prevalence of people with DS by age group, we aimed to clarify the effect of prenatal screening so that we can better interpret future trends.

Materials and Methods

Estimates of nonselective LBs of children with DS

The number of LBs with DS—in the absence of DS-related terminations of pregnancy—can be estimated on the basis of the maternal age distribution in the general population.[5] We applied the model of Morris et al.[5] Data on maternal age distribution in Australia and New Zealand were collected from the Australian Bureau of Statistics, Stats NZ, and the Demographic Yearbook Collection of the United Nations (Supplemental Materials 1A and B).

Estimates of actual LBs of children with DS

The number of children with DS that are born is reduced by the number of DS-related terminations of pregnancy. However, prenatal diagnostics were not available before 1967. We have assumed that, for both Australia and New Zealand, reduction was 0 in 1967, 1% in 1972, and 4% in 1977, similar to the estimates used in earlier studies.[3,4] Data on actual LBs of children with DS in New Zealand born in the 1970s are not available. However, for Australia, we found 3 studies that confirm that there were only small numbers of DS-related terminations in this period.[6-8]

On the basis of data from the National Perinatal Statistics Unit,[9] we estimated a reduction of 15% in 1982 in Australia. On the basis of the NZBDR, we estimated a reduction of 14% in 1982 in New Zealand. Reduction rates between 1977 and 1982 were interpolated.

For 1982-2003, the National Perinatal Statistics Unit reported the number of LBs of children with DS across Australia. In addition, we found regional data for New South Wales (1990-2018), Queensland (1981-1983; 1988-2004; 2008-2020), South Australia (1980-1998; 2002-2011; 2013-2017), Victoria (1983-2010; 2013-2016), and West Australia (1980-2014) (Supplemental Materials 1C and D).

For 1982-2003, we have used the estimates on the basis of the countrywide data. From 2004-2018, to reduce the possible random fluctuation in regional samples, we have used 5-year running averages based on the regional data combined. For 2019, we have used the 3-year average of 2018-2020. For 2020, we have used the average of 2019-2020.

The Clearinghouse Report (2014) reports data on LBs with DS in New Zealand for 1980-2012.[10] Professor Barry Borman of the NZBDR provided data for 1996-2020 by personal email. For the overlapping years (1996-2012), there seems to be an under-reporting in the Clearinghouse Report. The NZBDR annually provides data for the Clearinghouse Report. If a child with DS is reported to the NZBDR at a later time, it will be added to the NZBDR database, whereas the Clearinghouse Report is not updated. As such, we assumed a similar extent of underreporting for 1980-1995 and have corrected the data accordingly (Supplemental Materials 1C and D).

Modeling survival

For modeling survival in DS, we followed the approach of de Graaf et al.[4] On the basis of multiple historical studies on the survival of persons with DS in high-income countries, they constructed DS-specific survival by year of birth.

We have not found specific data on survival for people with DS in New Zealand. In Australia, however, this has been the focus of different studies.[11-16] The model projections of 1-, 5-, and 10-year survival rates by year were highly similar to the data from these Australian studies (Supplemental Materials 2A). However, the (Western) Australian research data from the late 1950s and 1960s show somewhat higher survival rates than projected by the model.[12] This might be the result of an undercounting in this time frame of children with DS who died before they were registered by the surveillance programs.

For modeling survival rates beyond age 10 years from 1950 onward, de Graaf et al[4,17] made use of the average of (highly similar) survival curves for people with DS from 7 different historical studies, one from Australia—ie, study by Glasson et al.[13] Up to 1950, de Graaf et al[4,17] used a hazardous curve based on the study by Penrose.[18] Differences were small between the modeled survival curve beyond age 10 years (as used from 1950 onward) and the curve constructed by Glasson et al[13] (Supplemental Materials 2A).

Prediction of numbers of people with DS alive and deceased by age and year

For both Australia and New Zealand, we applied our constructed survival curves to the estimated annual numbers of LBs of children with DS to predict the number, by age group, of people with DS alive in the population. We also predicted the number of deaths of people with DS by age group for different years (Supplemental Materials 3).

Validating the model

In Australia, the National Disability Insurance Agency (NDIA) is the government agency that provides funding for services for people with permanent and significant disabilities. On request, the NDIA provided data on the number of participants with DS in the NDIS, by age group, as of June 2020 and June 2021. We compared these to our modeled projections of people with DS alive by age (Supplemental Materials 3A).

The WHO Mortality Database comprises deaths, by primary cause of death, registered in national vital registration systems.[19] National systems can be incomplete, and deceased people with DS will not always be registered as having died with DS as the primary cause of death. However, if we were to assume that under-registration is not dependent on the age of the person, one could consider these data as a depiction of the age distribution of deaths of people with DS. We compared this distribution to the model predictions (see Supplemental Materials 3B).

Results

LBs and LB prevalence

For the most recent period, 2016-2020, we estimate 265 annual LBs of children with DS in Australia, corresponding to a LB prevalence of 8.6 per 10,000 LBs (1 in 1158). For New Zealand, this is 41 annual LBs, and a LB prevalence of 6.9 per 10,000 LBs (1 in 1450). Absent DS-specific elective terminations, nonselective LB prevalence would have been 25.4 per 10,000 LBs in Australia and 23.4 per 10,000 LBs in New Zealand. For this period, the reduction percentage, which is the net result of DS-related terminations on LB prevalence, was estimated at 66% for Australia and 71% for New Zealand.

In Figure 1, we compare the historical developments in LB prevalence for Australia and New Zealand. For comparison, we added the United States and Europe, excluding the former East Bloc countries because these have had very different historical developments.[4] The data for the United States and Europe were derived from earlier studies.[3,4,17] For 1946-1950, DS LB prevalence is estimated at 19.0 per 10,000 LBs for Australia and at 20.0 per 10,000 LBs for New Zealand. Europe (excluding the East Bloc) had a higher value of 23.7 per 10,000 LBs, and the United States a lower value of 15.8 per 10,000 LBs. For all 4 geographic regions alike, after 1946-1950, nonselective DS LB prevalence steeply decreased until around 1980. Subsequently, nonselective prevalence started to rise again, reaching the highest values in Australia and Europe (excluding the East Bloc), followed by New Zealand and the United States (Figure 1).

Regarding actual LB prevalence, more different patterns emerged by geographic location (Figure 1). In the United States, actual LB prevalence fell to 9.9 per 10,000 LBs for the period 1981-1985 and increased afterward to around 13 per 10,000 LBs in 2011-2015, the most recent period with data available.[3,20] In contrast, in Europe (excluding the East Bloc), the nadir was in the period 2001-2005 with 8.9 per 10,000 LBs followed by a slight increase in the most recent years to 9.6 per 10,000 in 2011-2015.[4,21] Australia and New Zealand appear to follow a path that is in-between the United States and Europe (excluding the East Bloc). In Australia, the actual LB prevalence decreased to 10.5 per 10,000 LBs in 1981-1985 and increased subsequently (as in the United States in the same period) to 11.9 per 10,000 LBs in 1986-1990, was similar at 11.8 per 10,000 in 1991-1995, and then decreased afterward (as in Europe in the same period) to 8.6 per 10,000 LBs in recent years. In New Zealand, actual DS LB prevalence decreased to 10.5 per 10,000 LBs in 1976-1980, stayed fairly constant up to 1991-1995 (10.9 per 10,000 LBs), peaked afterward to 13.2 per 10,000 LBs in 1996-2000, followed by a decrease to 12.5 per 10,000 LBs in 2001-2005, and subsequently to 6.9 per 10,000 in 2016-2020.

Reduction percentage refers to the percentage of potential LBs of children with DS that are not born as a result of DS-specific elective terminations (Figure 2). Starting in the late 1980s, the European reduction percentage became increasingly higher than that in the United States.[3,4,20] Again, we saw that Australia and New Zealand seem to follow an in-between path, first resembling the United States, but later in time matching that of European developments. For comparison, as of 2011-2015, the reduction percentage was estimated at 64% for Australia, 61% for New Zealand, 62% for Europe (excluding the former East Bloc), and only 32% for the United States.

Within Australia, we estimated the reduction rate by state. For the most recent years with data available for every main state (2008-2011 combined with 2013-2014), the reduction rate varied between 58% in Queensland to 69% in South Australia (the Australian average was 63%).

Population numbers and population prevalence

As of 2020, we estimate a total of 13,426 people with DS living in Australia, 36% under the age of 20 and 30% above the age of 40 (Figure 3). For New Zealand, this estimate is 3065 people, with 34% under the age of 20 and 32% above the age of 40 (Figure 4) (see Supplemental Materials 4). In absence of DS-related termination, the population of people with DS as of 2020 would have been 23,156 in Australia

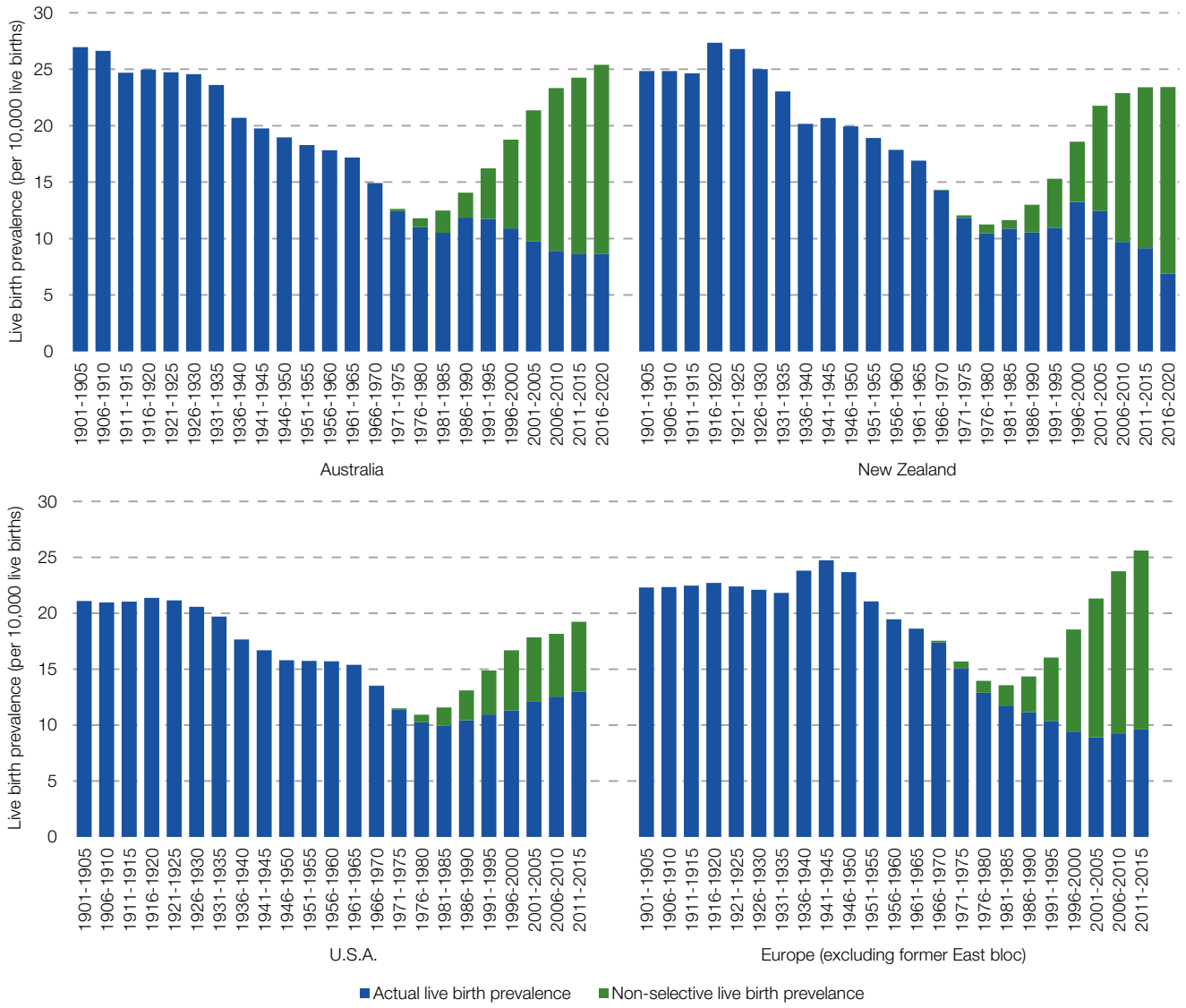

Figure 1 Estimates of live birth prevalence (nonselective and actual) of children with Down syndrome per 10,000 live births. U.S.A., United States.

and 4862 in New Zealand, corresponding to a population reduction rate of 42% and 37%, respectively. For comparison, as of 2015 (the most recent year with data available for all 4 geographic locations), these values were 36% for Australia and 30% for New Zealand, similar to the 32% in Europe (excluding the East Bloc) but much higher than the 21% in the United States.[4,17,20]

Actual DS population prevalence as of 2020 was estimated at 5.2 per 10,000 inhabitants in Australia and at 6.0 per 10,000 in New Zealand. As of 2015, DS population prevalence was estimated at 5.6 per 10,000 inhabitants in Australia, 6.8 per 10,000 in New Zealand, 6.7 per 10,000 in the United States,[17,20] and 6.3 per 10,000 in Europe (excluding the East Bloc).[4]

The difference between New Zealand and Australia in DS population prevalence partly reflects the higher DS LB prevalence in New Zealand between 1996 and 2008 (Figure 1). However, before 1996, for most 5-year periods, Australian DS LB prevalence was slightly higher to that in New Zealand. Still, in comparison to New Zealand, Australian DS population prevalence (with the exception of the 0- to 4-year olds) is consistently lower in every 5-year age group (Supplemental Materials 4). We deem this a result of a higher influx of immigrants in the general population into Australia than into New Zealand, increasing the value of the denominator.

DS population prevalence in Australia, New Zealand, and Europe alike has increased up to around 2000 and gradually decreased afterward (Supplemental Materials 4).[4] In contrast, in the United States, DS population prevalence has continued to increase in recent years.[17,20]

Validation

In Figure 5, we compare the model for DS population projections by age group for Australia in 2020 and 2021

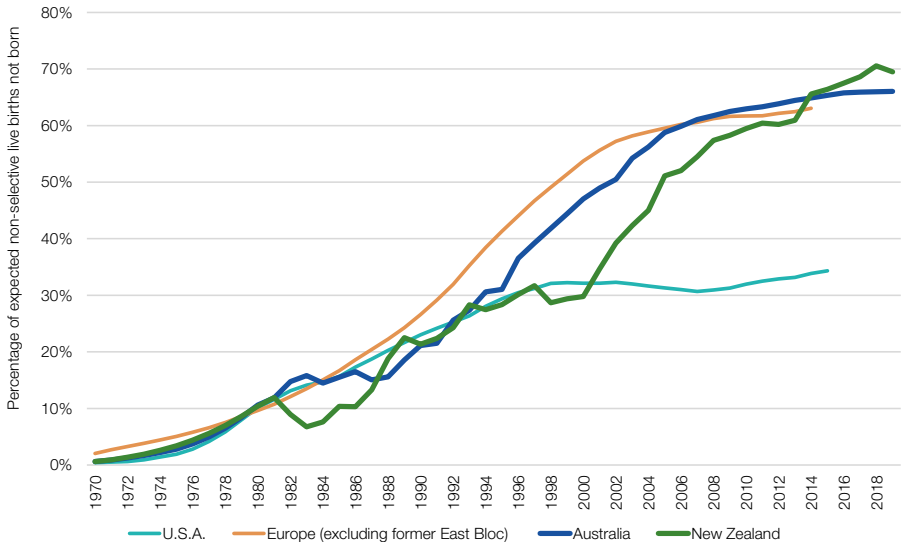

Figure 2 Reduction percentage of Down syndrome live births (5-year running averages). U.S.A., United States.

with the counts by the NDIA. We have omitted people of 65 years of age and older because one must be younger than 65 years to enter the NDIS.

For all age groups, the 2021 counts by the NDIA are higher than their 2020 counts. This implies that, although officially full rollout of NDIS was reached in 2020, still some people with DS in all age groups entered between June 2020 and June 2021. The increase is the strongest in the very young children, suggesting that, although officially all children with DS aged younger than 7 years are automatically eligible for the NDIS, there are structural delays in parents of young children with DS applying for access to the NDIS (Supplemental Materials 3A).

With the exception of the youngest age group, the model for 2021 had a fairly good fit with the 2021 numbers in the NDIS. The model predicted 13,338 people with DS under 65 years of age as of 2021; the NDIA reported 12,708, a difference of only 3%. If we exclude the 0 to 4 year olds, the

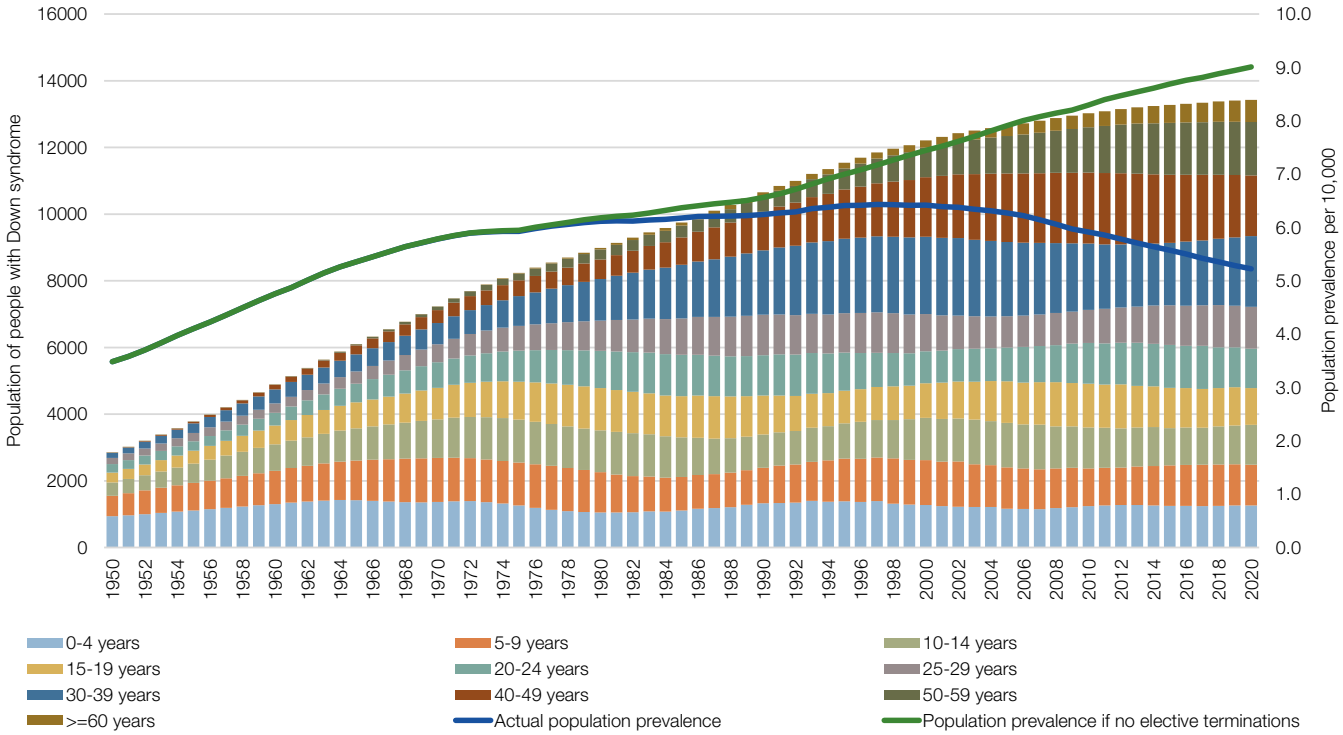

Figure 3 Estimated number of people with Down syndrome in Australia by age group and DS population prevalence estimates, 1950-2020.

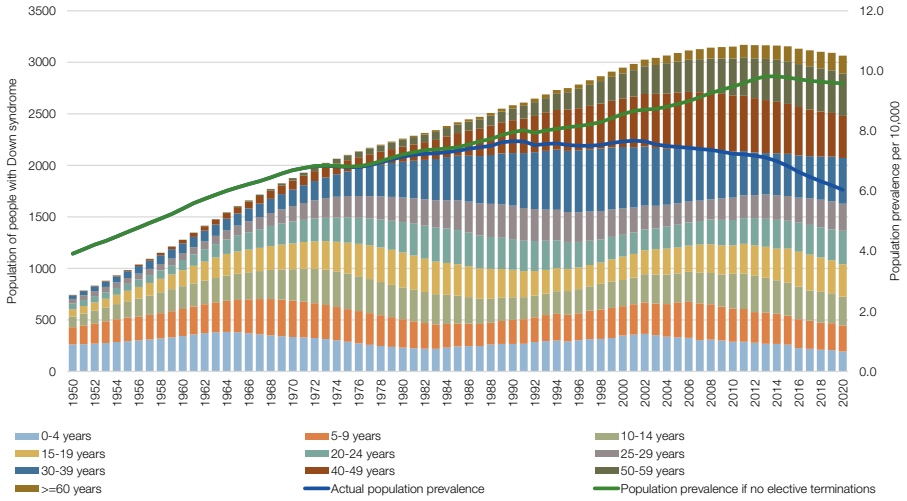

Figure 4 Estimated number of people with Down syndrome in New Zealand by age group and DS population prevalence estimates, 1950-2020.

difference is 0.7%. In the 20- to 39-year age group, as of 2021, the NDIA appears to count slightly more people (5%) than we had modeled. For the age range 40 to 55 years, the model predicted more people (9%) than the counts (Supplemental Materials 3A). Our best hypothesis regarding people with DS aged 40 years and older is that they and their families have been managing without government support for a long time, they are probably not accustomed to seeking formal support services or therapies and therefore may have a slower uptake to the NDIS.

In Supplemental Materials 3B, we show that the model projections of the age distribution of deaths of people with DS by year, for both Australia and New Zealand, are in line with the corresponding data from the WHO Mortality Database.[19]

Discussion

Development of DS LB prevalence

Europe (excluding the East Bloc) has the largest nonselective LB prevalence for DS, followed by Australia, New Zealand, and the United States (Figure 1). We see a similar pattern over time in all 4 geographic regions. After World War II (WWII), smaller family sizes and the earlier birth of the first child resulted in a decrease in nonselective LB prevalence for DS because children with DS are less likely to be born to younger mothers.[4,17] From around 1980 onward, as a result of the postponement of the birth of the first child, this trend reversed (Figure 1).

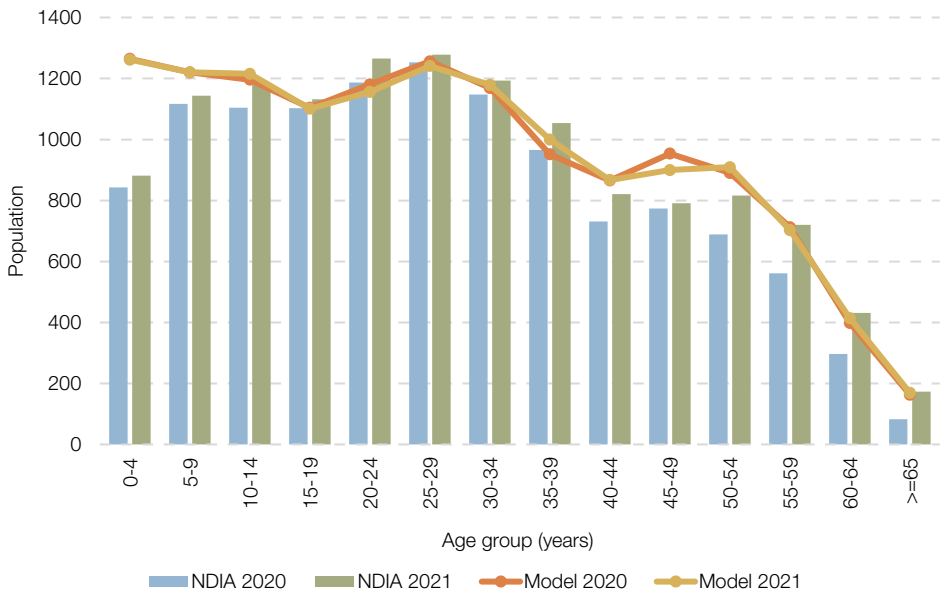

Figure 5 Estimates of people with Down syndrome by 5-year age group in Australia as of 2020 and 2021: A comparison between models and counts. NDIA, National Disability Insurance Agency.

The actual LB prevalence for DS after 1970 shows more striking differences by geographic location (Figure 1). In the United States, after the nadir in the period 1981-1985, actual LB prevalence for DS started to rise again.[3,4] By contrast, in Europe (excluding the East Bloc) actual LB prevalence for DS decreased until around 2004, followed by a very slight increase in the most recent years.[4] Australia and New Zealand seem to follow an in-between path. The analysis of the development of reduction percentage over time confirmed such an in-between path for Australia and New Zealand, first resembling the United States with a relatively slow increase in reduction but later catching up with a stronger rise in reduction percentages as in Europe (Figure 2). As of 2011-2015, the reduction percentage in Australia (64%) and New Zealand (61%) resembled the value of 62% of Europe (excluding the East Bloc), whereas the United States had a relatively low reduction percentage of 32%.[3,4,20]

Within Europe, excluding East Bloc and excluding countries with a very restrictive abortion policy (Malta and Ireland), reduction percentage for the period 2011-2015 varied between 40% in Sweden to 84% in Spain.[4] In the United States, as of 2014-2018, it varied between less than 20% in states such as Ohio to 66% in Maryland.[20] Differences in reduction percentages might be related to differences in maternal ages, differences in prenatal screening and reimbursement policies, differences in counseling expectant parents, religious/cultural differences, and any combination thereof. Within Australia, reduction percentages do vary as well, with Queensland having a relatively low percentage. In comparison to other Australian states, in Queensland, relatively more people live in smaller towns or rural areas.[22] Earlier studies have shown that living in a rural or nonmajor urban area is associated with lower uptake of prenatal screening.[23-25]

In Australia, after around 1995, the growth in reduction percentage began to differ from the US path. This coincided with the introduction in Australia of maternal serum screening (MSS) and the availability of an Australian Medicare reimbursement in 1993.[2,26] In contrast, in New Zealand, around 1996, after a pilot in the early 1990s, funding for second trimester MSS was withdrawn.[27] That might explain the relatively slower growth in the reduction percentage up to 2000. However, whereas we see a stronger increase in reduction percentage from 2000 onward, only in 2007 did MSS become part of the New Zealand National Screening Programme.[28] Therefore, the stronger increase in reduction percentage appears to have preceded this change in policy. However, before 2007, although a national policy on MSS was lacking, expectant couples could ask for nuchal translucency or for second trimester biochemical screening if they were aware of these possibilities and were willing to pay a fee.

In New Zealand, the introduction of NIPS from 2013 onward seems not to have had an accelerating influence on the reduction percentage, to date—ie, the reduction percentage continued increasing at more or less the same pace. In Australia, in most recent years, the rise in reduction percentage even appears to have leveled off. However, NIPS is not reimbursed in either Australia or New Zealand and brings considerable costs for the expectant women. In 2016-17, across Australia, two-thirds of pregnancies were screened, 72% were MSS and only 28% were NIPS.[29] The effect of NIPS on LB prevalence for DS might increase if public funding or reimbursement were available.

Development of the DS population and population prevalence

As of 2020, we estimated a total of 13,426 people with DS living in Australia and 3065 living in New Zealand. DS population prevalence was estimated at 5.2 per 10,000 inhabitants in Australia and at 6.0 per 10,000 in New Zealand.

After WWII, as a result of better survival of people with DS, especially in childhood, the total DS population size in both Australia and New Zealand strongly increased. In New Zealand the apex of population size was reached in 2011 and has been decreasing since. In contrast, in Australia the DS population is still increasing as of 2020. As of 2015, in the United States, the DS population size is still increasing too. However, in Europe (excluding the East Bloc), the population size has been decreasing already since 2000.[4,17]

DS population prevalence increased after WWII in both Australia and New Zealand. In Australia the apex was reached in 1997 and in New Zealand in 2001. For comparison, in Europe (excluding the East Bloc), the apex was reached in 1997, whereas in the United States, as a result of the much lower reduction of LBs of DS, the DS population prevalence has continued to increase in recent years.[4,17,20]

Improvement in survival of children with DS has changed the age distribution of people with DS. In 1950, in Australia, 79% of people with DS were aged younger than 20 years, and <1% were aged 40 years and older. As of 2020, these percentages were 36% and 30%, respectively. The corresponding values for New Zealand are highly similar. In 1950, DS was a primarily childhood syndrome; recently, there are many persons with DS in their fourth, fifth, and sixth decades of life. The United States and Europe (excluding the East Bloc) have seen a comparable development.[4,17]

Limitations of the method

The accuracy of the model's estimates are dependent on the quality of input data. After 2003, we used regional data for Australia. We assumed that actual LB prevalence would be similar between states with and without data. However, the available regional data covered 92% of the general births for 2000-2004, 83% for 2005-2009, 94% for 2010-2014, 69% for 2015-2018, but only 20% for 2019-2020. Therefore, the most recent values (2019-2020) might be less accurate. The value of LB prevalence for DS in 2019 is based on data from Queensland and New South Wales. For 2015-2018, an estimate based on these 2 states alone would be 4% higher than the estimate based on all states with available data. The

value for 2020 is based on only data from Queensland. The values of LB prevalence for Queensland were on average 7% higher for 2015-2018 than the estimate on the basis of all 5 states. If we had corrected for this difference, the reduction rate in Australia as of 2020 would have been estimated at 68% instead of 66%. We consider discrepancies in this range acceptable for modeling. In addition, birth defect surveillance programs might be affected by some undercounting. This could explain the fact that for the 20- to 39-year age group, as of 2021, the NDIA appears to count slightly more people (5%) than we had modeled. However, our model's estimates are higher than the NDIA counts for young children and for older adults. This suggests that more governmental action might be needed to reach out to families of both very young children with DS (aged 0-7 years) and to people with DS aged older than 40 years.

In our model, survival rates were based on diverse historical studies from high-income countries, including data from Australia, but also from the United States, Europe, Canada, and Japan. These estimated rates could be too high or too low for Australia and New Zealand. However, using Australian-based estimates of survival (Supplemental Materials 3A), instead, leads to highly similar results and a slightly less good fit between model and NDIA counts.

It is important to note that the mortality of people with DS in low-income countries will be much higher than in high-income countries. In estimating the worldwide population of people with DS, results from countries such as New Zealand, Australia, United States, and the European non–former East Bloc cannot be applied to low-income and under-resourced countries without adaptations.

Regarding migration of people with DS into or from Australia and New Zealand, we have assumed that net migration was zero. Both Australia and New Zealand have very strict rules regarding health requirements for people immigrating into the country.[30-34] However, before 2001, New Zealanders could enter Australia on a special category visa and directly apply for citizenship. New Zealand citizens who arrived in Australia after February 26, 2001, are not eligible for NDIS.[35] In 2019, there were around 570,000 New Zealand–born people living in Australia.[36] Some of them might have DS. Therefore, perhaps the higher number in the Australian NDIS, in comparison with the model for the age group 20 to 39 years, might partly be explained by some New Zealand–born people with DS being enrolled in the NDIS. However, earlier research has shown that United States interstate migration is much lower in people with DS than in the general population.[37] People with DS are usually more dependent on support than people without an intellectual disability. Therefore, we would expect the numbers of immigrants with DS to be very low.

Data Availability

We will supply data and materials individually upon request.

Acknowledgments

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Ethics Declaration

Only publicly available data were used for this study. All of the data were de-identified and did not qualify as human subjects research. As such, institutional review board approval was not necessary.

Conflict of Interest

B.G.S. occasionally consults on the topic of Down syndrome (DS) through Gerson Lehrman Group. He receives remuneration from DS nonprofit organizations for speaking engagements and associated travel expenses. B.G.S. receives annual royalties from Woodbine House, Inc, for the publication of his book, *Fasten Your Seatbelt: A Crash Course on Down Syndrome for Brothers and Sisters*. Within the past 2 years, he has received research funding from F. Hoffmann-La Roche Ltd, AC Immune, and LuMind-Research Down Syndrome Foundation to conduct clinical

trials for people with DS. B.G.S. is occasionally asked to serve as an expert witness for legal cases in which DS is discussed. B.G.S. serves in a nonpaid capacity on the Honorary Board of Directors for the Massachusetts Down Syndrome Congress and the Professional Advisory Committee for the National Center for Prenatal and Postnatal Down Syndrome Resources. B.G.S. has a sister with Down syndrome. G.d.G had a daughter with DS, who passed away in 2005 at the age of 15. He works as science and education officer at the Dutch Down Syndrome Foundation, a nonprofit organization. F.B. serves as CEO of Down Syndrome Education International and Down Syndrome Education USA, nonprofit organizations engaged in research and support for young people with Down syndrome. He had a sister with DS. E.S. works as CEO of Down Syndrome Australia, the leading nonprofit organization for people with DS and their families in Australia.

Additional Information

The online version of this article (https://doi.org/10.1016/j.gim.2022.08.029) contains supplementary material, which is available to authorized users.

References

1. Lindquist A, Hui L, Poulton A, et al. State-wide utilization and performance of traditional and cell-free DNA-based prenatal testing pathways: the Victorian Perinatal Record Linkage (PeRL) study. *Ultrasound Obstet Gynecol*. 2020;56(2):215-224. http://doi.org/10.1002/uog.21899
2. Maxwell S, Bower C, O'Leary P. Impact of prenatal screening and diagnostic testing on trends in Down syndrome births and terminations in Western Australia 1980 to 2013. *Prenat Diagn*. 2015;35(13):1324-1330. http://doi.org/10.1002/pd.4698
3. de Graaf G, Buckley F, Skotko BG. Estimates of the live births, natural losses, and elective terminations with Down syndrome in the United States. *Am J Med Genet A*. 2015;167A(4):756-767. http://doi.org/10.1002/ajmg.a.37001
4. de Graaf G, Buckley F, Skotko BG. Estimation of the number of people with Down syndrome in Europe. *Eur J Hum Genet*. 2021;29(3):402-410. Published correction appears in *Eur J Hum Genet*. 2022. https://doi.org/10.1038/s41431-020-00748-y
5. Morris JK, Mutton DE, Alberman E. Revised estimates of the maternal age specific live birth prevalence of Down's syndrome. *J Med Screen*. 2002;9(1):2-6. http://doi.org/10.1136/jms.9.1.2
6. Staples AJ, Sutherland GR, Haan EA, Clisby S. Epidemiology of Down syndrome in South Australia, 1960-89. *Am J Hum Genet*. 1991;49(5):1014-1024.
7. Mulcahy MT. Down's syndrome in Western Australia: cytogenetics and incidence. *Hum Genet*. 1979;48(1):67-72. http://doi.org/10.1007/BF00273276
8. Hui L, Muggli EE, Halliday JL. Population-based trends in prenatal screening and diagnosis for aneuploidy: a retrospective analysis of 38 years of state-wide data. *BJOG*. 2016;123(1):90-97. http://doi.org/10.1111/1471-0528.13488
9. Lancaster P, Pedisich E. Australian Institute of Health and Welfare National Perinatal Statistics Unit Birth Defects Series Number 1. Congenital malformations Australia 1981-1992. ATHW National Perinatal Statistics Unit. Published 1995. Accessed March 31, 2022. https://www.aihw.gov.au/getmedia/b46fda64-19c7-408d-ad92-6ab28b128f0a/aihw213.pdf.aspx?inline=true
10. International Clearinghouse Centre for Birth Defects. Annual report. Published 2010. International Clearinghouse Centre for Birth Defects Surveillance and Research. Accessed October 30, 2021. http://www.icbdsr.org/resources/annual-report/
11. Collmann RD, Stoller A. A life table for mongols in Victoria, Australia. *J Ment Defic Res*. 1963;7:53-59. http://doi.org/10.1111/j.1365-2788.1963.tb00783.x
12. Glasson EJ, Jacques A, Wong K, Bourke J, Leonard H. Improved survival in Down syndrome over the last 60 years and the impact of perinatal factors in recent decades. *J Pediatr*. 2016;169:214-220.e1. http://doi.org/10.1016/j.jpeds.2015.10.083
13. Glasson EJ, Sullivan SG, Hussain R, Petterson BA, Montgomery PD, Bittles AH. The changing survival profile of people with Down's syndrome: implications for genetic counselling. *Clin Genet*. 2002;62(5):390-393. http://doi.org/10.1034/j.1399-0004.2002.620506.x
14. Maaskant MA. *Mental Handicap and Ageing*. Theses. Maastricht University; 1993.
15. Bell JA, Pearn JH, Firman D. Childhood deaths in Down's syndrome. Survival curves and causes of death from a total population study in Queensland, Australia, 1976 to 1985. *J Med Genet*. 1989;26(12):764-768. http://doi.org/10.1136/jmg.26.12.764
16. Leonard S, Bower C, Petterson B, Leonard H. Survival of infants born with Down's syndrome: 1980-96. *Paediatr Perinat Epidemiol*. 2000;14(2):163-171. http://doi.org/10.1046/j.1365-3016.2000.00252.x
17. de Graaf G, Buckley F, Skotko BG. Estimation of the number of people with Down syndrome in the United States. *Genet Med*. 2017;19(4):439-447. http://doi.org/10.1038/gim.2016.127
18. Penrose LS. The incidence of mongolism in the general population. *J Ment Sci*. 1949;95(400):685-688. http://doi.org/10.1192/bjp.95.400.685
19. World Health Organization. WHO Mortality Database. World Health Organization. Updated February 15, 2022. Accessed September 17, 2019. https://www.who.int/data/data-collection-tools/who-mortality-database
20. de Graaf G, Buckley F, Skotko BG. People living with Down syndrome in the USA: births and population. Down syndrome population. Updated May 7, 2022. Accessed May 7, 2022. https://docs.downsyndromepopulation.org/factsheets/down-syndrome-population-usa-factsheet.pdf
21. de Graaf G, Buckley F, Skotko BG. People living with Down syndrome in Europe: births and population. Down syndrome population. Updated September 6, 2022. Accessed September 6, 2022. https://go.downsyndromepopulation.org/europe-factsheet
22. Informed Decisions. Demographic resources | .id the population experts. Informed Decisions. Accessed March 31, 2022. https://home.id.com.au/demographic-resources/
23. Muggli EE, Collins VR, Halliday JL. Mapping uptake of prenatal diagnosis for Down syndrome and other chromosome abnormalities across Victoria, Australia. *Aust N Z J Obstet Gynaecol*. 2006;46(6):492-500. http://doi.org/10.1111/j.1479-828X.2006.00648.x
24. Maxwell S, Brameld K, Bower C, et al. Socio-demographic disparities in the uptake of prenatal screening and diagnosis in Western Australia. *Aust N Z J Obstet Gynaecol*. 2011;51(1):9-16. http://doi.org/10.1111/j.1479-828X.2010.01250.x
25. Hayeems RZ, Campitelli M, Ma X, Huang T, Walker M, Guttmann A. Rates of prenatal screening across health care regions in Ontario, Canada: a retrospective cohort study. *CMAJ Open*. 2015;3(2):E236-E243. http://doi.org/10.9778/cmajo.20140110
26. Cheffins T, Chan A, Haan EA, et al. The impact of maternal serum screening on the birth prevalence of Down's syndrome and the use of amniocentesis and chorionic villus sampling in South Australia. *BJOG*. 2000;107(12):1453-1459. http://doi.org/10.1111/j.1471-0528.2000.tb11668.x
27. Stone P, Austin D. Report to the national screening unit assessment of antenatal screening for Down syndrome in New Zealand. Auckland UniServices. Published February 2006. Accessed March 31, 2022.

https://www.nsu.govt.nz/system/files/resources/assessment-antenatal-screening-down-syndrome.pdf
28. National Screening Unit. Guidelines for maternity providers offering antenatal screening for Down syndrome and other conditions in New Zealand. New Zealand Ministry of Health. Published November 2009. Accessed March 31, 2022. https://www.moh.govt.nz/notebook/nbbooks.nsf/0/2e66b2751bd4c631cc2576e3000515b5/$FILE/Guidelines_for_Maternity_Prov_web.pdf
29. The Royal College of Pathologists of Australasia. Australian health Genetics/Genomics Survey 2017 Report of key findings to: Department of Health. The Royal College of Pathologists of Australasia. Published May 2019. Accessed March 31, 2022. https://www.rcpa.edu.au/getattachment/4c0a26fb-f518-42eb-aff5-fad262661f89/Australian-Health-Genetics-Genomics-Survey-201-(2).aspx
30. Equal Justice Project. 'Burdens' and borders: disability discrimination in New Zealand immigration law. Equal Justice Project. Published May 4, 2020. Accessed March 31, 2022. https://www.equaljusticeproject.co.nz/articles/burdens-and-borders-disability-discrimination-in-new-zealand-immigration-law2020
31. Immigration New Zealand. Evidence you are in good health. Immigration New Zealand. Accessed March 31, 2022. https://www.immigration.govt.nz/new-zealand-visas/apply-for-a-visa/tools-and-information/medical-info/evidence-you-in-good-health
32. Australian Government Department of Home Affairs. Health. Australian Government Department of Home Affairs. Accessed March 31, 2022. https://immi.homeaffairs.gov.au/help-support/meeting-our-requirements/health
33. Australia. Parliament. Joint Standing Committee on Migration, Danby M. *Enabling Australia: Inquiry into the Migration Treatment of Disability*. *The Committee*; 2010. https://nla.gov.au/nla.obj-232410730
34. National Ethnic Disability Alliance. Factsheet: an Overview of Australia's migration health requirements and how they impact on people with disability and/or health conditions. National Ethnic Disability Alliance. Accessed March 31, 2022. https://www.neda.org.au/sites/default/files/fact-sheets/English/migration-disability-factsheet-english.pdf
35. Spinks H, Klapdor M. New Zealanders in Australia: a quick guide. Parliament of Australia Department of Parliamentary services. 132#Published August 29, 2016. Updated February 13, 2020. Accessed March 31, 2022. https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1617/Quick_Guides/NZAust
36. Australian Bureau of Statistics. Estimated resident population, country of birth - as at 30 June, 1996 to 2021. Accessed March 31, 2022. https://www.abs.gov.au/statistics/people/population/australias-population-country-birth/2021#data-download
37. de Graaf G, Buckley F, Dever J, Skotko BG. Estimation of live birth and population prevalence of Down syndrome in nine U.S. states. *Am J Med Genet A*. 2017;173(10):2710-2719. http://doi.org/10.1002/ajmg.a.38402