# The prevalence of visual impairment: a capture-recapture study in THREE URBAN REGIONS IN NEW ZEALAND

Sub-title: Visual impairment in urban New Zealand.

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# Abstract

## PURPOSE

To estimate the prevalence of blindness in three regions of New Zealand.

## Methods

Capture-recapture methods were used to estimate the prevalence of blindness as defined by New Zealand Blind Foundation criteria for membership, that is a best corrected visual acuity of ≤ 6/24, in different regions of New Zealand. Lists of people attending eye health assessments, or applications for the Blind Foundation were obtained in different regions. The study period was September 2011 to September 2014 in adults aged 15 years of age or over. Log-linear models were used to estimate the number of new cases throughout the study period. Corresponding estimated resident census figures were used from 2013 to derive a three-year cumulative incidence, and prevalence was extrapolated based on estimates of survival in people with visual impairment.

## Results

In the Auckland District Health Board and Waitemata regions where three lists were available the prevalence of blindness was 0.49% (95% confidence interval [CI]: 0.41 to 0.60). In Canterbury and Counties Manukau where two lists were available for analysis the prevalence of blindness was 0.52% (95% CI: 0.45 to 0.60) and 1.96% (95% CI: 1.20 to 3.61) respectively.

## Conclusion

This study is the first to use capture-recapture methods for measuring the prevalence of blindness in any region of New Zealand. The results are useful for planning vision health and rehabilitation services in this country.

# Introduction

The advent of several new sight saving medications and surgical treatments in the last few years has presented a challenge in planning for organizations that provide vision rehabilitation. In order to estimate the number of clients these organizations may expect in the years to come, they have traditionally used studies of the prevalence of blindness and low vision that have been conducted some time ago and whose data may no longer be applicable. These studies have generally involved large-scale population surveys in which each individual in the sample is required to attend a clinic for a complete visual assessment. As a result, these studies are time consuming and expensive. For these reasons, a study of the prevalence of blindness has never been conducted in New Zealand. Past estimates of the burden of visual impairment in this country have been obtained by extrapolating overseas surveys to the New Zealand population.1 In order to obtain more recent, locally determined, data to underpin the New Zealand Blind Foundation's (NZBF) strategic planning process, we decided to use capture-recapture methods, a relatively new method for conducting epidemiological studies that is less costly and provides results in a shorter time frame than from traditional surveys.

Capture-recapture is a statistical method for conducting prevalence studies that is being used more frequently for many diseases.2 The methods for epidemiological studies are drawn from those that measure the size of animal populations. The idea centres on enumerating the total population by capturing a sample of animals on one occasion, marking them, releasing them, and then re-capturing another sample. The proportion of marked to unmarked animals in the second sample enables the total population to be estimated, if the two capture occasions are assumed independent.

In epidemiology, the total population can be determined from lists of patients who have received healthcare services from more than one source. These lists are used in place of ‘captures’ in wildlife studies. A unique identifier is used to link individuals between lists of people receiving healthcare. The pattern of dependence between lists is then analysed using log-linear models that allow the unobserved population size to be estimated. The unobserved is then added to the observed (the total number of people on the lists) to calculate the population total.3

Capture-recapture methods were recently used to estimate the prevalence of blindness in Western Australia.3 This study used three separate lists of patients who had undergone an ophthalmic examination to assess the total burden of blindness and low vision in the region. The results obtained in this study were similar to those from a large population-based survey in the same country: the Blue Mountains Eye Study.

The ability to obtain three lists in Auckland, and two lists in other regions of New Zealand that were similar to those used in Western Australia, enabled a capture-recapture study of the prevalence of blindness in selected regions of New Zealand to be carried out.

# Materials and methods

The project aimed to estimate the three year cumulative incidence of blindness (as defined by the NZBF membership criteria for blindness), between the dates of September 2011 and September 2014 in several District Health Board (DHB) regions of New Zealand. Studies were undertaken in Auckland and Waitemata, Counties Manukau, Wellington, Canterbury and Dunedin.

### Inclusion criteria

Subjects were included if they had an ophthalmic examination between 1 September 2011 and 1 September 2014, and were resident in the DHB region (as defined by their permanent residential address); had a National Health Index (NHI) code to enable matching between lists; and were aged 15 years or more at the time of examination.

Subjects also needed to meet the NZBF membership criteria for blindness, a best corrected visual acuity (BCVA) of ≤ 6/24 in the better-seeing eye. This definition is used to classify patients in New Zealand as members and recipients of free vision rehabilitative services with the NZBF (which also includes bilateral restricted fields to < 20 degrees). For international comparisons only, a definition of ≤ 6/60 BCVA was also used and the results are presented in an appendix. Visual field information was not considered, since it was inconsistently recorded between lists.

### Lists

Subjects were obtained from lists of people who received eye health or rehabilitation services in the district, in which a Snellen acuity examination had been carried out. The three lists were sourced from:

* A low vision ophthalmology clinic from a regional secondary public hospital service
* An optometry clinic associated with the University of Auckland
* Membership applications to the NZBF

All three lists were available in the Auckland and Waitemata District Health Board regions, but only the ophthalmology and NZBF lists were able to be obtained in other regions of the country. Individuals were uniquely identified on each list by linking with the National Health Index (NHI) used in the New Zealand health system. Age of individuals at screening time was calculated from the time difference between the date of birth and that of the eye examination.

### Data processing

All data was standardised into a single format. Data was checked for plausibility and consistency. Cases on the NZBF list that did not have an NHI code were removed from the study. Cases were assigned to a ‘blind’ category based on the BCVA in their best-seeing eye.

### Statistical analysis

The total number of blind people in the region was calculated by adding the observed population to the exponentiated intercept term of the log-linear model of appearance and overlap of the lists of healthcare. *R* software (version 3.23) was used.4 Overlap between the lists was visualised using the *srd* package which renders scaled rectangle diagrams.5 The *Rcapture* package6 was used to estimate the 95% confidence interval associated with the log-linear model by profile likelihood.

During analysis, log-linear models of the summarised data were calculated with varying complexity of interaction between lists. The model that minimised Akaike’s information criterion statistic was selected as a trade-off between the two aims of best model fit and model parsimony. This step was only relevant to the three list model for the Auckland Waitemata District Health Board (AWDHB) region.

The incidence estimates from capture-recapture were then combined with the denominator population sourced from ‘estimated resident’ 2013 census counts of the population for the age range that corresponded to that served by the District Health Board’s hospital.

Since the population who were being examined in all lists were likely to represent new cases of people crossing the threshold of blindness for the first time, in the period between September 2011 and September 2014 (rather than established cases), the proportion estimated by capture-recapture to the total population is considered a ‘three-year cumulative incidence’ of blindness, rather than a *prevalence*. Divided by three it provides an estimate of annual incidence. Since blindness is a relatively rare disease, the capture-recapture annual incidence was multiplied by the median survival of Blind Foundation members (from membership application to death, calculated at 10 years), to estimate the prevalence of blindness and low vision in the region (since prevalence ≈ incidence \* duration). Equivalently, prevalence is about 3.33 times the three year cumulative incidence.

The analyses were carried out separately for young and old. In this case, the lists used in the capture-recapture methods included all individuals who met the NZBF minimum criteria for membership (BCVA ≤ 6/24). Since overlap between the two available lists were minimal in Dunedin (4) and Wellington (7), these analyses were abandoned, and the results are presented for those regions where overlap was sufficient to obtain a precise estimate - Auckland and Waitemata DHB (AWDHB), Counties Manukau DHB (CMDHB) and Canterbury DHB (CDHB).

### Ethical approval

The study received approval from the national Health and Disability Ethics Committee (ref: 14/NTB/101) and the research offices of each Health Board participating in the study.

# Results

After cleaning and removing those with missing data values, a total of 496 individuals were available for analysis, aged between 15 and 101 years at the time of their examination in the AWDHB region. The largest list was from the NZBF (*n* = 353), with 172 available from the hospital ophthalmology clinic, and 35 from optometry clinic records. The number of individuals in each list (aged 15 years and over) with the degree of between list overlap is displayed in the scaled rectangle diagrams depicted in **Figure 1**. These figures are similar to Venn diagrams, but are represented with rectangles rather than circles. The areas of the rectangles and degree of overlap are proportional to the numbers present in each cell. In figure 1 (a), the number of people on each list is depicted by the rectangles with the largest rectangle representing the number of people who met the criteria for blindness on the NZBF list. The next largest rectangle represents those in the ophthalmology list and the smallest rectangle represents the optometry list. In other regions, CMDHB and CDHB only two lists are represented, with the largest in each representing the NZBF, and the other the ophthalmology list. In the CMDHB region, there were 306 individuals available for analysis (186 from the NZBF list and 131 from the ophthalmology list). In the CDHB region, 391 individuals were available for analysis (290 from the NZBF list and 176 from the ophthalmology list). There was considerable overlap between lists in the AWDHB, and CDHB regions, with lesser overlap in the CMDHB region. Due to missing NHI records, 7% of subjects were excluded from the NZBF lists.

**[Insert figure 1]**

A summary of the findings by age cut-off and region is provided in **Table 1**. The prevalence of blindness (BCVA ≤ 6/24) for people aged 15 years or more was estimated to be 0.49% (95% confidence interval 0.41 to 0.60) in AWDHB. The figure for CDHB was similar to that for AWDHB (0.52%; 95% confidence interval: 0.45 to 0.60). CMDHB, however, had a prevalence four times higher than these two other regions (1.96%; 95% confidence interval: 1.20 to 3.61).

An analysis of the population aged 40 or older showed the prevalence of blindness to be 0.86% in AWDHB; 3.35% in CMDHB and 0.84% in CDHB . This analysis highlights the age-dependent nature of visual impairment (**Table 1**).

**[Insert Table 1 here]**

**Table 1. Summary table of capture-recapture model prevalence and estimated incident cases of blindness (BCVA ≥ 6/24) by region, and age category.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Prevalence (95% CI) | Population | Incident cases (95% CI) |
| Age ≥ 15 years |  |  |  |
| ADHB & Waitemata | 0.49 (0.41 to 0.60) | 817,030 | 1,204 (1,009 to 1,477) |
| Counties Manukau | 1.96 (1.20 to 3.61) | 377,100 | 2,215 (1,361 to 4,093) |
| Christchurch | 0.46 (0.39 to 0.56) | 438,741 | 606 (512 to 737) |
|  |  |  |  |
| Age ≥ 40 years |  |  |  |
| ADHB & Waitemata | 0.86 (0.72 to 1.06) | 445,040 | 1,153 (964 to 1,418) |
| Counties Manukau | 3.35 (2.02 to 6.40) | 205,140 | 2,062 (1,247 to 3,945) |
| Christchurch | 0.77 (0.29 to 2.39) | 244,830 | 563 (216 to 1,755) |

CI: confidence interval. ADHB: Auckland District Health Board.

**Table S1. Summary table of capture-recapture model prevalence and estimated incident cases of blindness (BCVA ≥ 6/60) by region, and age category.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Prevalence (95% CI) | Population | Incident cases (95% CI) |
| Age ≥ 15 years |  |  |  |
| ADHB & Waitemata | 0.20 (0.17 to 0.27) | 817,030 | 1,634 (1,389 to 2,206) |
| Counties Manukau | 1.02 (0.57 to 2.25) | 377,100 | 3,846 (2,149 to 8,485) |
| Christchurch | 0.23 (0.18 to 0.33) | 438,741 | 1,009 (790 to 1,448) |
|  |  |  |  |
| Age ≥ 40 years |  |  |  |
| ADHB & Waitemata | 0.34 (0.27 to 0.46) | 445,040 | 459 (360 to 620) |
| Counties Manukau | 1.56 (0.88 to 3.41) | 205,140 | 960 (540 to 2,100) |
| Christchurch | 0.37 (0.28 to 0.52) | 244,830 | 273 (207 to 383) |

For the purposes of obtaining a rough comparison of these results with survey and capture-recapture studies in other countries, a supplementary analysis was conducted to assess the prevalence of blindness according to the generally accepted international definition of blindness, BCVA ≤6/60 **(Table S1**). The prevalence of blindness meeting this definition for all subjects aged 40 and over was 0.34% for AWDHB, 1.56% for CMDHB and 0.37% for CDHB. The total prevalence of blindness from summing the numerators and denominators of all three regions, according to this definition (BCVA ≤6/60) was 0.63% for people aged 40 years or more.

# Discussion

This study is the first to our knowledge to use capture-recapture to estimate the prevalence of blindness in any region of New Zealand. In people aged 15 years or more, a prevalence of blindness (≤ 6/24)was estimated at 5 per 1,000 people in AMDHB and CDHB regions with a four-fold increase to 2 in 100 people in CMDHB. We used the NZBF criteria for membership for our definition of blindness (≤ 6/24),since we were primarily interested in the numbers of potential clients that the NZBF could expect in each major urban region.

Strengths of the study include the use of routinely collected health data, minimising problems associated with surveys, such as non-response that leads to selection bias. This study is also relatively efficient and less costly when compared to a population survey.

The results of the models had some face validity, in that estimates derived from the same lists that had a greater degree of age restriction, resulted in smaller total numbers of incident cases estimated as expected. One exception to this was in CMDHB where for BCVA ≤ 6/60 (**Table S1**), the point estimate of the incident cases was higher in the over 40 year estimate than the corresponding number for people aged 15 years or over. Over many repetitions, we would expect the number of cases estimated from a subsample of a capture-recapture study to be lower than from the total, however, it is possible that an apparently paradoxical increase may be observed in a single instance. The confidence intervals in the statistic for the 40 years and over group is wide (540 to 2,100) and extends beyond the range of the estimate for those aged 15 years and over (575 to 875), so these two estimates are not completely incompatible.

The study has some limitations. Because the study relies on existing lists, there was a small amount of missing data such as unique identifier (NHI) information present in the Blind Foundation list. In addition, capture-recapture methods rely on several assumptions, such as a closed population (no migration, loss or deaths). The log-linear models used were, however, able to account for between-list dependence involving different capture occasions. Models have a limited ability to account for between list dependence where two lists are present, but this mechanism is explicitly considered in models where three lists are available. There was some uncertainty in the average survival of people who met the criteria for blindness. The figure of ten years came from the best available data source: the NZBF member list and mortality records. However, survival is likely to be greater for people with low vision, and lower for people classified as blind, using the international definition (BCVA ≤6/60). For this reason, the prevalence of blindness at the level of 6/60 or less is likely to be overestimated.

The two list analyses carried out in CDHB and CMDHB are likely to be less accurate than the three list one carried out in AWDHB. The presence of three lists enables varying models of different levels of complexity to be estimated, including varying degrees of between list dependence, and the best fitting model selected, whereas in the case of two lists, only one model is possible. The higher prevalence of blindness obtained in CMDHB is striking, however, there are reasons this finding is plausible. Type-2 diabetes is more common in Counties Manukau, compared to other parts of Auckland, due to its high prevalence among people of Pacific and Māori descent.7 Type-2 diabetes is also more common at younger age groups in these populations.

Capture-recapture entails a number of assumptions associated with its use. Log-linear models, with the use of three lists are able to account for between-list interactions, however, the order of interactions between lists in the model (compared to the data) is limited so that the model can be solved. The counts within each combination of lists is assumed to be Poisson distributed, and clustering by covariates, such as by age group or ethnicity, may result in extra-Poisson variation. The method assumes also that NHI codes do not change and only true matches are identified. The NHI code system is curated in New Zealand, so that no two individuals share an identifier, so this assumption is likely to be met.

A summary of other studies that have estimated the prevalence of blindness is provided in **Table 2**. For comparison, we refer to our supplement tables which used a BCVA of ≤ 6/60. In our study, the prevalence of blindness in the population 40 years of age or more was 0.63% for the total of the three regions. This number is similar to those of the major population health studies. The Melbourne VIP study9 and the Beaver Dam Eye Study10, for example, both reported the prevalence of blindness at 0.5% using the same criteria for blindness and similar age groups. The Western Australia study,3 the only one that used capture-recapture methods, reported a prevalence of blindness of 0.43% for people aged 50 years and over.

**[Insert table 2 here]**

**Table 2. Summary of prevalence studies of blindness.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Study | Nation | Year | Method | *N* | Definition Blindness | Age (years) | Prev. (%) |
| Blue Mountain4 | Australia | 1992 - 1994 | Survey | 3,647 | ≤ 6/60 | ≥49 | 0.7% |
| Melbourne VIP8 | Australia | 1992 - 1996 | Survey | 4,734 | ≤ 6/60 | ≥40 | 0.5% |
| Beaver Dam9 | United States | 1988 - 1990 | Survey | 4,897 | ≤ 6/60 | ≥43 | 0.5% |
| Baltimore10 | United States | 1985 - 1988 | Survey | 5,300 | ≤ 6/60 | ≥40 | Whites: 0.9%  Blacks: 1.6% |
| Salisbury11 | United States | 1997 | Survey | 2,520 | ≤ 6/60 | ≥65 | Whites: 0.5%  Blacks: 1.7% |
| Rotterdam 12 | Nether-lands | 1990 - 1993 | Survey | 6,775 | ≤ 6/60 | ≥55 | 0.75% |
| Barbados13 | Barbados | 1988 - 1992 | Survey | 4,631 | ≤ 6/60 | ≥40 | Black: 3.0%  Mixed: 2.2%  White/ other: 0.8% |
| West Australia3 | West Australia | 2012 | Cap./ Recap. | 1,771 (3 lists) | ≤ 6/60 | No restrict. | 0.15% |
| ≥50 | 0.43% |
| NZ (Auck) | Auckland(NZ) | 2011 to 2014 | Cap./  Recap. | 496 (3 lists) | ≤ 6/24  (≤ 6/60) | ≥40 | 0.86%  (0.34%) |

B: Blind; Cap: Capture. Recap: recapture.

**CONCLUSION:**

This study is the first to use capture-recapture methods for measuring the prevalence of blindness in any region in New Zealand. While the goal of the study was to estimate the number of potential recipients of vision rehabilitation services from the NZBF, it also gives an indication of the overall prevalence of blindness in New Zealand. The results are useful for planning vision health and rehabilitation services in this country. The study was conducted in a much shorter time frame, and at a cost substantially less than that which would be incurred from a population survey. The results are similar to those obtained using population health surveys in other countries, and are an indicator of the potential for using this method for conducting similar surveys in other disease areas in New Zealand where routine health data exists.

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