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**Visualising the pharmaceutical management of cardiovascular risk in Aotearoa New Zealand with interactive maps: an individual-level national data linkage study**

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## Abstract‍ (= 200 words)

**Aims**

We assessed cardiovascular risk and drug treatment status of adults in Aotearoa New Zealand and present these data in interactive maps to inform cardiovascular risk management.

**Methods**

A 2013 cohort of almost all 30-74 year-old New Zealanders without cardiovascular disease was created by linking national datasets in Statistics NZ’s Integrated Data Infastructure (IDI), a repository of government and non-governmental datasets. Each person’s 5-year cardiovascular risk was predicted using policy-level risk prediction equations and their use of blood pressure lowering and lipid-lowering treatment was determined. We applied geographical maps and population cartograms for spatial representations of risk and drug treatment at the regional and subregional levels and for various population groups.

**Results**

We present a ‘family’ of interactive maps visualising variation in national cardiovascular risk profiles and dispensing of blood pressure-lowering and lipid-lowering medications at the regional and sub-regional level, stratified by predicted cardiovascular risk, diabetes status, gender and ethnicity.

**Conclusions**

We demonstrate that interactive visualisations of linked national health administrative datasets through different types of representations and scales could facilitate identification of disparities in cardiovascular risk management and implementation gaps. These visulations could support clinicians and policy makers to identify areas and population groups in most need for interventions.

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**All Articles should, as relevant:**

• Be up to 3000 words with up to 30 references (the word count is for the manuscript text only)

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Main text (Intrduction to Acknowledgement sections) = 2923 words. References = 29.

**Introduction**

Cardiovascular diseases (CVD) affect patients’ quality of life and life expectancy and are leading causes of premature preventable death globally1 and in Aotearoa New Zealand2. Public health researchers have documented persistent geographic disparities in CVD prevalence and mortality.5, 6 These disparities may reflect underlying inequities in socioeconomic conditions, demographic characteristics, built environment, public health policies, prevention policies for the disease, behavioural risk factors, and access to quality health care.6 There is also evidence that certain population groups are more at risk than others, even after analyses are adjusted for clinical and socio-demographic risk factors.7 In Aotearoa, high-risk populations include those of Māori, Pacific Island and South Asian ethnicities, residents of the most deprived communities and older age groups. Understanding the unique geographic patterns in CVD risk and risk management for different ethnic groups can help in the prevention and treatment of heart disease.3, 8

The use of big data in the population health field has become common and big health data have become increasingly available. In Aotearoa, health data can be securely linked to multiple large national datasets from many other government and non-governmental agencies at the individual-level in the Statistics NZ’s Integrated Data Infrastructure (IDI).9 This offers a unique opportunity to access various datasets in one research environment.

Visualisation offers intuitive and efficient ways to investigate and disseminate information. Based on human visual ability in perceiving complex structures and detecting patterns, visualisation can facilitate thinking, understanding, and knowledge discovery using various visual representations. Interactive visualisations that allow users to explorelarge datasets quickly and efficiently have the potential to augment big health data’s utilisation10 and are in high demand.However, less attention has been paid to ways of representing,11 exploring and gaining insights from big health data, and a well configured visualisation can identify gaps and inequities.12

The absolute benefits of CVD primary preventive pharmacotherapy are directly proportional to predicted CVD risk3, and a CVD risk-based strategy to assess eligibility for preventive medications such as blood pressure-lowering or lipid-lowering treatment provides a more effective and cost-effective approach than one based on raised levels of individual risk factors.4 The aim of this research is to develop a method of visualising the management of CVD risk in Aotearoa through visualisations of the use of preventive medications stratified by CVD risk over different comorbidity and demographic groupings at various geographical levels. The visualisations are interactive, allowing comparison between practices, areas, variables and subgroups across Aotearoa, and are accessible to practitioners, planners, policy makers and the public.

**Methods**

1. Data source and study area

The multiple linkable national datasets used for the regional and sub-regional level visualisation in this research were derived from the Statistics New Zealand’s Integrated Data Infrastructure (IDI). Data used for the national CVD risk profile visualisations were collected from the Ministry of Health. The study area covers all of Aotearoa New Zealand.

2. Measures and variables

Population denominator

We applied an ‘activity-based’ approach13 to construct a national population aged between 30 and 74 years for the period between 1 April 2012 and 31 March 2013, using multiple data sources in the IDI. The criteria for developing the population are described in Appendix 1.

Demographic characteristics

Gender status was available for two groups: male and female. Age was categorized into 9 groups (30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74 years). Ethnicity was preferentially identified from 3 sources in the following order: 2013 Census data, health data, and IDI personal details. For individuals with more than one ethnic group identified, a single group was assigned according to the following prioritisation order: Māori, Pacific, Indian (including Fijian Indian), Other, European. Detailed criteria for determining each individual’s ethnicity are described in Appendix 2.

Diabetes status

Based on the Virtual Diabetes Register methodology v686 by the New Zealand Ministry of Health, we identified individuals’ diabetes status between 1 April 2012 and 31 March 2013 in the IDI using comprehensive national administrative health datasets including inpatient, outpatient, laboratory testing claims, and pharmaceutical dispensing data collections (criteria described in Appendix 3).

Medication dispensing status

People who had at least one dispensing in each 6-month period between 1 April 2013 and 31 March 2016 of blood pressure lowering (BPL) medications alone, lipid lowering (LL) medications alone, and both BPL and LL medications (i.e. dual therapy) were identified in the IDI. All classes of BPL and LL medications were considered. They are listed in Appendix 4.

Cardiovascular disease risk score and risk strata

Each individual’s 5-year risk of hospitalisation or death from CVD was estimated on 31 March 2013 using sex-specific New Zealand policy equations3 with the following predictor variables: age, ethnicity, deprivation quintile based on NZDep2013 (an area-based socioeconomic measure),14 diabetes status, prior hospitalisation for atrial fibrillation, and baseline dispensing of cardiovascular medications (defined as ≥1 dispensing recorded in the 6-month period before 31 March 2013).

The study population was stratified into four 5-year CVD risk groups (<5% risk, 5–9% risk, 10–14% risk, and ≥15% risk).

3. Spatial scale and geographies

We represented data at three geographical scales, namely; national, regional (District Health Board (DHB)), and sub-regional scales. The national and DHB (n=20) level geographies are commonly used in Aotearoa. For the sub-regional level, we developed a customised geography called super data zone (SDZ) based on zone design criteria such as geographic contiguity, population equality, respecting existing administrative boundaries, considering elements of the physical and social environment, compactness, and internal homogeneity.15 The resultant SDZs (n=111) are nested within DHB boundaries and have 2013 census populations ranging from 26500 to 49800 (mean=38500). The SDZs also fully contain 2013 data zone (a customised small area geography developed to measure multiple deprivation16) boundaries.

4. Data aggregation and rate calculation at different level of geographies (described in Appendix 5).

5. Spatial and non-spatial representations (described in Appendix 6)

6. Interactive visualisation (described in Appendix 7).

InstantAtlas™ V 6.10.0 software18 was used to develop online interactive visualisations. This software offers several templates for users to quickly produce an attractive online atlas, without the need for complex programming knowledge.

**Results**

1. Visualisation of CVD risk profiles at the national level.

Figure 1 shows an interactive visualisation of national CVD risk profiles created using a Double Map template. The data used for this example represent the following sub-populations: Māori/Pacific men with diabetes and non-Māori/Pacific men with diabetes (Map A and Map B in Figure 1a), Māori/Pacific women with diabetes and non-Māori/Pacific women with diabetes (Map A and Map B in Figure 1b). The comparison in Figure 1a shows that CVD risk patterns for Māori/Pacific with diabetes (A panels) are much higher than their non-Māori/Pacific counterpart (B panels). For example, more than 90% of Māori and Pacific men aged 65-74 years were in the the highest CVD risk group (≥15%); while only 20% of non-Māori/Pacific men aged 65-69 years and 53% aged 70-74 years were in this high risk group. More than 94% and 84% of younger non-Māori/Pacific men aged 30-34 and 35-39 years respectively were in the lowest CVD risk group (<5%); while only 65% and 50% of their Māori/Pacific counterpart had a similar low CVD risk.

Figure 1b shows that Māori/Pacific women with diabetes also had higher CVD risk than non-Māori/Pacific women with diabetes. Both female populations had consistently lower CVD risk than their male counterparts (Figure 1). One can explore the CVD risk profiles for other population groups using the Data A and Data B menus. These interactive visualisations can be accessed [*here*](https://vareanz.blogs.auckland.ac.nz/interactive-maps/). A visual guide for using these interactive visualisations can be accessed [*here*](https://vareanz.blogs.auckland.ac.nz/interactive-maps/).

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Figure 1. Interactive visualisation for national level information using attribute maps for Māori/Pacific men with diabetes and non-Māori/Pacific men with diabetes (a), and Māori/Pacific women with diabetes and non-Māori/Pacific women with diabetes (b). The visualisation can be accessed at <https://vareanz.blogs.auckland.ac.nz/interactive-maps/>.

1. Visualisation of medication dispensing for the management of CVD at the regional level using population cartograms

Figure 2 shows the configuration of an interactive atlas of medication dispensing for the management of CVD at the DHB level created with InstantAtlas’ Double Map template. The layout and representation are different from the one shown in Figure 1 in order to best present the underlining data. Animation Panels and Line Charts are incorporated to visualise information by CVD risk stratum. National average information is displayed as a green coloured horizontal reference line in the Line and Bar chart panels respectively. Population cartograms, in which the size of each DHB is proportionate to its population, convey population and relative spatial information in the Map panels.

The data shown in Figure 2a are for the Indian population with diabetes. The percentage of Indian people with diabetes who were dispensed BPL and LL medications during the period from Oct 2015 to Mar 2016 is displayed in the A and B panels respectively. Higher percentages of BPL medication dispensing occurred in the North Island, with the Northland DHB being the highest. Waitemata, Auckland, Counties Manukau, and Waikato DHBs form a geographic cluster of high percentages of LL medication dispensing, but Hutt Valley DHB has a similarly high percentage.

Generally, the percentage of the Indian population with diabetes dispensed BPL medication is higher than the percentage dispensed LL medication, with national percentages being 72.2% and 68.7% respectively (see Comparison panels), but Hawke’s Bay DHB (highlighted in pink) is an exception (37.5% and 42.9% respectively) and it also had the lowest percentages in New Zealand. Percentages for one-fifth (for BPL) and one-quarter (for LL) of DHBs are suppressed (where the numerator < 6) for confidentiality reasons and are not shown in Bar Charts.

Generally, the percentage of the population with diabetes dispensed CVD medication increases as CVD risk increases (see the national percentages (green lines) in the Line Charts), but the Hawke’s Bay DHB (see pink lines in the Line Charts) is again an exception.

From the size of the northern DHBs in the cartogram in Figure 2a, we can see that majority of the Indian population resides in the North Island, and they are especially concentrated in the Auckland, Waitemata, and Counties Manukau DHBs (mouse over the cartogram to see DHB labels). In comparison, the European distribution over New Zealand is relatively spread out (Figure 2b). The regional variation in percentage of Europeans dispensed medications for the highest CVD risk group is relatively small (ranging from 68.4% to 79.2% for BPL, and from 56.5% to 74.4% for LL) compared to their Indian counterparts (ranging from 37.5% to 100.0% for BPL, and from 42.9% to 73.9% for LL).

One can explore patterns of dispensing for the Indian and/or European populations with diabetes for BPL, LL, or both medications for each CVD risk group using the Data A and Data B menus and the Animation panels. Online interactive visualisations for all e`thnic populations (including Māori, Pacific, European and Other) can be accessed [*here*](https://vareanz.blogs.auckland.ac.nz/interactive-maps/).

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Figure 2. Interactive visualisation of medication dispensing for the management of CVD for Indians (a) and Europeans (b) with diabetes at the District Health Board level using population cartograms. The visualisations can be accessed at <https://vareanz.blogs.auckland.ac.nz/interactive-maps/>.

1. Visualisation of medication dispensing for the management of CVD at the sub-regional level with a linked side-by-side geographical map and population cartogram.

Visualisations at the sub-regional level (Figure 3) can reveal more detailed geographical patterns with both rural areas and densely populated urban areas visible in the geographical map and population cartogram. Associated interpretations are provided in Appendix 8.

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Figure 3. Interactive visualisation of medication dispensing for the management of CVD for the New Zealand population at the Super Data Zone level for ≥15% (a) and 10-14% (b) CVD risk groups using linked side-by-side geographical map and population cartogram. The visualisation can be accessed at <https://vareanz.blogs.auckland.ac.nz/interactive-maps/>

**Discussion**

Increasingly available complex big health data, from various sources with different qualities, are inundating the health field. Interactive visualisations have played a critical role in sharing, exploring, and reasoning health data, discovering knowledge, generating hypotheses, disseminating findings, and facilitating decision making in the big health data era.19, 20 However, visualisations created by individuals with limited cartographic knowledge can lead to poorly designed maps, that may miss important information, mislead readers, and also increase anxiety (e.g. during the Covid-19 pandemic).21-24

A recent systematic scoping review25, which investigated interactive visualisation applications in population health and health services research, identified that the major applications of interactive visualisation are epidemiologic surveillance for infectious diseases, resource planning, health service monitoring and quality, and studying medication use patterns. Interactive visualisations of non-communicable diseases such as cardiovascular disease are relatively lacking.

Our study illustrates the application of interactive visualisations to describe the management of cardiovascular risk with various data-driven cartographic representations at different level of geographies using datasets covering almost all adult New Zealanders. Key features of this research are discussed here.

Representations

The particular strengths of this research are the innovative integration of various data-driven cartographic representations and spaces in interactive InstantAtlas to visualise various aspects of population health data. The integration of non-spatial attributes and population cartograms in the interactive visualisations represents an innovative use of InstantAtlas software, which was originally developed to visualise geographical maps, and extends the scope of its applications.

The representations are data driven, for example, gridded attribute maps are used to show national population CVD risk profiles; discontinuous population cartograms for the regional level visualisation; and side-by-side geographical maps and continuous population cartograms for the sub-regional level visualisation. When visualising different types of underlining data, different forms of representations are needed.

Interactive visualisations

Interactive visualisations have advantages over traditional static representation techniques that do not allow users to interact with the information.10 Interactivity is crucial to effective visualisation of big and complex data as humans have an irreplaceable role in the human-data interaction,26 and it is not possible to show everything at once given the limitations of both human eyes and computer displays.27 Interactivity enables users to dynamically select, filter and compare data, to see data at different level of details and to reveal aspects of the data that would have been missed in a static view, and to lead to insight.20

The visualisations developed using InstantAtlas software are highly interactive, and easy to use. The visualisations embed linked charts, tables and maps in one interface, which cooperatively displays both map classifications and corresponding quantities (in charts) and allows data selection and filtering. Although we only showcased the use of Single and Double Map templates of the software here, the InstantAtlas offers several additional templates. For instance, Area Profile template can be used to compare performance between DHB and other health organisations.28

Geographies

We visualised and explored data at three different geographical scales, i.e., national, regional and sub-regional scales, which constructed knowledge and understanding of the research subject at different levels and granularity.

The sub-regional geography, SDZ, was designed for health research applying criteria such as population equality, considering elements of the physical and social environment, compactness, and internal homogeneity. This geography is more suitable for this research than using arbitrary administrative area units.15

It is worthy to note that the modifiable area unit problem (MAUP) is generic to all spatially aggregated data. The results one observes at any given scale/zonation may vary when the scale/zonation changes.

Data and next steps

We generated national datasets such as a population denominator, diabetes prevalence, CVD risk profile, and CVD management using multiple linked datasets both from this research project and the IDI. These datasets, which enable the visualisations presented in this paper, are also used to create risk prediction equations and assess management of CVD risk at the individual, group, and national levels. While this paper showcases what one can do with interactive visualisations. Our future plan is to create a regularly updated contemporary profile of New Zealanders’ cardiovascular risk and risk management to facilitate efforts to close evidence-practice equity gaps.

Implications

The human eyes can easily extract and interpret complex patterns from visualisations without the need for advanced mathematical or statistical knowledge.29 This makes interactive visualisation a useful tool in many fields, including population health. Combining modern technology and human visual power, the visualisations we created for this study can be used to provide intuitive information for national planners and policy makers, regional health organisations, and local practitioners.

**Conclusion**

Interactive visualisations of big health data through different types of representations and at different scales can provide a useful tool to identify disparities in management of diseases and implementation gaps, and support policy makers to reach areas and population groups in most need for interventions.

**Disclaimer**

Access to the data used in this study was provided by Stats NZ under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975. The results presented in this study are the work of the author, not Stats NZ or individual data suppliers.

These results are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) which is carefully managed by Stats NZ. For more information about the IDI please visit https://www.stats.govt.nz/integrated-data/.

The results are based in part on tax data supplied by Inland Revenue to Stats NZ under the Tax Administration Act 1994 for statistical purposes. Any discussion of data limitations or weaknesses is in the context of using the IDI for statistical purposes, and is not related to the data’s ability to support Inland Revenue’s core operational requirements.

The diabetes population we constructed in the IDI is not the official VDR derived by the Ministry of Health in New Zealand.

**Acknowledgments**

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**Appendix 1: Criteria for construction of the population denominator in the Integrated Data Infrastructure**

A population denominator was constructed in the Statistics New Zealand Integrated Data Infrastructure (IDI) using on an activity-based approach. Participants eligible for inclusion were:

1. within the IDI spine with recorded activity in tax, education, or injury claims between 1 April 2012 and 31 March 2013; or

2. within at least one of the following health datasets between 1 April 2012 and 31 March 2013: primary care enrolment, community laboratory test claims, national outpatients, pharmaceutical dispensing, and publicly funded hospitalizations; and

3. Present in New Zealand for ≥6 months between 1 April 2012 and 31 March 2013; and

4. Aged 30–74 years on 31 March 2013 (since this is the recommended risk assessment age range in New Zealand and the age range of the development cohorts for the sex-specific VARIANZ equations).

Individuals were excluded from the population denominator if they: (i) died between 1 April 2012 and 31 March 2013; or (ii) were hospitalized for CVD (including coronary heart disease, stroke, transient ischaemic attacks, peripheral vascular disease, and coronary-related procedures) or heart failure on or before 31 March 2013; or (iii) were dispensed anti-anginals ≥3 times between 1 April 2008 and 31 March 2013; or (iv) were dispensed loop diuretics ≥3 times between 1 April 2008 and 31 March 2013 (as this is an indicator of non-hospitalized heart failure); or (v) data used to determine predicted 5-year CVD risk were missing.

**Appendix 2: Criteria for determining each individual’s ethnicity**

The ethnicity classification used in all national statistical reports in Aotearoa New Zealand is derived from the following question:

Which ethnic group do you belong to? *Mark the space or spaces which apply to you.*

New Zealand European

Māori

Samoan

Cook Island Māori

Tongan

Niuean

Chines

Indian

Other (such as Dutch, Japanese, Tokelauan). Please state

For these analyses, an individual’s ethnicity was defined in the following priority order as: (1) Māori if any of the person’s ethnic codes was Māori. (2) Pacific if any of the person’s ethnic codes was Pacific (including Cook Island Māori) and none of them was Māori. (3) Indian if any of the person’s ethnic codes was Indian and none of them were Māori or Pacific (except if individuals had both Pacific and Indian codes, in which case they were assumed to be Fijian Indian and were classified in the Indian category). The remaining priorities, in order, were (4) Chinese, (5) Other Asian, (6) Middle Eastern/Latin American/African and Other (MELAA/Other), (7) European.

Note: Approximately 90% of all South Asian people in Aotearoa are Indian.

**Appendix 3: Procedures and criteria to developed a diabetes population numerator**

Based on the Virtual Diabetes Register methodology, v686, by Ministry of Health, we constructed a diabetes population numerator for the study period in the Integrated Data Infrastructure using following procedures and criteria:

1. Extract publicly funded hospitalisation discharges between 1 April 2003 and 31 March 2013 that contain ANY diagnosis of:
2. E10 - Type 1 diabetes mellitus
3. E11 -Type 2 diabetes mellitus
4. E13 - Other specified diabetes mellitus
5. E14 - Unspecified diabetes mellitus
6. O240 - Pre-existing diabetes mellitus, Type 1, in pregnancy
7. O241 - Pre-existing diabetes mellitus, Type 2, in pregnancy
8. O242 - Pre-existing diabetes mellitus, other specified type, in pregnancy
9. O243 - Pre-existing diabetes mellitus, unspecified, in pregnancy
10. Extract events in National Non-Admitted Patient Collection (NNPAC) with a date of service between 1 April 2011 and 31 March 2013 that contain any of the following purchase unit codes:
11. M20006 - Diabetes education and management
12. M20007 - Diabetes fundus screening
13. Extract records in pharmaceutical data with a date of dispensing between 1 April 2012 and 31 March 2013 that have been dispensed the following 19 subsidised diabetes-related medications on two or more occasions: insulin lisproh, acarbose, glibenclamide, gliclazide, glipizide, insulin neutral, insulin isophane, insulin zinc suspension, metformin hydrochloride, tolazamide, tolbutamide, rosiglitazone, insulin aspart, pioglitazone, insulin glargine, insulin lispro with insulin lispro protamine, insulin glulisine, insulin aspart with insulin aspart protamine, and insulin isophane with insulin neutral.

1. Extract laboratory claims with a visit date between 1 April 2012 and 31 March 2013 with four or more HbA1c, glycosylated haemoglobin tests (lab test code = BG2) AND two or more ACR, microalbumin, early morning urine tests (tab test code = BP8).
2. Identify and remove women who ONLY meet the following data conditions (i.e. remove gestational diabetes):

* Women with a publicly funded birth discharge who were only dispensed insulin, within 5 months before and two weeks after the birth discharge date from between 1 April 2012 and 31 March 2013.
* Women that only had an HbA1c lab test, within the above period around birth.
* Women aged 12-45 (at dispensing) only dispensed metformin hydrochloride.

**Appendix 4: Lists of CVD management medications**

All blood pressure lowering and lipid lowering medications subsided for use in Aotearoa during our study period (ending 31 March 2016) were included in our study and are listed below.

**Blood pressure-lowering medications**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **ACE**  **inhibitor** Benazepril Captopril Cilazapril Enalapril Lisinopril Perindopril Quinapril Trandolapril | **ARB**  Candesartan Losartan  **Beta blocker** Acebutolol Alprenolol Atenolol  Bisoprolol Carvedilol | **Beta blocker** Celiprolol Labetalol Metoprolol Nadolol Oxprenolol Pindolol Propranolol  Sotalol Timolol | **CCB**  Amlodipine Diltiazem Felodipine Isradipine Nifedipine Verapamil | **Other** Amiloride Clonidine Clopamide Hydralazine Methyldopa Triamterene | **Thiazide** Bendrofluazide Chlorthalidone Chlorothiazide Cyclopenthiazide Hydrochlorothiazide Indapamide Methyclothiazide |

**Lipid-lowering medications**

|  |  |
| --- | --- |
| **Statins** | **Other lipid lowering medications** |
| Atorvastatin | Acipimox |
| Fluvastatin | Bezafibrate |
| Pravastatin | Cholestyramine |
| Simvastatin | Clofibrate |
| Ezetimibe with simvastatin | Colestipol |
|  | Ezetimibe |
|  | Gemfibrozil |
|  | Nicotinic acid |

**Appendix 5: Population/sub-population groups, data aggregation, and rate calculation**

At the national level, the population was subgrouped by diabetes status, ethnic group, and diabetes status/ethnic group. For each sub-population group, the number of individuals was aggregated by age group, and 5-year CVD risk group for men and women separately. Then the percentage of the population in each corresponding age/CVD risk group was derived using the total population of each age group as denominators (row %). The 95% confidence intervals of each percentage were also calculated.

At the DHB and SDZ level, the population denominator was divided into the following sub-population groupings for men and women respectively. They were populations with or without a history of diabetes respectively; populations with a history of diabetes by ethnic group (Māori, Pacific, Indian, European, and Other); and populations without a history of diabetes by ethnic group.

For each sub-population group, the total number of individuals (denominator) and the number of individuals who were dispensed management medications (numerator) were aggregated by geographical area and 5-year CVD risk group. Then the percentage of the population who were dispensed medications (BPL, LL and both respectively) in each geographical area and in each CVD risk group was derived for visualisation.

**Appendix 6: Spatial and non-spatial representations**

We applied geographical maps and population cartograms for spatial representations at the regional and subregional levels. At the national level, we used attribute maps to show 5-year CVD risk profiles for various population groups.

People are familiar with geographical maps, but they can be problematic when used to represent population health data at a national level since densely populated urban areas are often too small to be effectively visualised. Population cartograms, with the size of geographical areas proportionate to the population of interest, make densely populated urban areas with small land areas more visible.

At the DHB level, we created a non-contiguous population cartogram based on the total census 2013 population using the R cartogram package and then manually shifted the areas to optimise their relative positions and minimise gaps in-between in ArcGIS software.17 This non-contiguous cartogram retains the general shapes and relative positions of corresponding geographical areas for ease of identification. This semi-manually created non-contiguous cartogram of the total population was then used as a base to automatically create non-contiguous population cartograms for sub-population groups (e.g., populations by diabetes status, by ethnic group) using the R cartogram package.

However, the semi-manual approach is not ideal for creating a sub-regional cartogram, where there are more than 100 SDZ areas. Here, we created contiguous population cartograms using the R cartogram package at the SDZ level. Automatically creating this contiguous cartogram is quick and easy; however, the shapes of areas are distorted in order to achieve criteria such as population-by-area and contiguity constraints.

Attribute maps, spatialise non-spatial information so that we can visualise patterns of non-spatial attribute data (e.g., population/sub-population CVD risk profiles) using interactive mapping software. The attribute map used in this research is made up of rectangular grids generated using the R sf package with each row of the grid showing an age group and each column showing a CVD risk group.

**Appendix 7: Interactive visualisation**

We designed several data-driven visualisation approaches and representations to interactively visualise CVD risk and management information at different geographical scales for this research. Firstly, we visualised CVD risk profiles for various population groups at the national level with attribute maps using Double Map template. We used fixed equal interval classification to map and compare information. Secondly, we visualised medication dispensing for the management of CVD at the regional level using population cartograms in Double Map template. A Natural Breaks classification, which groups similar values into one class and maximises the differences between classes, was applied for mapping. Thirdly, we visualised medication dispensing for the management of CVD at the sub-regional level using Single Map template. Since the shapes of areas of contiguous cartogram of SDZ are distorted, which challenges readers spatial recognition; we applied a side-by-side geographical map and population cartogram representation with the same colour coding in the map and the corresponding cartogram in order to facilitate the linkage between them.

**Appendix 8: Interpretations of Figure 3**

This figure shows the layout of an interactive visualisation of medication dispensing for the management of CVD for New Zealand population created using Single Map template. The linked side-by-side geographical map (left) and population cartogram (right) are displayed in the Map panel. We can see that densely populated urban areas are expanded in the cartogram.

There are clear geographical differences in the population with ≥15% CVD risk who were dispensed both BPL and LL medications (Figure 3a). Five of the areas with the lowest dispensing percentages are concentrated in the Canterbury DHB (see pink highlighted areas in the cartogram). The five areas with the highest dispensing percentages are clustered in the Counties Manukau DHB (see the darkest areas inside the green circle).

For people with 10-14% CVD risk who were dispensed both BPL and LL medications (Figure 3b), five areas in the Northland DHB had a small cluster of low dispensing percentages. We can see that three areas, namely ‘Waiheke & other islands’, ‘Otakiri - East Coast’, and ‘Linwood North - Christchurch East’, had consistently low dispensing percentages across the two CVD risk groups.

Interactive visualisations for all CVD risk groups and medications can be accessed at [*here*](https://vareanz.blogs.auckland.ac.nz/interactive-maps/).

|  |  |
| --- | --- |
| a | Map  Description automatically generated |
| b | Map  Description automatically generated |

Figure 3. Interactive visualisation of medication dispensing for the management of CVD for the New Zealand population at the Super Data Zone level for ≥15% (a) and 10-14% (b) CVD risk groups using linked side-by-side geographical map and population cartogram. The visualisation can be accessed at <https://vareanz.blogs.auckland.ac.nz/interactive-maps/>