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Mechanised residential ventilation systems: do health outcomes change following installation?

Lucy Telfar Barnard

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1222 Moonshine Rd,
RD1, Porirua 5381
Private Bag 50 908
Porirua 5240
New Zealand
branz.nz

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He Kainga Oranga/Housing and Health Research Programme, University of Otago, Wellington

31 March 2016

Author contact details

Lucy Telfar-Barnard
University of Otago Wellington School of Medicine and Health Science
lucy.telfar-barnard@otago.ac.nz

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BRANZ also provided useful comments on an earlier draft. However the author takes sole responsibility for the analysis and views contained in the study.

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List of Abbreviations

ATC	Anatomic therapeutic chemical
CCID	Close contact infectious diseases
COPD	Chronic obstructive pulmonary disease
H&HRP	He Kainga Oranga/Housing and Health Research Programme
HRPAH	Housing-related potentially avoidable hospitalisations
ICD-10	International Statistical Classification of Diseases and Related Health Problems (a medical classification list by the World Health Organization)
MoH	Ministry of Health
MRVS	Mechanised residential ventilation system
NHI	National health index
NMDS	National Minimum (hospitalisations) dataset
NZDep2013	2013 Census-based measure of socioeconomic deprivation
QV	Quotable Value New Zealand Ltd

Executive Summary

Background

- This report is an evaluation of changes in the incidence of health events, pharmaceutical usage and mortality following installation in 44,889 homes of one of three companies' mechanised residential ventilation systems (MRVS) between 2009 and 2011.
- Previous public health research suggests MRVS may reduce respiratory disease symptoms, but building science research suggests MRVS may make indoor temperatures lower in winter; both respiratory and circulatory symptoms are adversely affected by cold indoor temperatures.

Method

- We conducted a retrospective cohort study. MRVS companies provided addresses with systems installed. CoreLogic matched these addresses to addresses in the Quotable Value Ltd (QV) database; 52,828 of the treatment addresses were able to be matched to a QV property listing, a match rate of 78.6%.
- The cohort was selected by matching dwellings with MRVS installed (treatment dwellings), by address, to up to 10 similar (control) dwellings in the same Census Area Unit (CAU); 44,889 treatment dwellings (66.8% of all treatment dwellings) were able to be matched to at least one NHI occupant and at least one occupied control address.
- Count data analysis for hospitalisations was based on exposure time measured in 'person-days', adjusted by date of birth or death where relevant. We controlled for age structure and season.
- The association between MRVS treatment and hospitalisation outcomes was measured as the "difference in difference", between treatment and control groups before and after treatment.
- Our mortality analysis used a sub-cohort of the study group, comprised of those aged 65 and over who were hospitalised, but not deceased, prior to treatment date. We then compared mortality rates after treatment between the treatment and control groups.
- Methodological limitations included imprecision in assigning NHI records to addresses, and the possibility that control group households may have installed MRVS through a company not involved in the study, or a self-installed system. We were also unable to directly assess potential benefits such as reduced GP visits, days off school/work, or improved home satisfaction due to reduced condensation.

Results

- There was no significant difference in hospitalisation rates following MRVS installation between people in treated and control households across all measured categories of hospitalisation except one: treatment households had fewer non-respiratory close contact infectious diseases (CCIDs) after treatment date, compared to control households. The difference was small, but statistically significant.
- While differences between the treatment, control and census population were statistically significant, they were not meaningful except for differences by NZDep2013 socioeconomic deprivation quintile. Nonetheless, there may be inherent differences between people who choose to install MRVS and those who do not that are not able to be measured in this study, which could limit the generalisability of results.

- In demographic subcategories, children aged under 5 years had less respiratory hospitalisations and winter-associated hospitalisations following MRVS installation. Asian peoples had less total hospitalisations and "housing-related potentially avoidable hospitalisations". Males and Māori had less non-respiratory CCID hospitalisations. Elderly adults aged 80+ years had significantly higher total hospitalisation rates following MRVS installation. These differences were small, and statistically significant only before adjustment for multiple testing.
- There was no significant difference in any mortality outcomes between treatment and control groups.
- Hospitalisation rates were higher in the treatment group than in the control group, both before and after treatment.
- MRVS installation showed a significant association with increased circulatory prescription dispensings. There was no overall significant difference for any other dispensing category. Total pharmaceutical dispensings following MRVS installation were significantly higher for males, adults aged 25 to 44 years and adults aged 80 years and over. Circulatory scripts were elevated for males, European/Other, and adults aged 25 to 44 years.
- Installation of MRVS was associated with higher hospitalisation rates in dwellings with Fibre Cement (likely containing asbestos) roofs.
- Prescription rates were elevated following MRVS installation for people living in State House –style dwellings and Villas. Hospitalisation rates were lower following installation in dwellings with brick cladding.

Conclusion

- MRVS must under no circumstances be installed in dwellings with asbestos roofs.
- The elderly and people with circulatory illness who wish to improve their home environment should consider all options carefully. MRVS installation may not be their best option for health.
- Further research into why circulatory illness, as measured by prescriptions, appears to increase following installation of MRVS would be useful.

Background

Life indoors creates moisture, from cooking and cleaning, bathing and breathing. Even homes without unflued gas heaters or clothes dried indoors regularly have issues with indoor damp, condensation and humidity[1]. Controlling indoor humidity and moisture levels requires both heating, to make moisture airborne, and ventilation, to exchange the moisture-laden air with dryer air; or a dehumidifying appliance. However, while New Zealand Building Code insulation requirements have increased over recent decades, the Code has only limited requirements in relation to ventilation, and no requirements for fixed heating. The Housing Improvement Regulations 1947 require all dwellings to have an approved form of heating and adequate ventilation in the bathroom and kitchen, but these regulations are very seldom enforced.

One of the most obvious symptoms of indoor damp is morning window condensation, or “crying windows”. Wiping down windows in the morning is both labour-intensive and a regular reminder of poor building performance.

MRVS have been available in New Zealand for at least 20 years. These first systems pushed ceiling air through vents into the living spaces beneath, forcing the damp air out through gaps in the building envelope. Since these early systems were introduced, other companies have entered the market, and systems now have options for thermostatic control, different types of heat exchangers, inline heating, filter types, the source of incoming air (exterior or roofspace), and balanced pressure systems which take air from the living spaces at the same rate as new air is pumped in. Based on the data in this study, we estimate, like McChesney[2], that at least 10% of New Zealand homes now have a mechanical ventilation system, though no full survey has been conducted.

In recent years New Zealand has started paying greater attention to the potential health benefits of better housing standards. Following this trend, ventilation system companies’ advertising language has focussed on the potential health benefits of the systems. However, empirical evidence for any such health benefits has been absent, and MRVS company websites continue to claim benefits, such as reduction of dust mites, which are not borne out by empirical research.

Introduction

Previous research has shown that the quality of housing affects the health of the population. Improvements to housing can potentially prevent ill health, especially in sections of the population exposed to substandard housing.[3 4] People in developed countries spend more than 90% of their time indoors, and an estimated 60 – 70% of their time indoors at home[5]. Even so, although research in the area is growing, we still know little at a population level about the specific health effects of the indoor environment.[6 7]

New Zealand research to date has found that MRVSs reduce, but do not eliminate household dust mites[8]; and that they can improve self-reported health[9]; but that some system types reduce indoor temperatures on cold days[10 11], which could be health-adverse. A Canadian trial found installing heat recovery MRVS in 68 homes of Inuit children in Nunavut improved air quality and reduced risk of wheezing and rhinitis (where these were not associated with cold air exposure)[12], however the climate in Nunavut is polar, so not directly comparable to New Zealand, and the study was underpowered, with most results null. US research has found positive health effects for ventilation as part of a package of dwelling treatments for asthma prevention[13], but the research was not able to report on the effects of ventilation alone. A

review in Indoor Air of research to 2005[14] called for more studies on the relationship between ventilation rates and health, especially in diverse climates, and in buildings other than offices.

Other conditions highlighted as associated with ventilation rates include allergic symptoms[15], COPD[16] and tuberculosis[17]. Outdoor air pollution and high particulate (PM10, PM2.5) levels are linked to circulatory illness, but research on indoor air and circulatory illness is lacking. Overseas research linking ventilation rates to lung cancer involve exposure to radon, which is not found in New Zealand.

The potential for MRVS to reduce indoor temperatures in winter is concerning because it is well established that low indoor temperatures in the home can have adverse health consequences for the occupants, particularly during winter.[18] [19] For this reason, health outcomes associated with cold indoor temperatures were included in the study.

Aims

We aimed to measure the relationship between installing an MRVS ("treatment") and health outcomes. We focused on health outcomes identified as related to a poor indoor air quality and/or most likely to be affected by housing improvement. Specifically we focused on circulatory health, including congestive heart failure; and respiratory health, including asthma. We used pharmaceutical prescriptions, hospitalisations and mortality as our measures of health outcomes.

Methodology

The methodology for this study is substantially similar to that used in the Telfar Barnard et al 2011 evaluation of the Warm Up New Zealand: Heat Smart scheme[20]. Some parts of this section repeat the methodology section of that study, but are included here for ease of reference and completeness.

We conducted a retrospective cohort study. The cohort was selected by matching, by address, dwellings that had installed an MRVS between 2009 and 2011, to similar (control) dwellings in the same Census Area Unit (CAU), and, via an anonymisation process, by identifying hospital records for individuals listed on the New Zealand National Health Index (NHI) as resident at those treatment and control addresses. The data are described in more detail later in the section.

Treatment and matched control addresses were assigned a treatment date based on the month the treatment dwelling had an MRVS installed. Where the ventilation company had noted follow-up visits, the treatment month became a treatment period. We obtained prescription, hospitalisation and mortality (outcome events) data for the cohort for the period 1 January 2007 to 31 December 2013.

Count data analysis for outcome events was based on exposure time measured in 'person-days'. Individuals contributed person days while alive (i.e. not before birth or after death). We controlled for gender, age structure, ethnic group, and quintile for the NZDep2013 measure of socioeconomic deprivation. Prescription rates were measured for total scripts, antibacterial scripts, respiratory-related scripts, respiratory and allergy-related scripts, and circulatory illness-related scripts. Hospitalisation rates were measured for total, ICD-10 chapter 9 (circulatory), ICD-10 chapter 10 (respiratory), asthma, chronic obstructive pulmonary disease

(COPD), close contact infectious disease (CCID), non-respiratory CCID, "Housing Related Potentially Avoidable Hospitalisations" (HRPAH) and winter-associated hospitalisations.

Person days, pharmaceutical scripts and hospitalisations were categorised as either "before" or "after" treatment, based on the MRVS installation period. The outcome was measured as a relative rate ratio, the "difference in difference" in outcome rates between treatment and control groups before and after MRVS installation.

Our mortality analysis used a sub-cohort of the study group, comprised of those aged 65 and over who were hospitalised, but not deceased, prior to treatment date. We compared all-cause, circulatory and respiratory mortality rates after treatment between the treatment and control groups.

Data description

Data sources

Ventilation companies

Three ventilation companies provided a combined list of 189,329 addresses for dwellings with ventilation systems installed in New Zealand properties. 67,209 of these were installed during the 2009 and 2011 inclusive study installation period; the other addresses were excluded as possible controls. Besides addresses of installed dwellings, this list also included the month of installation or warranty start date. One company provided information on whether their systems were positive or balanced pressure systems, and whether or not the system had an inline heater or heat transfer system. The other two companies indicated that all systems installed during the study period were positive pressure systems. The companies were promised they would not be explicitly identified, so remain nameless throughout this report.

QV Housing data

CoreLogic is a multi-national property information, analytics and services provider, who work with Quotable Value New Zealand Ltd (QV) in the use of QV property and ratings data. CoreLogic matched ventilation company addresses for treated dwellings to addresses in their database, and then used a dwelling match protocol (see Table 1) to identify up to 10 control addresses for each dwelling.

CoreLogic Dwelling match protocol

CoreLogic used a scoring system to measure the accuracy of match between treatment and potential control dwellings which was based on the results in the Telfar Barnard 2010 PhD thesis.[21] This score ensured that controls were selected in order of greatest suitability.

Fields used, and the maximum score applied for each field, are described in Table 2.

Matches on Census Area Unit (CAU), property category, house type and single/multi-story (levels) were all mandatory. Dwelling construction decade was allowed to vary by up to three decades, with the score dropping by 2 points for each decade distance from the target decade. Floor area was allowed to vary by up to 50%, with the score dropping by 1 point for each 10% difference from the target. Number of bedrooms and main roof garages were scored with a maximum of score 5, subtracting 1 for each variance number of bedrooms and garages between the comparable and the target. Wall materials and condition, and roof materials and condition, were given a score of 10 where both materials and condition matched, 7 where building materials matched and 0 if materials didn't match. A score of 10 points was assigned if the "modernised" indicator matched and 0 if it did not match

Table 1. Matching of treatment and control dwellings, by count and percentage

Number of Comparables	Count	% of cohort addresses	% of total treatment addresses
10	49,366	94.6%	73.45%
9	269	0.5%	0.40%
8	273	0.5%	0.41%
7	287	0.6%	0.43%
6	261	0.5%	0.39%
5	288	0.6%	0.43%
4	274	0.5%	0.41%
3	305	0.6%	0.45%
2	388	0.7%	0.58%
1	460	0.9%	0.68%
Total	52,171	94.6%	77.63%

Table 2. Weighting of CoreLogic Matching

QV variable	Definition	Maximum Points	Notes
Census area unit	Stats NZ defined areas – there are approx. 1860, of varying population sizes, covering the whole of NZ.	10	Mandatory match
Category	Residential/commercial/industrial etc.	10	
House Type	See Appendix 2	10	
Levels (single/multi-story)		10	
Decade	Decade in which the dwelling was constructed	10	Points variable, see below
Floor Area		10	
Bedrooms	Number of bedrooms	5	
Main Roof Garages	Number of garages included under the main roof of the house (and therefore included in the floor area).	5	
Building	Wall material	10	
Roof	Roof material	10	
Modernised		10	

QV data for cohort dwellings

Having created our initial cohort CoreLogic then provided us with the following data for all cohort dwellings:

- building construction decade
- dwelling type
- census area unit
- floor area
- number of levels
- number of bedrooms
- number of main roof garages
- roofing and cladding materials
- roofing and building condition
- indicator of modernisation

Not all fields were ultimately used in the study.

Following our initial identification of the study cohort, we used a combination of prioritisation and random selection to ensure control dwellings were assigned to no more than one treatment dwelling, but that as many treatment dwellings as possible had at least one control. This was necessary as control dwellings could only be assigned a single before and after (treatment) date.

Ministry of Health data

The Ministry of Health (MoH) provided CoreLogic with addresses for every NHI record, with a unique identifier. CoreLogic matched these addresses to its list of addresses and provided H&HRP with two unique identifier numbers, one to link to health data and the other to link to dwelling data.

MoH provided H&HRP with all NHI records coded to a unique encrypted health identifier, with demographic information attached, as well as mortality, hospitalisation (NMDS) and prescription data for the period 2007 to 2013.

We excluded dwellings that did not have an occupant according to the NHI data provided1.

From the standard data supplied we used the following fields:

Demographic data[22]:

- Date of birth (age for a given exposure day was assigned according to age on the first of the month)
- Date of death (as listed in the NHI)
- NZ residency status
- Sex
- Ethnic group

Prescription (PHARMS) data[23]:

- Formulation id (PHARMAC Identifier for each formulation of a drug)
- Date of dispensing

Hospitalisation(NMDS) data[22]:

- Event start date (date of hospital admission)
- Admission type (used to describe the type of admission for a hospital healthcare health event)
- Clinical code (ICD-10 primary diagnosis)

Mortality data

- Date of death

Summary of data protocol and sources

The data protocol and sources described above are summarised in Figure 1 and Table 3. Figure 1 sets out the data protocol, detailing the collection of data from the ventilation companies initial provision of data for 67,209 dwellings to the creation of the final cohort of

1 It is important to note that dwellings without an occupant according to NHI records are unlikely to be unoccupied in reality. NHI address records are updated regularly from public hospital databases or sweeps of primary healthcare provider databases; however interactions with hospitals are rare events, so it is possible that the current occupants of an “unoccupied” dwelling have not interacted with a hospital or primary healthcare provider while living at that address, while previous occupants have had their address updated due to an interaction with either hospital or primary healthcare provider (See Methodological Limitations section for further discussion).

341,546 dwellings and 1,052,720 individuals. Table 3 summarises the data sources utilised by the study and the variables that they provided.

Figure 1. Data protocol (d=dwellings, n=people)

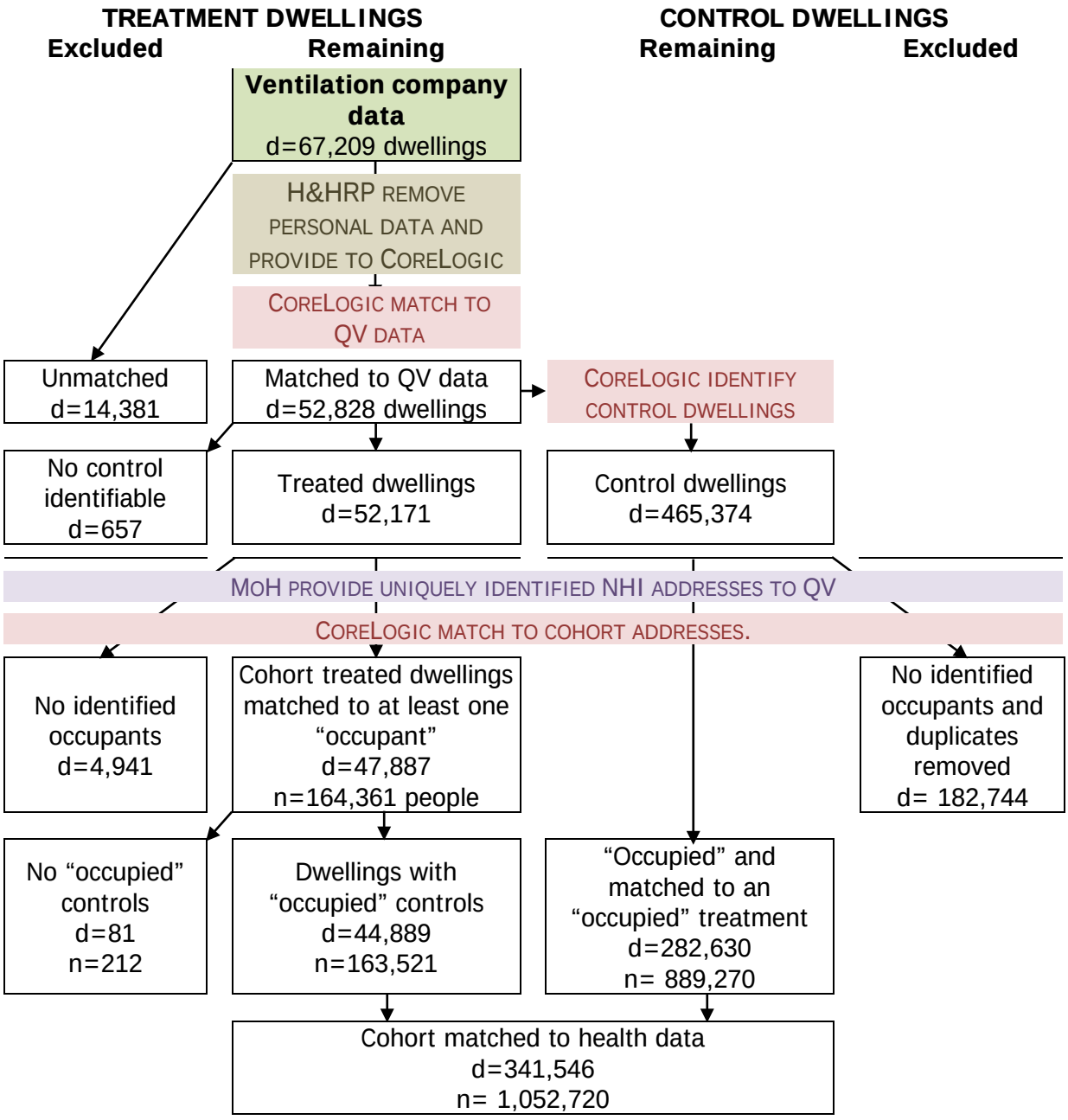


Table 3. Summary of data sources and variables

Data source / holder	**Ventilation companies**	**QV**	**Ministry of Health**	**H&HRP (derived)**
Identifier	Assigned ID	qpid	id	nuid
Linked fields	nuid (H&HRP) address (QV)	nuid (H&HRP) address (MRVS, MoH)	nuid address (QV)	Assigned ID, qpid, id
Research data				
(dwelling)	Installation date Installation type			Installation date Installation type
		Census meshblock Construction decade House type Category Levels (single/multiple) # of bedrooms Wall material Wall condition Roof material Roof condition Modernised (Y/N)		Census meshblock House health risk typology (based on decade, type, and condition)
(individual)			Date of birth Date of death NZ Resident (Y/N) Sex Ethnic group (3 fields)	Age by month Date of death Sex Modified total ethnicity
(outcome) NMDS hospitalisations PharmHouse pharmaceutical prescriptions MORT mortality			Date of admission Admission type Diagnosis code Dispensing date Subsidy key (as medication identifier) Date of death Diagnosis code (primary cause)	Age at admission Age on dispensing Age at death

Dataset creation

Exposure time

Exposure days were calculated by day, taking into account dates of birth and death if these occurred during the study period; and assigned by month to "before" or "after" treatment date; exposure days during the month or period of treatment were excluded because the exact date of treatment may have been spread over several days.

Pharmaceutical data

Pharmaceutical data linked to our cohort was extracted from the PHARMS dataset, which is jointly owned and managed by the Ministry of Health and PHARMAC. PHARMS contains records of claims made by community pharmacies for the dispensation of prescribed pharmaceutical products subsidised by PHARMAC and listed in the Pharmaceutical Schedule A-G. Dispensations recorded in PHARMS are linked to the relevant individual's NHI ID number.

The data extract provided by the Ministry of Health included extensive details about each dispensation, including the main active chemical, formulation, quantity prescribed, duration of prescription and cost data.

We have focused on prescription events as the basis of our analysis: as such the key fields we utilised from the PHARMS extract were the date of dispensing, and the Formulation id, a six digit code that serves to identify the active chemical ingredient in a product, the amount present, and the product type (tablet, solution, injection).

Table 4. Pharmaceuticals included in study by outcome measure.

Outcome	Description
Total dispensations	All dispensations
Circulatory illness related dispensations	ATC Code Level 1: Cardiovascular System OR ATC Code Level 1: Blood and Blood Forming Organs, Chemical name "Aspirin" OR ATC Code Level 3: "HMG CoA Reductase Inhibitors (Statins)"
Respiratory illness related dispensations	Chemical name "Prednisone" OR ATC Code Level 3: "Inhaled Corticosteroids", "Inhaled Corticosteroids with Long-Acting Beta-Adrenoceptor Agonists", "Beta-Adrenoceptor Agonists", "Inhaled Beta-Adrenoceptor Agonists", "Inhaled Anticholinergic agents", "Inhaled Beta-Adrenoceptor Agonists with Anticholinergic Agents", "Methylxanthines", "Other Bronchodilators" and "Cough Preparations"
Respiratory and allergy related dispensations	ATC Code Level 1: Respiratory System and Allergies
CCID related dispensations	ATC Code Level 1: Antibacterials

Pharmaceutical categories

The PHARMS data extract was linked to data extracted from the SiMPle database, an online database made available by PHARMAC which contains extensive details regarding every product that has been subsidised by PHARMAC during its operation. The key information utilized from the SiMPle database was a three level ATC (Anatomic Therapeutic Chemical) code classification associated with each formulation id. Formulation ids were selected based on previous research[20 24], to identify four sets of ATC codes from the SiMPle dataset where usage

rates might theoretically be altered by a change in ventilation or indoor temperature. A key source of information on the potential connections between insulation/heating and health was a report prepared for Housing New Zealand Corporation by *He Kainga Oranga*/Housing and Health Research Programme University of Otago, Wellington following a workshop on "Potentially Avoidable Hospitalisations Related to Housing Conditions" (*He Kainga Oranga*, 2008).

Hospitalisations

Exclusions

Based on our previous research [21 25], we excluded a number of admissions from the study. These were excluded either as non-relevant and likely to hide any effect (to bias results towards the null); or because they had the potential to introduce systematic bias.

Table 5. Type and reasons for excluding hospitalisation data

Exclusion	NMDS description	Reason for exclusion
Birth events	Event type="BT"	Not adverse health events
Transfers	Admission source="T"	Not a new health event
Readmissions	Admission date within 30 days of previous discharge date	Not a new health event
Non-New Zealand residents	New Zealand resident indicator="N"	Not relevant to study
ICD-10 Chapter 15 (Pregnancy, childbirth and the perenium)	Clinical code starting with "O"	Majority not adverse health events; distribution of hospitalisations driven by birth rate and events nine-months prior.
ICD-10 Chapter 16 (Certain conditions originating in the perinatal period)	Clinical code starting with "P"	Majority non-relevant health events; distribution of hospitalisations driven by birth rate and events nine-months prior.
ICD-10 Chapter 17 (Congenital malformations, deformations and chromosomal abnormalities)	Clinical code starting with "Q"	Distribution of hospitalisations driven by birth rate and events nine-months prior.

Hospitalisation categories

Hospitalisations were assigned to one of the hospitalisation sets of interest based on previous research using primary diagnosis ICD-10 codes, as described in Table 6.

Table 6. ICD-10 codes included in each hospitalisation outcome group.

Outcome	Description
Total hospitalisations	All hospitalisations other than exclusions (see above)
Circulatory illness	ICD-10 Chapter 9
Respiratory illness	ICD-10 Chapter 10

Asthma	ICD-10 code "J45" or "J46"
Close-contact infectious diseases (CCIDs)	See webappendix pp3 – 10 to Baker et al 2012 for full CCID selection methodology.[26] Note addition of "J09" to original list. J09 was used in 2009 to identify Influenza A(H1N1), and was not in use when the list was originally compiled.
Non-respiratory CCIDs	As above excluding ICD-10 Chapter 10
Chronic obstructive pulmonary disease (COPD)	ICD-10 code "J43" or "J44"
Winter illnesses	161 ICD-10 codes comprised of the highest impact seasonal illnesses for each of the Māori and Pacific Peoples ethnic groups, and for the total population; with highest impact defined as an illness with 100+ total annual admissions, and either an excess winter hospitalisation index of 1.05 or more and an absolute winter excess of 100 or more hospitalisations; or an excess winter hospitalisation index of 1.08 or more. See Telfar Barnard 2010[21] for complete list
Housing-related potentially avoidable hospitalisations	A set of ICD-10 codes identified by Baker et al as likely to be associated with housing conditions, but excluding the ICD-10 Chapter 9 & 10 codes in that list under the heading of "seasonality", as both chapters and seasonality are measured separately.

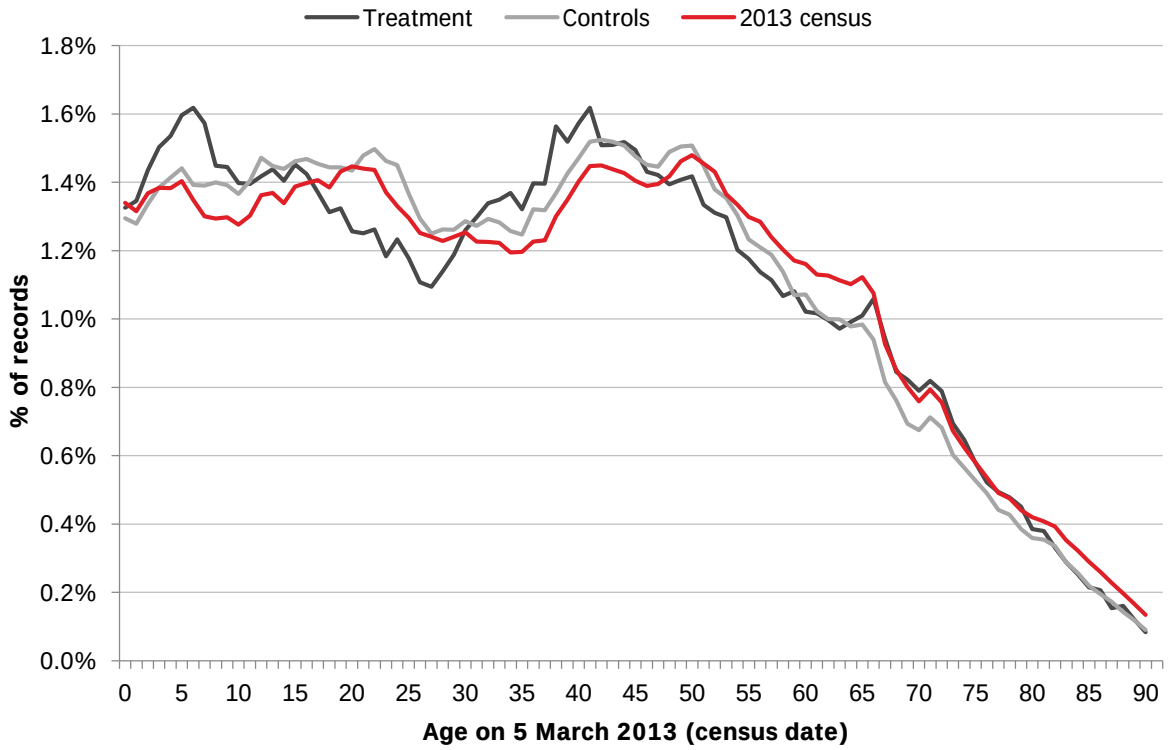
Data analysis

Key characteristics

Demographic characteristics

This study is observational, rather than experimental, and this leads to the possibility for confounding where the self-selecting treatment group differs systematically from the matched control group. We have therefore compared the treatment and control groups using the demographic characteristics available to us: ethnicity, age, sex, and NZDep quintile. The distributions across these variables are shown in Figure 3.

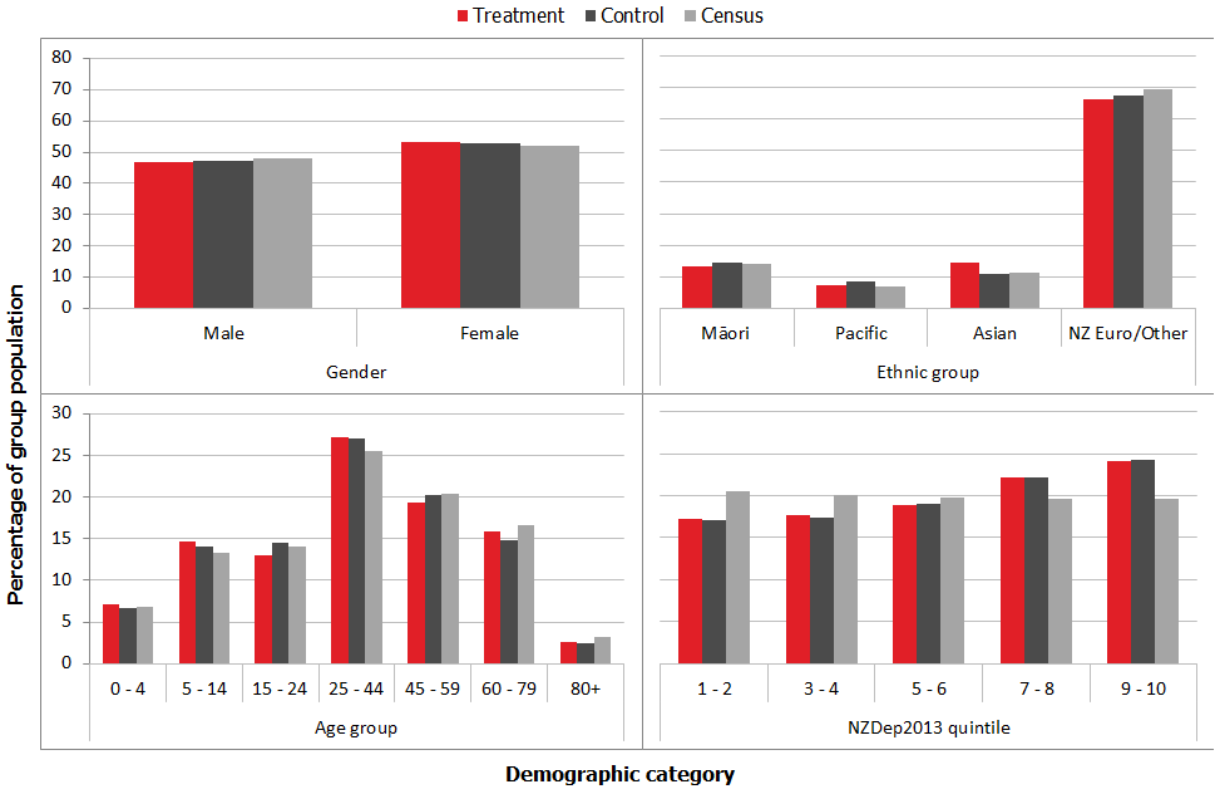
Figure 2. Distribution of 5 March 2013 treatment, control, and census populations by year of age.



Analysis of the characteristics of the individuals within the study suggests that there were statistically significant differences between the treatment and control groups in the distribution of age group, ethnicity and NZDep quintile, and between treatment and control and 2013 New Zealand census populations in all demographic variables. The clearest difference between treatment, control and census populations is by age group (Figure 2): The treatment group has more school-aged children, more adults aged 30 to 42, and fewer adults aged 15 to 28. Therefore, controlling by age group was a necessity.

With sample sizes as large as those in the study it was inevitable that Chi-square tests of differences between the populations would show statistically significant differences for most demographic characteristics. The more important question is whether the differences have any clinical significance. While overall differences may not appear large (Figure 3), there are further differences within sub-categories, such that all variables are included in regressions.

Figure 3. Distribution of 5 March 2013 treatment, control, and census populations by sex, age group, ethnic group and NZDep quintile.



Dwelling characteristics

Telfar Barnard et al 2011 compared the distribution of dwelling types between treatment, control and total NHI populations, using earlier 2006 data for the NHI population. This data is now out of date, meaning that comparison of dwelling attributes between the study cohort and the total NHI population were not possible. Control dwellings were identified on the basis of similarity to the treatment dwellings, meaning there is no meaningful difference between treatment and control groups by dwelling variables. However, the distribution of each of the dwelling variables is described below.

Dwelling Style

Nearly three quarters (74.6%) of the dwellings in the study were 'Post-war Bungalows'. The next most common styles were 'Pre-war Bungalows' (8.1%), 'Quality Bungalows' (8.0%), Villas (3.7%), and 'State Houses' (2.3%). All other housing types represented less than 1% of the total cohort. For a description of the architectural characteristics associated with each style, see Appendix 2 House typologies.

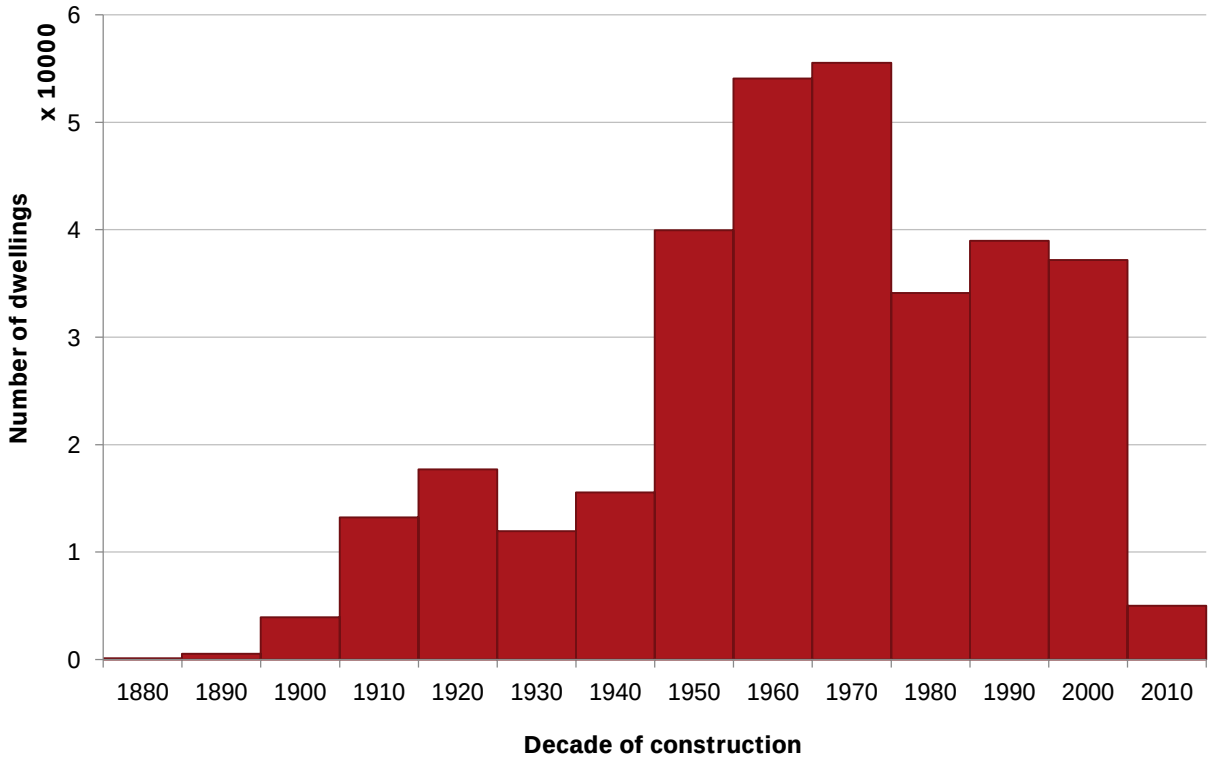
Decade of construction

The decade of construction of dwellings in the cohort is shown in Figure 4 below. For reporting purposes, dwellings were aggregated into three categories, pre-1950; 1950 to 1970, and 1980 – 2010s. The distribution of dwellings in the cohort amongst those three categories is shown in Table 7.

Table 7. Distribution of cohort dwellings by construction era.

Era	Number of dwellings	% of dwellings
pre-1950	63,045	19.2%
1950 - 1979	149,574	45.6%
1980 - 2010	115,258	35.2%

Figure 4. Distribution of cohort dwellings by decade of construction.



Exterior wall cladding

QV data includes 13 possible cladding types. The most common cladding type was weatherboard (35.7%), followed by Brick (25.3%), Fibre Cement (12.0%), Roughcast etc. (9.8%), Mixed Materials (9.6%), and Concrete (5.7%). All other cladding types (Aluminium, Glass, Malthoid/Fabric, Plastic, Steel/Galvanised Iron, Stone, and Tile Profile) represented less than 1% each of the cohort.

Roofing materials

QV data includes 13 possible roofing materials, covering the same materials as for wall cladding above. The most common roofing material was Steel/Galvanised Iron (59.4%), followed by Tile Profile (39.1%). All other roofing materials represented less than 1% each of the cohort, however we included Fibre Cement in the analyses on the basis that Fibre Cement roofs were likely to include asbestos and thus unlikely to be suitable for installation of roofspace ventilation systems. The cohort contained 218 treated and 1,015 control dwellings with Fibre Cement roofs.

Model selection

Hospitalisation: Count data

As this study set out to replicate the method used in Telfar Barnard et al 2011, we used the same negative binomial regression model to assess hospitalisation count data.

Results are presented as relative rate ratios (RRR). The RRR is the modelled association between MRVS installation and hospitalisation outcomes; the "difference in difference", between treatment and control groups before and after treatment. An RRR of 1.00 indicates the treatment was not associated with any change in rates, an RRR below 1.00 indicates that the treatment was associated with a reduction in hospitalisation rates and an RRR of more than 1.00 indicates the treatment was associated with an increase in hospitalisation rates. This is a measure of the following equation, modelled using negative binomial regression:

T= Treatment group
C=Control group
b=before treatment month
a=after treatment month
h=number of hospitalisations
d=number of person days

$$RRR \approx \frac{\left(\frac{h_{Ta}}{d_{Ta}}\right)/\left(\frac{h_{Tb}}{d_{Tb}}\right)}{\left(\frac{h_{Ca}}{d_{Ca}}\right)/\left(\frac{h_{Cb}}{d_{Cb}}\right)}$$

The model included sex, age group, ethnicity and NZDep2013 quintile as potential confounders. Results are presented with 95 % confidence intervals (95% CI).

Mortality

We could not use the same "difference in difference" approach described above for mortality data because it would necessarily have included both treatment bias and systematic bias: People could not have contracted to install an MRVS in their dwelling if they were dead, meaning that the mortality rate in the treatment group before treatment date would be lower than in the control group. The hospitalisation rate prior to installation date for treatment group members aged 60 years and over was slightly, but not significantly, higher than for the control group (RR 1.02, 95%CI 0.99 – 1.05, p=0.226), but the treatment group pharmaceutical script rate was significantly higher than the control group prior to installation (RR 1.06, 95%CI 1.06 – 1.06, p<0.001). Because the treatment group were found to be on average less healthy than the control group before treatment, their mortality rate after treatment would be expected to be higher later. The difference in difference between before and after and treatment and control groups would therefore be bound to appear adverse, as follows:

$$\left(\frac{Treatment\ mortality\ rate\ after}{Treatment\ mortality\ rate\ before} \div \frac{Control\ mortality\ rate\ after}{Control\ mortality\ rate\ before}\right) = \left(\frac{High}{Low} \div \frac{Average}{Average}\right) > 1$$

To remove this bias, we used a sub-cohort of the study population, comprised of those aged between 65 and 89 inclusive at the time of installation, who had been hospitalised but were not deceased prior to treatment date so as to ensure that the health status of treatment and control groups would be more similar.

As the sub-cohort was already limited to a specific age-group, the model adjusted only for cost of previous hospitalisation, as a marker for severity of illness. We adjusted for cost by including the dollar value of previous hospitalisations in the study period as a continuous variable in the Poisson model.

Exposure time was measured as time between treatment date and the 31 December 2013 (the end of the study period).

We used a standard Poisson model with individual-level data to assess the difference in mortality rates between the treatment and control groups in the sub-cohort, adjusting for sex, ethnicity and NZDep2013 quintile.

Pharmaceuticals: Dispensings

Each pharmaceutical dispensing was counted as an individual event and analysed in the same way as hospitalisation events.

Methodological limitations

This study has a number of limitations which affect the interpretation of the results. The first of these is imprecision in assigning health records to particular addresses. Addresses were matched according to individual addresses on 16 December 2015, when NZHIS produced the NHI dataset for matching by CoreLogic. These addresses are not necessarily accurate, as they record only the individual's address at last contact with a health provider, rather than their actual address on 16 December 2015. In other words, we cannot be absolutely certain that people reside where we think they do. There is no difference in health status between the treatment and control group prior to system installation, and therefore NHI addresses should be no more or less up-to-date in the treatment than the control group. However, the decision to install a ventilation system or to go to the trouble of asking a landlord to install a system may indicate an intention to remain at that address over a longer term, making the treatment group, on average, less mobile than the control group. Lower residential mobility would increase the likelihood of more accurate addresses in the treatment group than the control group.

The results of the study are also inevitably biased towards the null because although we know the treatment dwellings have received treatment, we cannot be sure that the control dwellings have not received treatment during the study period. The companies who participated in this study represent the largest part of New Zealand's ventilation system market, so as a group, the control group is expected to be much less likely than the treatment group to have MRVS installed, but the control group will likely include dwellings with MRVS installed by a company which did not participate in the study, or self-installed. The comparison overall is therefore not between "treated" and "untreated" groups of dwellings, but between "all treated" and "fewer treated" groups of dwellings.

At the same time, it is also possible that installation of an MRVS is a marker of other changes to the dwelling or to behaviour. A householder installing an MRVS may also be more likely to install insulation or heating, or, if installing MRVS in the hope it will remedy poor health (e.g. asthma) may also make other changes to improve their health (e.g. vacuum more often, switch to allergen-resistant bedding).

It should also be noted that hospitalisations are at the more severe end of the health outcome scale. Other health outcomes not measured here are general well-being, school and work absences, and doctor visits.

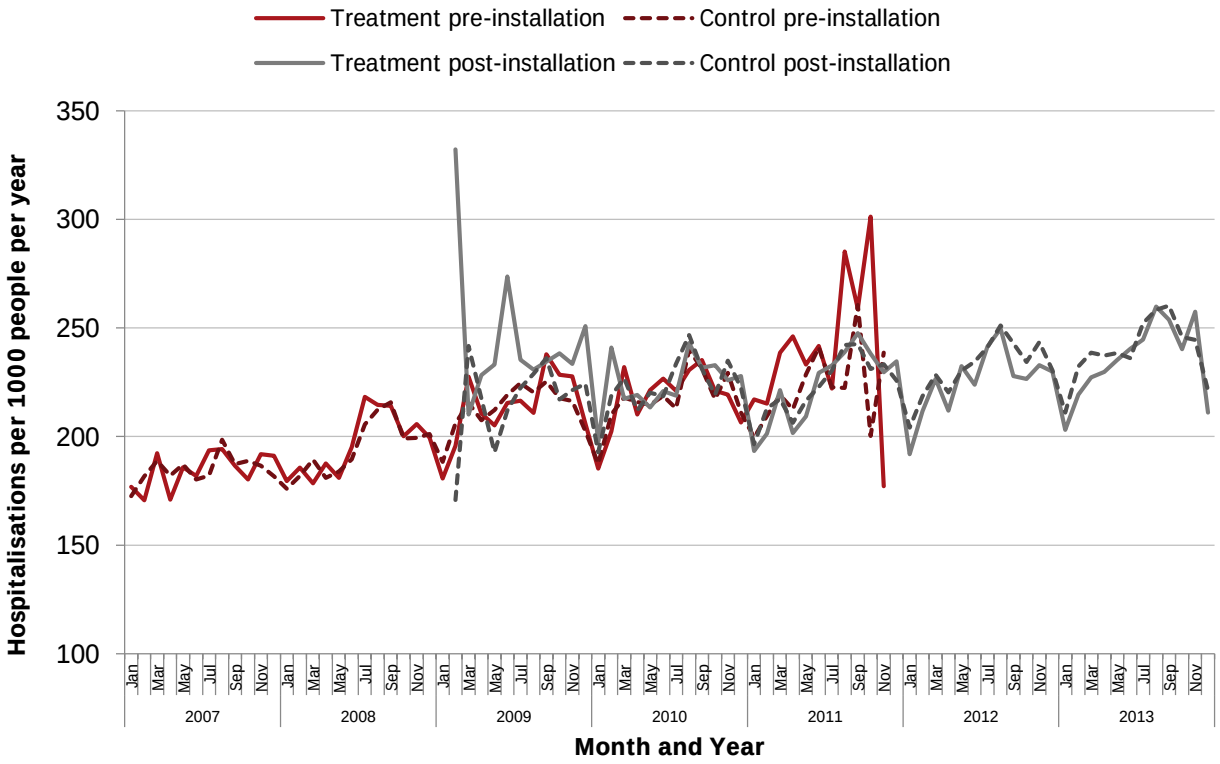
The study also includes a further possible bias towards the null. Any benefits of mechanized ventilation systems are dependent on the systems being installed, operated and maintained according to the manufacturers design, guidelines and instructions. These instructions may include the use of home heating; and regular maintenance of any system air filters. We would expect that at least some householders did not maintain or operate their systems as instructed or intended. Operating a system with blocked or unclean filters, or in a way that caused indoor temperatures to drop below control household temperatures, could have adverse health effects on dwelling occupants.

Results

Hospitalisations

After controlling for demographic differences, there was no difference in hospitalisation rates between the treatment and control group before or after treatment. Figure 5 shows average daily hospitalisation rates by month for treatment and control groups before and after treatment.

Figure 5. Monthly average hospitalisation rates per day for treatment and control groups before and after treatment (age-adjusted to total population)*



* Spikes in the early post-installation period, and the late pre-installation period are due to the rarity of hospitalisation and the smaller denominators in these periods.

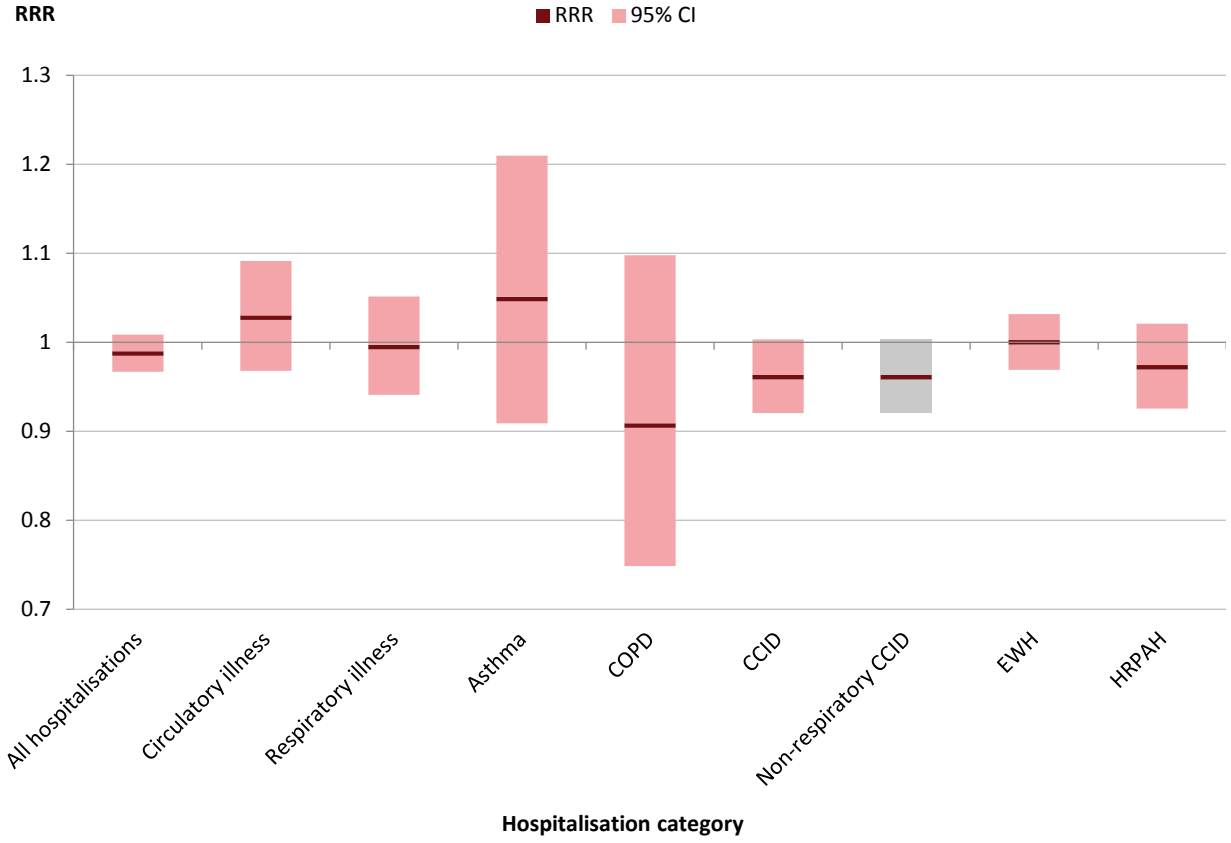
Treatment had no significant effect on hospitalisation rates across most hospitalisation categories. Non-respiratory CCIDs showed the only significant reduction in hospitalisation rates, with an RRR of 0.94 (95%CI 0.90-0.99, p=0.024). (Table 8, Figure 6).

Table 8. Treatment effect (RRR) for measured hospitalisation outcomes.

Outcome	RRR	95% CI	p-value
Total hospitalisations	0.98	(0.96 – 1.00)	0.123
Circulatory illness	1.03	(0.97 - 1.09)	0.390
Respiratory illness	0.99	(0.94 - 1.05)	0.853
Asthma	1.05	(0.91 - 1.21)	0.519
COPD	0.94	(0.77 - 1.14)	0.527

CCID	0.96	(0.92 – 1.00)	0.069
Non-respiratory CCID	0.94	(0.89 - 0.99)	0.029
Winter illnesses	1.00	(0.97 - 1.03)	0.970
HRPAH	0.97	(0.93 - 1.02)	0.256

Figure 6. Treatment effect for different categories of hospitalisation



RRRs for demographic sub-categories were generally non-significant or non-meaningful (see Tables in Appendix 1) with the exceptions listed below. It should be noted that the number of significant results found was as be expected according to chance, and these results are therefore not necessarily meaningful, but warrant further investigation or research.

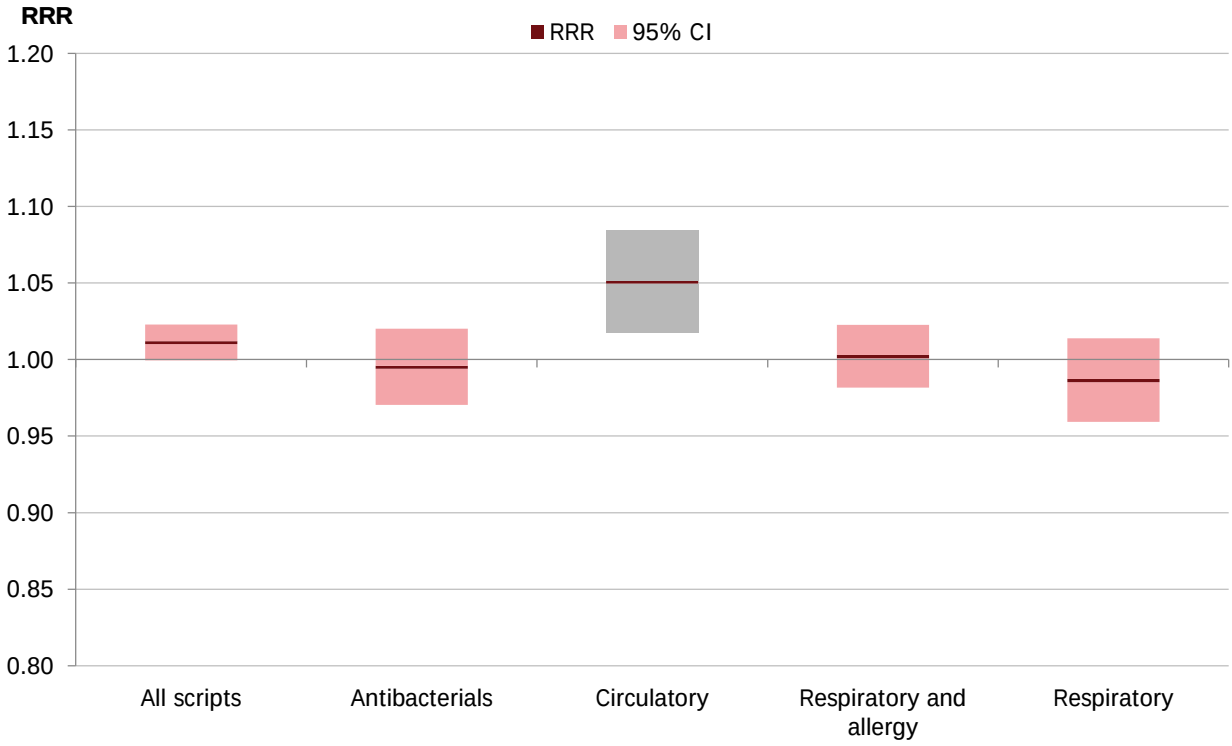
- Installation of MRVS was associated with increased total hospitalisation rates in elderly adults aged 80+ (RRR 1.11, 95%CI 1.01 – 1.22, p=0.026) and decreased rates in Asian peoples (RRR 0.90, 95%CI 0.84 - 0.96, p=0.003).
- ICD-10 Chapter 10 (respiratory) hospitalisations decreased in children aged under 5 years (RRR 0.90, 95%CI 0.82 – 1.00, p=0.041).
- CCID hospitalisations decreased amongst Asian peoples (RRR 0.85, 95%CI 0.74 – 0.98, p=0.025) and in the NZDep2013 7-8 quintile (RRR 0.84, 95%CI 0.76 – 0.93, p=0.001)
- Non-respiratory CCIDs decreased for males (RRR 0.92, 95%CI 0.85 – 1.00, p=0.041), Māori (RRR 0.86, 95%CI 0.76 – 0.97, p=0.016), Asian peoples (RRR 0.83, 95%CI 0.69-1.00, p=0.046) and in the NZDep2013 5-6 quintile (RRR 0.81, 95%CI 0.71 – 0.92, p=0.002).
- Winter-associated illnesses decreased for children aged under 5 years (RRR 0.92, 95%CI 0.85 – 0.99, p=0.29).

- 'Housing-related potentially avoidable hospitalisations' decreased for Asian peoples (RRR 0.82, 95%CI 0.70-0.96, p=0.016).

Pharmaceuticals

There was no significant change in pharmaceutical dispensings following installation of an MRVS for most categories of pharmaceuticals. The single, and notable, exception was pharmaceutical dispensings in the circulatory category, which showed a 5.1% increase (RRR1.05, 95%CI 1.02 – 1.08%, p=0.002) following MRVS installation. Figure 7 shows the RRRs and confidence intervals for each medication category.

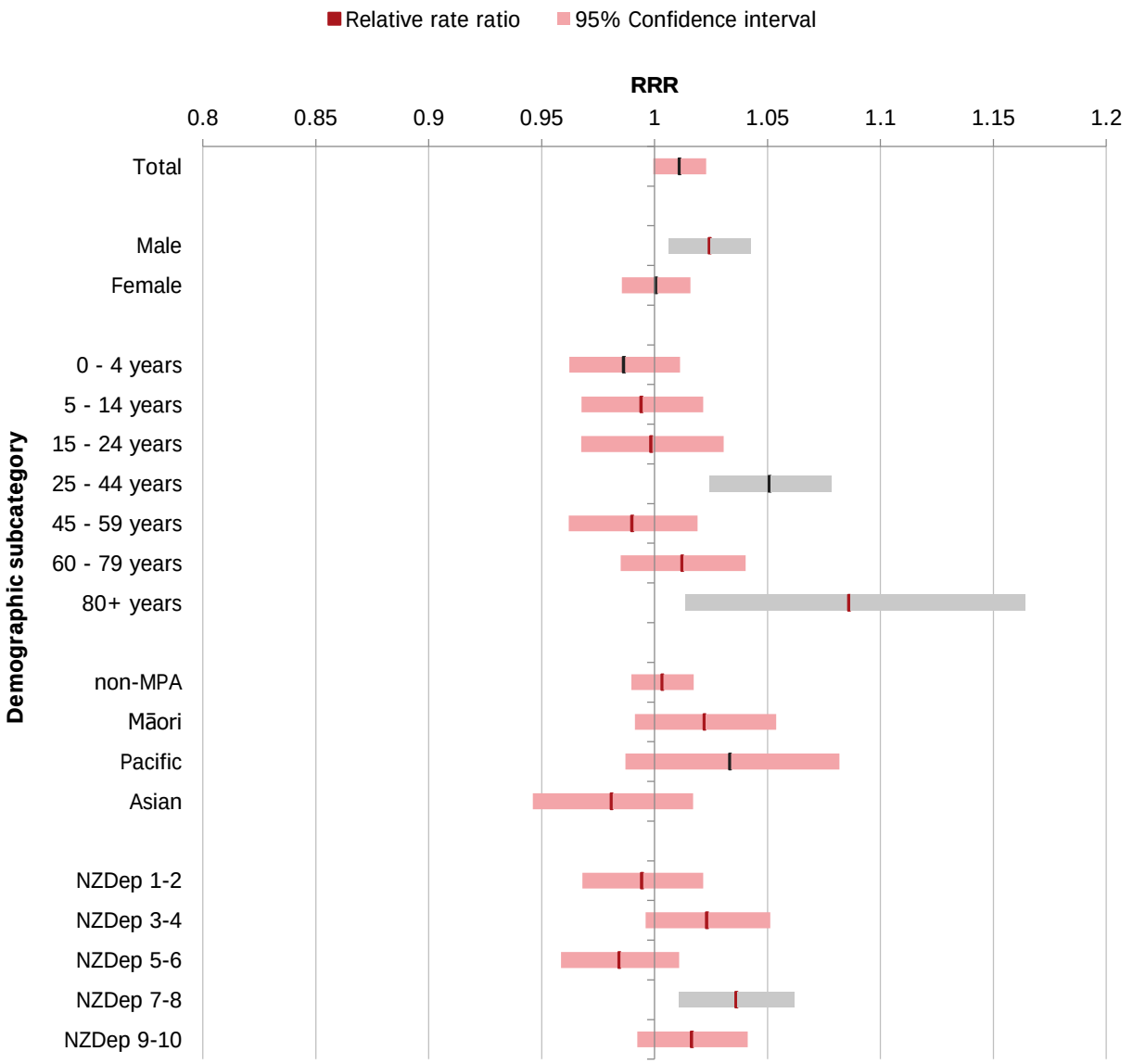
Figure 7. Treatment association for different categories of pharmaceutical dispensings



RRRs for demographic sub-categories were similarly non-significant or adverse. Differences in prescription rates for all dispensings are shown in Figure 8. While most RRRs were non-significant, men had slightly higher prescription rates following MRVS installation (RRR 1.02, 95%CI 1.01 – 1.04, p=0.008), as did adults aged 25 to 44 years (RRR 1.05, 95%CI 1.02 – 1.08,p<0.001) and elderly aged 80+ years (RRR 1.09, 95%CI 1.03 – 1.16, p=0.019).

For circulatory scripts, the elevated prescription rate following MRVS installation was significant for males, adults aged 25 – 55, non-MPA people, Pacific people, and NZDep2013 quintile 7-8. See Appendix 1 for all results.

Figure 8. Treatment association for different categories of total pharmaceutical dispensings



Mortality

We measured mortality outcomes using a standard poisson model. There was no significant difference in mortality rates between treatment and control groups following MRVS installation, for all previously-hospitalised seniors (RR 0.96, 95%CI 0.91-1.02, p=0.205), (Table 9).

Among those in the mortality sub-cohort who had been hospitalised with circulatory conditions (ICD-10 chapter IX), there was no significant difference in mortality rates between the treatment and the control groups (RR 0.99, 95%CI 0.91-1.07, p=0.765) (Table 10).

Among those in the mortality sub-cohort who had been hospitalised with respiratory conditions (ICD-10 chapter X), there was no significant difference in mortality rate after treatment between the treatment and control groups (RR 0.96, 95%CI 0.87 – 1.06, p=0.415) (Table 11).

As there were no significant effects for mortality, we did not investigate differences by dwellings characteristics.

Table 9. Effect of treatment on mortality rates in people aged 65+ hospitalised prior to treatment month

	Hospitalised before treatment month	Deaths after treatment month	Deaths per 1000 people per year	RR (95% CI) p-value	Adjusted RR* (95%CI) p-value
Treatment	9,454	1,434	42.3 (40.1-44.6)	1.01 (0.95-1.07)	0.96 (0.91-1.02)
Control	40,007	5,988	42.1 (41.0-43.2)	p=0.701	p=0.205

*Adjusted for sex, 5-year age-group, ethnicity, NZDep2013 quintile, and hospitalisation costs

Table 10. Effect of treatment on mortality rates in people aged 65+ hospitalised with circulatory illness prior to treatment month

	Hospitalised before treatment month	Deaths after treatment month	Deaths per 1000 people per year	RR (95% CI) p-value	Adjusted RR* (95%CI) p-value
Treatment	3,382	699	56.3 (52.1-60.6)	1.01 (0.93-1.10)	0.99 (0.91-1.07)
Control	14,056	2,839	56.4 (54.3-58.5)	p=0.740	p=0.765

*Adjusted for sex, 5-year age-group, ethnicity, NZDep2013 quintile, and hospitalisation costs

Table 11. Effect of treatment on mortality rates in people aged 65+ hospitalised with respiratory illness prior to treatment month

	Hospitalised before treatment month	Deaths after treatment month	Deaths per 1000 people per year	RR (95% CI) p-value	Adjusted RR* (95%CI) p-value
Treatment	1,765	483	73.3 (66.5-80.0)	1.00 (0.90-1.11)	0.96 (0.87-1.06)
Control	6,795	1,866	76.5 (73.0-80.0)	p=0.997	p=0.415

*Adjusted for sex, 5-year age-group, ethnicity, NZDep2013 quintile, and hospitalisation costs

Dwelling attributes

QV data included house type, roofing and wall cladding materials, and dwelling construction decade. We aggregated the construction decades into three construction eras: pre-1950, 1950-1979, and 1980 onwards. We tested associations using total, ICD 10 Chapter 9 (Circulatory), ICD-10 Chapter 10 (Respiratory), and non-respiratory CCID hospitalisations; and total and circulatory prescriptions.

Pharmaceuticals

Total scripts were significantly elevated following MRVS installation in State Houses (RRR 1.09, 95%CI 1.00 – 1.19, p=0.049) and Villas (RRR 1.07, 95%CI 1.01 – 1.15, p=0.033). Circulatory scripts were particularly elevated for people living in both ‘Quality Bungalows’ (RRR 1.15, 95%CI 1.03 – 1.28) and State Houses (RRR 1.32, 95%CI 1.03 – 1.70, p=0.031), suggesting that individual wealth is not necessarily a factor in the higher level of circulatory prescriptions associated with MRVS installation.

Hospitalisations

Installation of an MRVS was associated with elevated total hospitalisation rates for 'Baches' (RRR 1.63, 95%CI 1.07 – 2.47, p=0.023) but there was no significant difference for other dwelling types . Hospitalisation rates were significantly lower for dwellings clad in brick (RRR 0.95, 95%CI 0.91 – 0.99, p=0.014), and significantly higher for dwellings roofed with 'Fibre cement' (RRR 1.38, 95%CI 1.02-1.87, p=0.038). No other dwelling variables showed any significant differences. The high RRR for baches may mean many baches are already better ventilated than other houses, as construction materials and methods were often ad hoc, so additional ventilation reduces thermal comfort without any ventilation benefit.

In dwellings with 'Fibre Cement' roofs, circulatory hospitalisation rates were particularly elevated following MRVS installation (RRR 2.93, 95%CI 1.06 – 8.06, p=0.037). There were no other meaningful differences for other hospitalisation outcomes or dwelling characteristics.

System type

There are a range of MRVS system types available on the market. The primary differences between systems are whether they are positive pressure or balanced pressure systems, and whether or not they have a heat recovery unit as part of the system.

A small sub-sample of the data included heat recovery systems. We compared outcomes between these heat-recovery systems and other systems, and found no significant difference in outcomes, however this may have been due to insufficient data.

Conclusions

Potentially the most important and disturbing finding of this study was that MRVS systems had been installed into some roof spaces clad in Fibre Cement (likely containing asbestos); the poorer health of people in those dwellings following MRVS installation is entirely unsurprising.

Across health outcomes, compared to their controls, the results were consistent with the installation of MRVS having little or no associated change in health status. However, some sub-groups have results which warrant further investigation: some categories of hospitalisation were less common in younger MRVS households, elderly households appeared significantly less healthy following installation; and prescription rates for circulatory scripts were also significantly elevated. These results may have been significant by chance, but further research would help clarify these apparent associations.

The elderly tend to be more sedentary than younger age groups, and have less active circulation. While both elderly and children have less active thermoregulatory systems, children default towards overheating, while the elderly default towards cold. We hypothesize that, if MRVS systems reduce indoor temperatures in the winter, then in children the detrimental effects of the cold are offset by the benefits of cleaner, less damp air; and/or parents in homes with MRVS may have undertaken other measures to ensure they provide additional heating when necessary; whereas for the elderly, the detrimental effects of cold outweigh the benefits of fresh air, and/or the elderly may be less inclined to heat their homes, and less likely to notice when they are colder than they should be.

If propensity to low indoor temperatures in winter is the driver for the association between MRVS installation and elevated circulatory prescription rates, this study may also provide a useful additional clue to the role of cold in circulatory illness.

This was an observational study. Observational studies carry the possibility of confounding[2], where the self-selecting treatment group differs systematically from the matched control group. However, there was little meaningful difference between treatment and control groups in this study, and little meaningful difference in overall health.

Methodological limitations included imprecision in assigning NHI records to addresses and the possibility that control group households may have installed insulation or heating during the study period outside of WUNZ:HS. We were also unable to directly assess potential benefits such as reduced GP visits, days off school/work and improved comfort.

Recommendations

MRVS systems should under no circumstances be installed in dwellings with roof claddings that contain asbestos. Where systems are already installed in such dwellings, they should be deactivated. While removal would be ideal, it should only be carried out by professionals trained in asbestos hazard prevention.

Older people should consider all options before installing an MRVS, and if they do install a system, ensure they have good insulation and thermostatically-controlled affordable heating options to maintain healthy indoor temperatures. While the association with adverse hospitalisation outcomes may only be significant in people aged 80 years and over, people

[2] Confounding occurs when a variable affects both the outcome and the potentially explanatory variable. For example, if we measured the association between regularly wearing lycra and body mass we might conclude that wearing lycra assisted with weight loss. The confounder in this example would be exercise, if people who regularly wear lycra are more likely to exercise often.

hoping to age in place may wish to future-proof their homes by ensuring that indoor environment systems will continue to promote good health through the different stages of aging.

BRANZ and other building science specialists may wish to investigate what other ventilation options are available for recently-built homes, and in particular, whether the New Zealand Building Code makes sufficient provision for ventilation.

Appendix 1 Additional data tables and charts

Table A 1. Hospitalisation rates for treatment and control populations at baseline, 1 January 2007 to 31 December 2009.

Variable	Treatment rate	Control rate	Total population rate
Age group*			
0-4 years	70.1 (66.8 - 73.4)	65.0 (63.1 - 66.8)	63.1 (62.4 – 63.5)
5-14 years	43.1 (41.2 - 45.3)	39.4 (38.3 - 40.2)	36.9 (36.5 – 37.2)
15-24 years	65.7 (63.1 - 68.3)	65.7 (64.2 - 67.2)	53.7 (53.3 – 54.02)
25-44 years	59.1 (57.3 - 60.6)	62.1 (61.0 - 62.8)	53.3 (59.9 – 53.7)
45-59 years	83.2 (80.7 - 85.8)	81.4 (79.9 - 82.9)	79.9 (79.6 – 80.3)
60-79 years	131.8 (128.1 - 135.8)	134.7 (132.1 - 136.9)	161.3 (160.6 – 161.7)
80-89 years	224.5 (201.1 - 247.5)	226.3 (214.3 - 238)	316.8 (313.5 – 320.1)
Sex			
Male	78.5 (77.0 - 79.9)	76.7 (75.9 - 77.4)	75.9 (75.9 – 76.3)
Female	68.6 (67.2 - 69.7)	69.4 (68.6 - 69.7)	70.8 (70.4 – 71.2)
Ethnic Group			
Non-MPA(Euro/Other)	76.7 (75.2 - 77.7)	74.1 (73.4 - 74.8)	71.5 (71.2 – 71.5)
Total Maori	82.5 (78.8 - 86.1)	88.7 (86.9 - 90.9)	109.9 (109.1 – 110.6)
Total Pacific	102.9 (96.0 - 109.9)	109.9 (105.5 - 114.2)	107.7 (106.2 – 108.8)
Total Asian	45.3 (42.7 - 48.2)	44.5 (43.1 – 46.0)	44.9 (44.2 – 45.3)
NZDep quintile			
1-2	51.1 (48.9 - 53.3)	49.3 (48.2 - 50.4)	50.0 (49.6 - 50.4)
3-4	54.8 (52.9 - 56.6)	56.2 (55.1 - 57.3)	56.9 (56.9 - 57.3)
5-6	67.2 (65.0 – 69.0)	65.0 (63.9 - 66.1)	66.4 (66.4 - 66.8)
7-8	84.0 (81.8 - 86.1)	83.6 (82.1 - 84.7)	85.8 (85.4 - 86.1)
9-10	116.4 (113.2 - 119.4)	114.6 (112.8 - 116.4)	109.9 (109.5 - 110.2)

*Age group is age group at start of study period (1 January 2007). People not yet born were not included. Rates are adjusted for the difference between the NHI population and the census population, and standardised to all other variables.

Table A 2. Age-standardised treatment, control and Census populations at baseline, 1 January 2008 (treatment and control), and 6 March 2006 (Census).

Population	**Treatment**		**Control**		**2013 Census**	
	n	%	N	%	n	%
Sex						
Male	72,266	46.96	348,465	47.00	1,621,845	48.03
Female	81,622	53.04	392,967	53.00	1,754,574	51.97
Age group						
0-4 years	10,998	7.15	49,746	6.71	294,357	6.82
5-14 years	22,675	14.73	104,878	14.15	576,135	13.35
15-24 years	20,113	13.07	108,222	14.60	608,250	14.10
25-44 years	41,930	27.25	200,539	27.05	1,100,000	25.50
45-59 years	29,682	19.29	149,765	20.20	881,268	20.43
60-79 years	24,528	15.94	109,522	14.77	716,835	16.62
80+ years	3,962	2.57	18,760	2.53	137,352	3.18
Ethnic group						
NZ Euro/ Other	101,890	66.21	500,542	67.51	2,942,121	69.34
Māori	20,541	13.35	105,957	14.29	598,602	14.11
Pacific	11,002	7.15	61,579	8.31	295,944	6.97
Asian	22,041	14.32	81,362	10.97	471,708	11.12
NZDep2013 quintile						
NZDep 1-2	26,425	17.17	127,241	17.16	873,315	20.59
NZDep 3-4	27,234	17.70	128,423	17.32	853,605	20.12
NZDep 5-6	29,080	18.90	140,934	19.01	837,927	19.75
NZDep 7-8	34,029	22.11	164,430	22.18	829,980	19.57
NZDep 9-10	37,120	24.12	180,404	24.33	833,133	19.64
Total people	153,888		741,432		4,242,048	
Dwellings	47,887		281,948		1,570,695*	

*Occupied private dwellings

RRRs by pharmaceutical category and demographic sub-categories

Table A 3. All scripts and antibacterials

Demographic group	**All scripts**			**Antibacterials**		
	RRR	95%CI	p-value	RRR	95%CI	p-value
Total	1.01	(1.00 - 1.02)	0.063	0.99	(0.97 - 1.02)	0.691
Male	**1.02**	**(1.01 - 1.04)**	**0.008**	1.00	(0.96 - 1.04)	0.951
Female	1.00	(0.99 - 1.02)	0.940	0.99	(0.96 - 1.03)	0.622
0 - 4 yrs	0.99	(0.96 - 1.01)	0.283	0.95	(0.89 - 1.02)	0.146
5 - 14 yrs	0.99	(0.97 - 1.02)	0.675	1.00	(0.94 - 1.07)	0.995

15 - 24 yrs	1.00	(0.97 - 1.03)	0.927	0.97	(0.91 - 1.04)	0.437
25 - 44 yrs	**1.05**	**(1.02 - 1.08)**	**0.000**	1.04	(0.99 - 1.10)	0.126
45 - 59 yrs	0.99	(0.96 - 1.02)	0.497	0.98	(0.92 - 1.04)	0.468
60 - 79 yrs	1.01	(0.98 - 1.04)	0.383	1.01	(0.95 - 1.08)	0.680
80+ yrs	**1.09**	**(1.01 - 1.16)**	**0.019**	0.94	(0.81 - 1.09)	0.419
non-MPA	1.00	(0.99 - 1.02)	0.624	1.00	(0.97 - 1.03)	0.910
Māori	1.02	(0.99 - 1.05)	0.161	0.99	(0.93 - 1.05)	0.764
Pacific	1.03	(0.99 - 1.08)	0.160	0.93	(0.85 - 1.01)	0.092
Asian	0.98	(0.95 - 1.02)	0.298	0.93	(0.86 - 1.01)	0.099
NZDep 1-2	0.99	(0.97 - 1.02)	0.686	0.99	(0.93 - 1.06)	0.854
NZDep 3-4	1.02	(1 - 1.05)	0.095	1.05	(0.98 - 1.11)	0.159
NZDep 5-6	0.98	(0.96 - 1.01)	0.247	0.99	(0.93 - 1.05)	0.722
NZDep 7-8	**1.04**	**(1.01 - 1.06)**	**0.005**	0.98	(0.93 - 1.04)	0.539
NZDep 9-10	1.02	(0.99 - 1.04)	0.183	0.98	(0.94 - 1.03)	0.410

Table A 4. Respiratory, and respiratory and allergy

Demographic group	**Respiratory**			**Respiratory and allergy**		
	RRR	95%CI	p-value	RRR	95%CI	p-value
Total	0.99	(0.96 - 1.01)	0.327	1.00	(0.98 - 1.02)	0.853
Male	0.99	(0.95 - 1.03)	0.625	1.01	(0.98 - 1.04)	0.525
Female	0.98	(0.95 - 1.02)	0.326	1.00	(0.97 - 1.02)	0.716
0 - 4 yrs	0.98	(0.92 - 1.05)	0.634	1.01	(0.97 - 1.06)	0.592
5 - 14 yrs	0.97	(0.91 - 1.04)	0.406	1.00	(0.95 - 1.05)	0.958
15 - 24 yrs	1.01	(0.93 - 1.11)	0.742	1.01	(0.95 - 1.07)	0.808
25 - 44 yrs	0.98	(0.92 - 1.04)	0.449	1.01	(0.97 - 1.06)	0.683
45 - 59 yrs	0.96	(0.90 - 1.02)	0.201	0.98	(0.93 - 1.03)	0.443
60 - 79 yrs	0.99	(0.93 - 1.06)	0.817	1.00	(0.95 - 1.06)	0.899
80+ yrs	1.01	(0.86 - 1.19)	0.899	0.98	(0.85 - 1.13)	0.798
non-MPA	0.99	(0.95 - 1.02)	0.396	0.99	(0.97 - 1.02)	0.698
Māori	0.98	(0.92 - 1.05)	0.622	1.01	(0.96 - 1.07)	0.695
Pacific	0.96	(0.87 - 1.06)	0.440	0.98	(0.91 - 1.05)	0.567
Asian	0.95	(0.87 - 1.04)	0.248	0.98	(0.93 - 1.03)	0.465
NZDep 1-2	0.97	(0.9 - 1.04)	0.338	0.98	(0.93 - 1.03)	0.402
NZDep 3-4	0.99	(0.92 - 1.05)	0.676	1.01	(0.97 - 1.07)	0.559
NZDep 5-6	0.98	(0.92 - 1.04)	0.511	0.99	(0.95 - 1.04)	0.758

NZDep 7-8	1.02	(0.96 - 1.08)	0.530	1.03	(0.98 - 1.07)	0.221
NZDep 9-10	0.98	(0.93 - 1.04)	0.494	1.00	(0.96 - 1.04)	0.849

Table A 5. Respiratory, and respiratory and allergy

Demographic group	**Circulatory**		
	RRR	95%CI	p-value
Total	**1.05**	**(1.02 - 1.08)**	**0.002**
Male	**1.06**	**(1.01 - 1.11)**	**0.022**
Female	1.04	(1.00 - 1.09)	0.051
0 - 4 yrs	1.25	(0.40 - 3.86)	0.698
5 - 14 yrs	1.07	(0.50 - 2.29)	0.852
15 - 24 yrs	1.52	(0.99 - 2.36)	0.058
25 - 44 yrs	**1.14**	**(1.01 - 1.30)**	**0.037**
45 - 59 yrs	0.97	(0.91 - 1.03)	0.348
60 - 79 yrs	1.04	(0.99 - 1.09)	0.086
80+ yrs	1.05	(0.95 - 1.16)	0.327
non-MPA	**1.04**	**(1.00 - 1.08)**	**0.029**
Māori	1.02	(0.91 - 1.13)	0.785
Pacific	**1.23**	**(1.05 - 1.42)**	**0.008**
Asian	1.07	(0.96 - 1.19)	0.252
NZDep 1-2	1.07	(0.99 - 1.17)	0.105
NZDep 3-4	1.00	(0.93 - 1.09)	0.913
NZDep 5-6	1.06	(0.99 - 1.14)	0.117
NZDep 7-8	**1.11**	**(1.04 - 1.18)**	**0.002**
NZDep 9-10	1.01	(0.94 - 1.07)	0.822

RRRs by hospitalisation category and demographic sub-categories

Table A 6. All-cause and ICD-10 Chapter 10 (Circulatory)

Demographic group	**All-cause**			**Circulatory**		
	RRR	95%CI	p-value	RRR	95%CI	p-value
Total	0.99	(0.97 - 1.01)	0.244	1.03	(0.97 - 1.09)	0.390
Male	0.98	(0.95 - 1.01)	0.194	0.99	(0.91 - 1.09)	0.903
Female	1.00	(0.97 - 1.03)	0.761	1.05	(0.97 - 1.14)	0.195

0 - 4 yrs	0.95	(0.90 - 1.01)	0.104	1.27	(0.63 - 2.55)	0.503
5 - 14 yrs	0.96	(0.90 - 1.02)	0.206	0.94	(0.62 - 1.41)	0.748
15 - 24 yrs	0.96	(0.90 - 1.02)	0.202	0.91	(0.60 - 1.38)	0.658
25 - 44 yrs	0.98	(0.94 - 1.03)	0.509	1.05	(0.84 - 1.29)	0.685
45 - 59 yrs	0.96	(0.91 - 1.01)	0.082	0.88	(0.77 – 1.00)	0.051
60 - 79 yrs	1.02	(0.98 - 1.07)	0.361	1.08	(0.99 - 1.18)	0.070
80+ yrs	**1.10**	**(1.00 - 1.21)**	**0.040**	1.13	(0.97 - 1.33)	0.118
non-MPA	1.00	(0.98 - 1.03)	0.74	1.05	(0.98 - 1.13)	0.136
Māori	0.96	(0.91 - 1.02)	0.175	1.05	(0.88 - 1.26)	0.570
Pacific	0.95	(0.88 - 1.03)	0.208	0.78	(0.61 - 1.01)	0.060
Asian	**0.90**	**(0.84 - 0.97)**	**0.004**	0.94	(0.74 - 1.20)	0.608
NZDep 1-2	0.97	(0.92 - 1.03)	0.322	0.91	(0.77 - 1.07)	0.268
NZDep 3-4	0.97	(0.92 - 1.02)	0.278	**1.21**	**(1.04 - 1.42)**	**0.015**
NZDep 5-6	0.99	(0.94 - 1.04)	0.729	1.08	(0.94 - 1.25)	0.265
NZDep 7-8	1.00	(0.96 - 1.04)	0.942	1.07	(0.95 - 1.21)	0.249
NZDep 9-10	1.00	(0.96 - 1.04)	0.838	0.93	(0.83 - 1.04)	0.203

Table A 7. ICD-10 Chapter 10 (Respiratory) and Asthma

Demographic group	**Respiratory**			**Asthma**		
	RRR	95%CI	p-value	RRR	95%CI	p-value
Total	0.99	(0.94 - 1.05)	0.853	1.05	(0.91 - 1.21)	0.519
Male	0.99	(0.92 - 1.07)	0.793	1.04	(0.85 - 1.27)	0.717
Female	1.00	(0.92 - 1.08)	0.946	1.04	(0.86 - 1.27)	0.665
0 - 4 yrs*	**0.90**	**(0.82 – 1.00)**	**0.041**	0.85	(0.66 - 1.1)	0.227
5 - 14 yrs	1.08	(0.90 - 1.29)	0.428	1.02	(0.76 - 1.38)	0.883
15 - 24 yrs	0.92	(0.74 - 1.14)	0.441	0.95	(0.57 - 1.56)	0.828
25 - 44 yrs	1.07	(0.91 - 1.25)	0.435	1.32	(0.9 - 1.93)	0.153
45 - 59 yrs	0.97	(0.82 - 1.14)	0.675	1.00	(0.65 - 1.53)	0.994
60 - 79 yrs	0.97	(0.85 - 1.1)	0.654	1.20	(0.77 - 1.86)	0.427
80+ yrs	0.99	(0.78 - 1.24)	0.909	2.32	(0.72 - 7.42)	0.158
non-MPA	1.01	(0.94 - 1.09)	0.793	1.12	(0.91 - 1.37)	0.300
Māori	0.97	(0.87 - 1.10)	0.667	0.98	(0.74 - 1.29)	0.860
Pacific	0.99	(0.84 - 1.16)	0.888	0.99	(0.69 - 1.44)	0.967
Asian	0.84	(0.7 - 1.01)	0.069	0.81	(0.54 - 1.21)	0.308

NZDep 1-2	1.00	(0.86 - 1.17)	0.999	1.06	(0.69 - 1.63)	0.780
NZDep 3-4	0.99	(0.85 - 1.14)	0.854	1.11	(0.77 - 1.61)	0.565
NZDep 5-6	0.97	(0.85 - 1.1)	0.617	1.11	(0.78 - 1.57)	0.562
NZDep 7-8	0.95	(0.84 - 1.06)	0.331	0.99	(0.74 - 1.32)	0.920
NZDep 9-10	1.05	(0.96 - 1.16)	0.292	1.09	(0.85 - 1.40)	0.508

*2 – 4 years for asthma

Table A 8. CCID and non-respiratory CCID

Demographic group	**CCID**			**Non-respiratory CCID**		
	RRR	95%CI	p-value	RRR	95%CI	p-value
Total	0.96	(0.92 – 1.00)	0.069	**0.94**	**(0.89 - 0.99)**	**0.029**
Male	0.95	(0.89 - 1.01)	0.092	**0.92**	**(0.85 - 1)**	**0.041**
Female	0.97	(0.91 - 1.03)	0.369	0.96	(0.88 - 1.04)	0.306
0 - 4 yrs	0.95	(0.88 - 1.03)	0.183	0.97	(0.87 - 1.07)	0.522
5 - 14 yrs	0.99	(0.87 - 1.13)	0.870	0.91	(0.78 - 1.07)	0.246
15 - 24 yrs	0.97	(0.84 - 1.11)	0.650	1.01	(0.85 - 1.19)	0.942
25 - 44 yrs	0.94	(0.84 - 1.04)	0.240	0.89	(0.78 - 1.01)	0.072
45 - 59 yrs	1.00	(0.88 - 1.13)	0.993	0.95	(0.81 - 1.11)	0.481
60 - 79 yrs	0.91	(0.82 - 1.02)	0.094	0.92	(0.79 - 1.07)	0.273
80+ yrs	0.90	(0.73 - 1.10)	0.291	0.88	(0.64 - 1.21)	0.432
non-MPA	0.98	(0.93 - 1.04)	0.491	0.98	(0.91 - 1.05)	0.507
Māori	0.92	(0.84 - 1.01)	0.092	**0.86**	**(0.76 - 0.97)**	**0.016**
Pacific	0.95	(0.84 - 1.08)	0.420	0.92	(0.79 - 1.08)	0.322
Asian	**0.85**	**(0.74 - 0.98)**	**0.025**	**0.83**	**(0.69 – 1.00)**	**0.046**
NZDep 1-2	1.00	(0.89 - 1.13)	0.935	1.03	(0.89 - 1.20)	0.692
NZDep 3-4	0.93	(0.83 - 1.04)	0.190	0.89	(0.77 - 1.03)	0.130
NZDep 5-6	**0.84**	**(0.76 - 0.93)**	**0.001**	**0.81**	**(0.71 - 0.92)**	**0.002**
NZDep 7-8	0.99	(0.90 - 1.08)	0.817	0.99	(0.88 - 1.11)	0.813
NZDep 9-10	1.01	(0.93 - 1.09)	0.818	0.97	(0.88 - 1.07)	0.553

Table A 9. COPD and Winter-associated illness

Demographic group	**COPD**			**Winter-associated illness**		
	RRR	95%CI	p-value	RRR	95%CI	p-value
Total	0.94	(0.77 - 1.14)	0.527	1.00	(0.97 - 1.03)	0.970
Male	0.93	(0.70 - 1.23)	0.592	0.99	(0.94 - 1.03)	0.505

Female	0.94	(0.72 - 1.22)	0.640	1.01	(0.97 - 1.06)	0.518
0 - 4 yrs				**0.92**	**(0.85 - 0.99)**	**0.029**
5 - 14 yrs				0.96	(0.86 - 1.07)	0.439
15 - 24 yrs				0.97	(0.87 - 1.09)	0.601
25 - 44 yrs				1.04	(0.96 - 1.13)	0.290
45 - 59 yrs	0.77	(0.48 - 1.22)	0.262	0.96	(0.89 - 1.04)	0.282
60 - 79 yrs	0.92	(0.72 - 1.17)	0.474	1.04	(0.98 - 1.11)	0.158
80+ yrs	1.20	(0.76 - 1.91)	0.440	1.09	(0.97 - 1.22)	0.141
non-MPA	0.91	(0.72 - 1.14)	0.399	1.02	(0.98 - 1.06)	0.339
Māori	0.90	(0.58 - 1.40)	0.646	0.96	(0.89 - 1.04)	0.355
Pacific	0.76	(0.34 - 1.68)	0.498	0.96	(0.86 - 1.07)	0.481
Asian	1.66	(0.48 - 5.70)	0.422	0.91	(0.82 - 1.02)	0.096
NZDep 1-2	1.00	(0.49 - 2.03)	0.997	0.94	(0.87 - 1.02)	0.155
NZDep 3-4	0.86	(0.49 - 1.51)	0.607	1.03	(0.95 - 1.11)	0.490
NZDep 5-6	0.96	(0.59 - 1.56)	0.874	1.01	(0.94 - 1.08)	0.829
NZDep 7-8	0.77	(0.53 - 1.10)	0.155	1.01	(0.95 - 1.08)	0.733
NZDep 9-10	1.11	(0.81 - 1.53)	0.506	1.00	(0.94 - 1.06)	0.953

Table A 10. Housing-related potentially avoidable hospitalisations

Demographic group	**Housing-related potentially avoidable hospitalisations**		
	RRR	95%CI	p-value
Total	0.97	(0.93 - 1.02)	0.256
Male	0.95	(0.89 - 1.02)	0.131
Female	0.99	(0.93 - 1.07)	0.886
0 - 4 yrs	0.92	(0.85 - 1.01)	0.079
5 - 14 yrs	1.03	(0.89 - 1.19)	0.719
15 - 24 yrs	1.02	(0.85 - 1.22)	0.831
25 - 44 yrs	0.92	(0.81 - 1.04)	0.194
45 - 59 yrs	0.93	(0.81 - 1.07)	0.304
60 - 79 yrs	0.97	(0.87 - 1.09)	0.644
80+ yrs	1.07	(0.86 - 1.34)	0.537
non-MPA	0.99	(0.93 - 1.06)	0.748
Māori	0.93	(0.84 - 1.03)	0.189
Pacific	0.98	(0.86 - 1.13)	0.802
Asian	**0.82**	**(0.70 - 0.96)**	**0.016**

NZDep 1-2	1.01	(0.88 - 1.16)	0.920
NZDep 3-4	0.99	(0.86 - 1.12)	0.828
NZDep 5-6	0.88	(0.78 - 0.99)	0.037
NZDep 7-8	0.94	(0.85 - 1.04)	0.240
NZDep 9-10	1.03	(0.94 - 1.12)	0.512

Appendix 2 House typologies

QV dwelling types

These dwelling type descriptions were provided to H&HRP in 2012 by Property IQ, a then subsidiary of QV.

Dwelling Types, referred to by QV as 'House types', are used by Valuers as a general way of characterising a house. They are not strictly defined nor mutually exclusive and there can be overlaps between different house types. House type is chosen by the first Registered Valuer to inspect and value a property.

Table A 11. QV Dwelling types .

Dwelling Type	Description
Apartment	generally built 1920s onwards - common entrance way, purpose built from the 1960s onwards, multi-storey blocks often with several apartments per floor. 5+ apartments per block. Apartments are normally joined on 2 walls.
Bach	any age - basic design, materials, layout, often small floor size, two bedrooms, and open plan, frequently extended in different styles and materials. Also called a crib in Southland.
Contemporary	generally built 1970s onwards - modern, contemporary design, many roof breaks and pitches, high studs, grand entrance halls, often different angles walls, not uniform design. Often stucco, plaster walls. Building features are often associated with weather-tightness issues.
Cottage	generally built 1890-1900 door facing street, gable roof, veranda along front, single storey, weather clad, iron roof with two sloping slides
Pre-war bungalow	generally built 1920-1940s - House faces street - greater utility and less ostentatious, narrow weatherboard, iron roof, lower stud and gable, bay and boxed windows, verandas part of main roof. Timber joinery inside. Timber shingles
Bungalow - post war	generally built 1950s onwards - 'standard' dwelling using average quality materials and design. Can have gable, Dutch gable or Hip roof lines. Often located for sunshine, not necessarily facing the street. Normally single storey, but sometime appears a dual storey if built over garage on sloping sections
Quality Bungalow	generally built 1950s onwards - high quality materials, design, grand designs often with swimming pools, tennis courts etc., can often be two storeys, larger sections.
Quality Old	generally built 1920-1940s - Tudor and Georgian influences, English styles, large and grand, good quality materials, fixtures and fittings, usually 2 storey, weatherboards, stucco, brick and shingles, often in combination. Timber joinery. Sometimes referred to as "Arts and Crafts".

Spanish Bungalow	generally built 1930-1950 - Art Deco and Spanish styles, predominantly 30s and 40s built, horizontal lines feature in design, often curved walls, low pitched roofs, always stucco clad, and parapets around roof line.
State House	generally built late 1930s onwards - purpose build by the government for social housing, often simple materials and basic design but constructed well, often multiunit, weatherboard cladding, clay or concrete tile roofs *N.B. QV refer to these as 'State Rentals' but the author has relabelled them to avoid confusion with social housing stock, as a large proportion are now in private ownership.*
Townhouse	generally built 1970s onwards - high site coverage, low maintenance sections, better quality than a Unit, can be detached or semi reattached, often separated by a garage. Normally two storey. Stucco plaster wall coverings; can be prone to weather tightness issues. Often crossleased.
Unit	generally built 1950s onwards - attached and semi-detached, 1-3 bedrooms, small <100m2, basic design, open plan. Often cross leased.
Terraced Apartment	generally built 1990s onwards - medium to high quality fixtures and fittings, often 2-3 levels, 3-5 units in the complex, party walls between the apartments. These are NOT necessarily "flats". Often own entrance and garage with dwelling space above.
Villa	generally built 1900 - 1920s - door faces street, weatherboard, high stud, can be one or two storey, iron roof with four sides and single point, eaves, brackets, finial, fretwork common

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