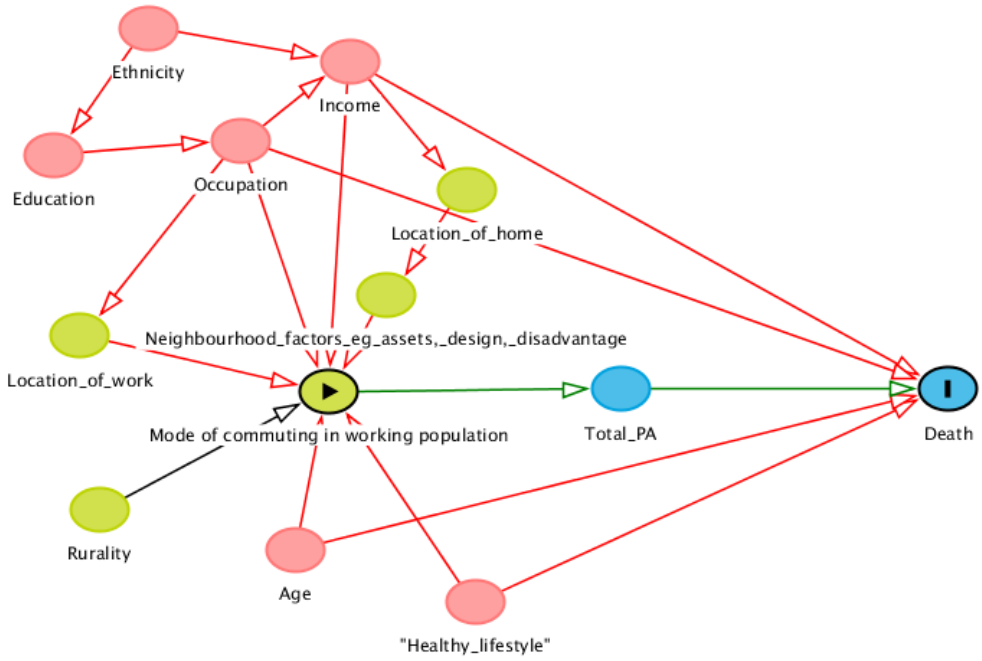
Supplementary Material

S1: Figure: Causal diagram



S2: Quantitative bias analysis exposure misclassification input parameters

We undertook QBA for cycling compared to private vehicles only.

We initially estimated the sensitivity and specificity of the travel to work census question for classifying regular cyclists accurately (using a definition of a regular cyclists as someone who cycled to work 4 or more days of the week).

		Outcome: 'True' regular cyclist (cycle to work 4 or 5 days a week)		
		Yes	No	
Test: Census question cycled to work that day	Yes	A	B	
	No	C	D	

To do this we created a table of scenarios about how likely people were to cycle on particular numbers of days of the week (see below). As NZ is a low prevalence cycling country we assume that cyclists were relatively committed individuals and more likely to cycle frequently; however we explored a range of scenarios. Sensitivity (the chance that a person who was a regular cyclist would cycle on census day, and thus tick the box on the census form) for each scenario was calculated by weighting the distribution of cyclists who cycle 4 or 5 days of the week in the scenarios below being seen on those days (i.e. a 100% chance for people who cycle five days a week and an 80% chance for those who cycle four days a week). The sensitivity values were in a reasonably tight range from 0.86 to 0.90.

	Distribution of cycling over days of the week					Sensitivity	1 - PPV
Scenarios	1	2	3	4	5		
A	0.2	0.2	0.2	0.2	0.2	0.90	0.40
B	0.1	0.2	0.4	0.2	0.1	0.87	0.57
C	0.1	0.25	0.3	0.25	0.1	0.86	0.50
D	0.1	0.15	0.25	0.3	0.2	0.88	0.34
E	0.08	0.12	0.25	0.3	0.25	0.89	0.30

Specificity (the chance that if someone is not a regular cyclist, i.e. cycles only 3 or fewer days a week, will have not have ticked the census box) was estimated with two steps:

- First, we calculated one minus the positive predictive value (PPV) for the five scenarios above in the table. This estimate was more variable ranging from 0.30 to 0.60. This estimate multiplied by the number of people answering yes to cycling on census night, then divided by the number of people answering yes to use of a motor vehicle, gives an *approximate* estimate of one minus the specificity (assuming no misreporting).[1]
- Second, the above assumes perfect recording of cycle use versus non-cycle use on census day. There will be some errors simply due to 'ticking the wrong box'. We assumed about 0.2% of people made such random errors – which would be about 1800 of 90000 people recorded as cycling.

[1] It is approximate for two reasons: the denominator of people reporting yes to using a car will not be exactly correct for true use of car – but will make little difference at the level of accuracy we require; the non-cycle users include pedestrians and public transport users, but again this will not make too much difference at the level of accuracy required.

The sum of the two components above gives an approximate estimate of one minus the specificity. It was dominated by the second component of random error. However, even if we assumed a 2% random error (driving the specificity to just less than 98%) it made little difference to the misclassification adjusted rate ratio – which was more influenced by the value of the sensitivity.

From the range of sensitivities and specificities above we calculated the mean and standard deviation and then estimated a plausible range of values (slightly larger than the minimum and maximum values). Namely:

- Sensitivity:
    - Assumed inputs of: mode = 0.88; minimum = 0.84; maximum = 0.92.
    - Gives parameters of beta distribution of: alpha = 2090; beta = 285
    - With this beta distribution have: median = 0.880; 2.5th percentile = 0.867; 97.5th percentile = 0.893.
- Specificity:
    - Assumed inputs of: mode = 0.996; minimum = 0.980; maximum = 0.999.
    - Gives parameters of beta distribution of: alpha = 855; beta = 5.3
    - With this beta distribution have: median = 0.994; 2.5th percentile = 0.988; 97.5th percentile = 0.998.

S3: Table: Demographics of people aged 20-64 who were employed and walked or used transport to go to work on census day (i.e. our final cohort)

Variable	1996	2001	2006
Gender			
Males	549,306	506,550	623,334
Females	418,119	419,907	524,982
Age			
20-24	117,402	89,424	110,886
25-34	269,364	235,191	259,197
35-44	276,867	271,524	321,342
45-54	215,076	226,242	287,631
55-64	88,716	104,073	169,254
Ethnicity			
Total NZ Mäori	96,087	87,435	116,670
Total Pacific	31,887	32,097	44,925
Total Asian	34,425	45,252	91,806
nonMPA (European/Other)	804,000	760,776	895,914
Missing	5,955	4,815	5,310
Education			
No Qualifications	231,009	180,354	192,090
School Qualifications	296,904	342,441	364,287
Post-School Qualifications	439,515	403,662	591,936
Income			
Lowest Income	112,422	132,795	261,693
Middle	325,893	241,500	425,037
Highest Income	529,110	552,165	461,583

Variable	1996	2001	2006
NZDep			
Dep1-6	661,845	636,738	775,989
Dep7&8	177,240	169,737	217,482
Dep9&10	128,340	119,982	154,839
Rurality			
Urban (Main & Sec)	855,291	819,858	1,008,525
Rural & Other	112,137	105,909	139,788
Car access			
No	35,421	25,455	25,533
Yes	932,004	901,002	1,122,780
Smoking Status			
Smoker	230,958	N/A	237,042
Ex-Smoker	209,721	N/A	251,382
Never Smoked Regularly	500,316	N/A	623,112
Not Specified	26,433	N/A	36,774
Travel to work			
Bicycle	34,074	27,324	28,422
Walked or jogged	61,080	57,363	70,149
Public Transport	42,441	44,061	57,177
Motor Vehicle	825,015	791,091	984,096
Other Modes	4,815	6,618	8,469
Weighted deaths			
Bicycle	135	99	204
Walked or jogged	342	270	606
Public Transport	219	153	360
Motor Vehicle	4,494	3,456	8,985

Variable	1996	2001	2006
Other Modes	51	36	78
Total	5,241	4,014	10,233

All numbers in this table have been random rounded to base 3 as per Statistics New Zealand confidentiality protocols. This table reports numbers for the cohort with no missing data (i.e. the population regressions were performed on) so is smaller than the numbers reported in the tables in the main article.

S4: Table: Deaths, person time, standardised mortality rates by mode of travel to work on census day

Mode of transport on census day	Deaths	Person time (years)	Standardised mortality rate per 100 000 person years (95% CI)	Standard Rate Ratio (95% CI)
Male				
Cycling	441	334,771	183 (156 -211)	0.95 (0.82 – 1.11)
Walking/jogging	768	443,410	209 (189 – 229)	1.08 (0.98 – 1.20)
Public transport	483	319,467	212 (185 – 240)	1.10 (0.97 – 1.26)
Motor vehicle	12741	7,329,318	192 (188 -197)	Ref
Female				
Cycling	72	108,200	90 (63-117)	0.83 (0.62 – 1.12)
Walking	561	525,825	121 (108 – 133)	1.12 (1.00 – 1.25)
Public transport	375	433,198	117 (102 – 132)	1.08 (0.94 – 1.27)
Motor vehicle	5781	5,849,365	108 (105 - 112)	Ref
Sex combined				
Cycling	513	442,971	161 (139 - 183)	1.03 (0.90 - 1.19)
Walking	1332	969,235	161 (150 - 173)	1.03 (0.96 - 1.11)
Public transport	858	752,665	156 (142 - 170)	1.00 (0.91 - 1.10)
Motor vehicle	18522	13,178,683	156 (153 - 159)	Ref

Standardised rates and rate ratios are age and ethnicity standardised. All cohorts combined. Ages 20-64 on census night.

All numbers in this table have been random rounded to base 3 as per Statistics New Zealand confidentiality protocols.

S5: Table: Regression modelling mode of transport on census day and all-cause mortality, by gender.

	Transport mode	Deaths (n)*	Age, ethnicity and cohort adjusted rate ratio (95%CI)	Multivariable† adjusted rate ratio (95%CI)
All - cause mortality				
Male	Cycling	357	0.95 (0.83-1.08)	0.87 (0.76 – 0.99)
	Walking/jogging	621	1.10 (1.00-1.21)	0.96 (0.87 – 1.06)
	Public transport	387	1.03 (0.91-1.16)	0.99 (0.88 – 1.12)
	Motor vehicle	10,431	Ref	Ref
Female	Cycling	63	0.92 (0.70-1.22)	0.83 (0.63 – 1.10)
	Walking/jogging	462	1.17 (1.05-1.30)	0.99 (0.88 -1.11)
	Public transport	291	1.05 (0.91-1.19)	0.94 (0.82 - 1.08)
	Motor vehicle	4,821	Ref	Ref
Ischaemic heart disease				
Male	Cycling	69	0.99 (0.75-1.32)	0.90 (0.67-1.20)
	Walking/jogging	96	0.87 (0.68-1.10)	0.76 (0.60-0.96)
	Public transport	75	1.02 (0.78-1.34)	0.99 (0.75-1.31)
	Motor vehicle	2,190	Ref	Ref
Female	Cycling	6	1.35 (0.51-3.56)	1.04 (0.39-2.78)
	Walking/jogging	36	1.42 (0.95-2.12)	1.00 (0.66-1.51)
	Public transport	30	1.83 (1.19-2.81)	1.49 (0.94-2.34)
	Motor vehicle	294	Ref	Ref
Road traffic crash				
Male	Cycling	33	0.96 (0.61-1.52)	1.01 (0.64-1.61)
	Walking/jogging	48	1.09 (0.74-1.61)	1.04 (0.70-1.55)
	Public transport	18	0.54 (0.29-1.01)	0.65 (0.34-1.22)
	Motor vehicle	669	Ref	Ref

	Transport mode	Deaths (n)*	Age, ethnicity and cohort adjusted rate ratio (95%CI)	Multivariable† adjusted rate ratio (95%CI)
Female	Cycling	6	0.99 (0.26-3.78)	0.98 (0.25-3.76)
	Walking/jogging	21	1.33 (0.76-2.32)	1.22 (0.69-2.15)
	Public transport	6	0.53 (0.21-1.33)	0.60 (0.24-1.53)
	Motor vehicle	177	Ref	Ref

†Adjusted for age, ethnicity, cohort, area deprivation, educational qualification, household income, car access, and rurality.

All numbers in this table have been random rounded to base 3 as per Statistics New Zealand confidentiality protocols.

S6: Table: Regression modelling including smoking variable (1996 and 2006 cohorts only, sex combined)

	Model 1	Model 1 plus smoking
All-cause mortality		
Bicycle	0.82 (0.71-0.94)	0.88 (0.77-1.01)
Walked or jogged	0.95 (0.87-1.03)	0.97 (0.89-1.06)
Public Transport	0.93 (0.84-1.04)	0.96 (0.86-1.07)
Motor Vehicle	Ref	Ref
Ischaemic heart disease		
Bicycle	0.85 (0.62-1.18)	0.95 (0.69-1.31)
Walked or jogged	0.82 (0.65-1.03)	0.84 (0.67-1.06)
Public Transport	0.95 (0.72-1.25)	0.99 (0.75-1.30)
Motor Vehicle	Ref	Ref
Road traffic crash		
Bicycle	0.88 (0.53-1.48)	0.92 (0.55-1.55)
Walked or jogged	1.03 (0.72-1.49)	1.05 (0.73-1.51)
Public Transport	0.67 (0.38-1.17)	0.68 (0.39-1.20)
Motor Vehicle	Ref	Ref

Model 1: Adjusted for age, sex, ethnicity, cohort, area deprivation, educational qualification, household income, car access, and rurality. All numbers in this table have been random rounded to base 3 as per Statistics New Zealand confidentiality protocols.

Table S7: Table: Regression modelling removing first year of deaths as a test of possible reverse causation

Transport mode	Model 1 rate ratio (95% CI)	Model 2 rate ratio (95% CI)
All - cause mortality		
Cycling	0.87 (0.77-0.98)	0.83 (0.73-0.95)

Transport mode	Model 1 rate ratio (95% CI)	Model 2 rate ratio (95% CI)
Walking/jogging	0.97 (0.90-1.04)	1.00 (0.92-1.09)
Public transport	0.96 (0.88-1.05)	0.98 (0.89-1.08)
Motor vehicle	Ref	Ref
Ischaemic heart disease		
Cycling	0.90 (0.68-1.19)	0.89 (0.65-1.21)
Walking/jogging	0.81 (0.66-1.00)	0.77 (0.60-0.97)
Public transport	1.10 (0.87-1.39)	1.11 (0.86-1.43)
Motor vehicle	Ref	Ref
Road traffic crash		
Cycling	1.01 (0.65-1.57)	0.86 (0.50-1.48)
Walking/jogging	1.09 (0.79-1.51)	1.01 (0.69-1.49)
Public transport	0.62 (0.37-1.04)	0.69 (0.39-1.19)
Motor vehicle	Ref	Ref

Model 1: Adjusted for age, sex, ethnicity, cohort, area deprivation, educational qualification, household income, car access, and rurality. Model 2: Model 1 with first 1 year of follow up removed. All numbers in this table have been random rounded to base 3 as per Statistics New Zealand confidentiality protocols.

Table S8 Impact of exposure misclassification on estimates of the relative risk of all-cause mortality for those cycling to work compared with travelling by private motor vehicle, European/other ethnicity aged 45-64, by gender

	Baseline RR (95%CI)	RR adjusted for exposure misclassification (median, 2.5th and 97.5th percentiles for total uncertainty †)
Men		
All-cause mortality	0.71 (0.60 - 0.85)	0.64 (0.47-0.78)

	Baseline RR (95%CI)	RR adjusted for exposure misclassification (median, 2.5th and 97.5th percentiles for total uncertainty †)
All-cause mortality - never smokers	0.67 (0.49 - 0.9)	0.59 (0.41 - 0.83)
Women		
All-cause mortality	0.97 (0.7 - 1.35)	0.91 (0.51 - 1.27)

† Includes both random error (as per the usual confidence interval) plus propagated uncertainty about the sensitivity and specificity bias parameters in the Monte Carlo simulation.