# Abstract

We used longitudinal information on area deprivation status to explore the relationship between residential-deprivation mobility and Cardiovascular Disease (CVD). Data from 2,418,397 individuals who were: enrolled in any Primary Health Organisation within New Zealand (NZ) during at least 1 of 34 calendar quarters between 1<sup>st</sup> January 2006 to 30<sup>th</sup> June 2014; aged between 30 and 84 years (inclusive) at the start of the study period; had no prior history of CVD; and had recorded address information were analysed. Including a novel trajectory analysis, our findings suggest that movers are healthier than stayers. The deprivation characteristics of the move have a larger impact on the relative risk of CVD for younger movers than for older movers. For older movers any kind of move is associated with a decreased risk of CVD.

# Keywords

Mobility; Deprivation; Cardiovascular disease; Trajectories; New Zealand

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### Introduction

Migration is an inherently selective process. It redistributes populations differentiated by stage in the lifecourse, socioeconomic status and ethnicity, to give a few examples (Boyle et al., 1998; Morrison and Nissen, 2010; Mosca and Wright, 2010; Simpson and Finney, 2009). This selective sorting is one mechanism through which neighbourhood level inequalities in health can emerge or are maintained (Boyle, 2004; Norman et al., 2005). This is a well-established area of investigation, capturing a multitude of geographies, health outcomes and populations. Yet the evidence for persistent social and spatial inequalities in health demonstrates the need to better understand the complexities of the relationship between health and migration.

Age is the strongest and most consistent predictor of migration (Plane, 1993): we are most mobile as young adults. At our most mobile, moves are commonly associated with entering higher education, seeking (graduate) employment, partnering and family formation (Fotheringham et al., 2004). In early childhood, moves may be prompted by changing housing needs while moves in later life are often associated with retirement or seeking (in)formal care. Thus, the factors governing a migration event vary with age, as does the relationship with health (Norman et al., 2005).

Young adult migrants tend to be healthier compared to young adult non-migrants, whereas older migrants tend to be less healthy than older non-migrants (Bentham, 1988; Norman et al., 2005). The apparent age- and health-selectivity of migration is complicated by wider socio-demographic attributes, individual circumstances and experience of particular health outcomes. Movers are not a homogenous group and aggregate summaries of their characteristics (e.g. their better health) are misleading (Larson et al., 2004). For example, Tunstall et al. (2014) found lower rates of poor general health and higher rates of poor mental health in aggregate analysis. But when stratified by age group, movers of all ages had equivalent or higher rates of poor general health and poor mental health relative to stayers.

The evidence for differences in health between movers and stayers varies depending not only on the health outcome in question (Boyle et al., 2002), but also the nature of the migration event. In the context of health, moves need to be defined in terms of frequency and the socio-spatial trajectory of the move. Frequent movers have the greatest risk of poor health outcomes (Geronimus et al., 2014), but highly mobile groups are disproportionately excluded from analysis given the difficulties in tracking them over time (Morris et al., 2018). Therefore, less is known about the experience of highly

mobile groups. The relationship between health and migration varies depending on the socio-spatial trajectory of a move, which is important in terms of the role of selective sorting in contributing to health inequalities between areas. The health of those moving from less to more deprived areas tends to be poorer than the health of those moving in the opposite direction (Norman et al., 2005; Exeter et al., 2011).

Although the strength of the association varies depending on the time-frame investigated, the choice of health outcome, and the measure of deprivation. For example, a study in England and Wales covering a twenty-year time period found that selective migration could contribute to widening area level health inequalities for mortality and limiting long-term illness (Norman et al., 2005). In contrast, when looking at first change of address during a 10 year time period in the Netherlands, the influence of selective migration was found to be too small to contribute to neighbourhood inequalities in health and health-related behaviours (Van Lenthe et al., 2007). More recently, a UK-based study concluded that moves towards a more socioeconomically deprived area were associated with poorer general and mental health relative to more favourable socio-spatial trajectories, however this patterning did not hold for deprivation in the physical environment (Tunstall et al., 2014). Similarly, in New Zealand, risk of hospitalisation for a cardiovascular event was found to be higher for people moving to less deprived areas than for those moving in the opposite direction (Exeter et al., 2014).

It is notable that research into the socio-spatial trajectories of a move tends to determine change through combinations of area deprivation at the start and end points of the study period. However, for individuals who move several times over the observed period, this may not be representative of their experiences of deprivation. Furthermore, new residents in an area may not have been settled long enough for aspects of that area to have an influence on their health and health behaviours (Clarke et al., 2013; Curtis et al., 2004). Estimated associations between deprivation and health for those who move near the start or end of the observed period may therefore be biased.

This paper utilises a temporally-rich, morbidity-specific dataset to gain further insights into the complexities of the health-migration relationship. We focus on cardiovascular disease (CVD), an outcome of interest for a number of reasons. Firstly, CVD is the leading cause of death globally. In New Zealand (NZ) CVD is the largest single cause of death, which for many people would be premature or preventable (Ministry of Health, 2015). Secondly, a plethora of international evidence

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demonstrates a consistent association between neighbourhood-level socioeconomic factors with CVD (Chan et al., 2008; Cubbin et al., 2006; Grey et al., 2010; Pujades-Rodriguez et al., 2014; Ramsay et al., 2015). For example, Chan et al (2008) found that in NZ, people living in more deprived areas were between 1.5 to 2.5 times more likely to have CVD than people living in the least deprived areas, depending upon age. The nature of the local labour market (e.g. unemployment, instability, job-related stress), smoking uptake, healthcare provision are environmental risk factors associated with risk of CVD (Lang et al., 2012) and vary markedly by level of area deprivation. Thus, movement within and between different neighbourhoods will be pertinent to CVD risk: whether through the accumulation of exposure to pathogenic environments (Wannamethee et al., 2002), disrupting access to healthcare (Jelleyman and Spencer, 2008), influencing uptake of risky health-related behaviours, or through the complex interplay between the stress of a migration event (Oishi, 2010) combined with the stressors necessitating this move.

This paper extends existing research into the health-migration relationship in a number of ways. First, we test whether conclusions are enhanced when using a more nuanced measure of sociospatial trajectories than differences between the first and last recorded experience of deprivation. Second, we contribute to literature examining the mechanisms driving inequalities in CVD in New Zealand, important given the prevalence of CVD-related preventable, premature deaths in the country (Ministry of Health, 2015). We use trajectory analysis to group individual's patterns of movement across deprivation quintiles in order to: i) determine the optimal number of trajectory groupings which captures the variability in movement patterns across the observed time period; and ii) model the association between these trajectories and risk of first CVD event, comparing these results with those participants who either move within the same deprivation quintile, or do not move during the study period.

Trajectory analysis has been used across different disciplines to categorise individuals into groups (Choi et al., 2012; Muthen and Muthen, 2000; Nagin and Land, 1993; Nagin and Odgers, 2010). This approach can reduce potential bias caused by loss to follow-up, and improve the efficiency of the statistical analyses by using all the available data from multiple time points rather than the first and last observations (Kenward and Carpenter, 2007; Little and Rubin, 2002). Trajectory analysis is therefore a useful tool that could offer important insights into whether specific deprivation trajectories increase the risk of CVD. To account for any existing selection effects and establish a cohort of similar risks, excluding those participants in poor health at the start of the study period is common practice (Boyle, 2004; Darlington-Pollock et al., 2016; Exeter et al., 2015; Norman et al.,

2005). Following Darlington-Pollock et al.'s (2017) approach to establishing directional effects, we compare the risk of CVD for those who move prior to their first CVD event with risk of CVD for those who do not move prior to their first CVD event.

### Data and methods

A cohort of participants was identified using an encrypted unique health identifier assigned to the majority of NZ residents enrolled in any Primary Health Organisation (PHO). These identifiers were used to link patient records in four national routine health databases: Enrolment with a Primary Health Organisation (PHO), hospital discharges, mortality records and pharmaceutical dispensing claims from community pharmacies. The cohort and sample have been described in detail elsewhere (Darlington-Pollock et al., 2016). Figure 1 details the selection of the analytic sample. Participants were eligible for inclusion in this analysis if they were enrolled in any PHO within NZ during at least 1 of 34 calendar quarters between 1<sup>st</sup> January 2006 to 30<sup>th</sup> June 2014, were aged between 30 and 84 years (inclusive) at the start of the study period. The cohort was censored such that people who had a CVD event and then moved were counted as stayers up to the event. Participants with a prior history of CVD at 1<sup>st</sup> January 2006, or prior to joining the cohort thereafter, were also excluded from the analysis. Those who were missing any address information were removed from the sample, leaving an analytic sample of 2,418,397 individuals.

### Ethics

Ethical approval for this study was first granted by the Multi-Region Ethics Committee in 2011 (ref: MEC/11/EXP/078) with subsequent approvals from the Health and Disabilities Ethics Committee.

## Measures

### Cardiovascular Events

First major CVD event was defined by ICD-10-AM codes as a hospitalisation or death from: ischaemic heart disease; ischaemic or haemorrhagic cerebrovascular events, transient ischaemic attacks; peripheral vascular disease, congestive heart failure, other atherosclerotic CVD deaths.(Wells et al., 2015). For ICD-10-AM codes see appendix 1. Of the analytic sample, 6.93% had their first CVD event during the 34 calendar quarters observed.

## Demographic measures

Age in years was treated as a continuous variable ranging from 30 to 84 (mean=49.08, SD=13.40). Patient's self-identified ethnicity was prioritised according to national protocols to ensure each individual was assigned to one ethnic group. This study reports results by ethnicity for Māori (8.73%, Pacific (4.98%), Indian (2.49%), Other Asian (5.87%) and New Zealand European and All Other Ethnic groups combined (NZEO 77.93%). We distinguished between Indian and other Asian ethnic groups as Indian participants are known to have a higher risk of CVD (Ministry of Health, 2015).

#### Geographical measures

We used Meshblock codes from the PHO enrolment database to identify the location of a patient in each calendar quarter. Census Meshblocks are geographical units that consist of an average population of approximately 100 persons. This is the lowest level of geography available with census data in New Zealand. We used the New Zealand Index of Deprivation (NZDep2006) to measure socioeconomic deprivation at the Meshblock level (Atkinson et al., 2014). NZDep2006 combines nine variables representing eight dimensions of deprivation using principal components analysis, and deprivation scores for each Meshblock were categorised into quintiles whereby Quintile 1 (Q1) represents the least deprived 20% of areas in NZ, and Quintile 5 (Q5) the 20% most deprived. Note that the 2011 Census was postponed until 2013 due to devastating earthquakes, and therefore NZDep2013 was not released until the very end of our study period, hence NZDep2006 has been used throughout. Note that quintiles of area deprivation linked to individual records are available for research purposes rather than the original continuous scores.

#### Mobility

We defined three major residential-deprivation mobility groups: those who moved between deprivation quintiles ('movers': n=949,537)), those who moved within the same deprivation quintiles ('churners': n=256,179)), and those who did not move ('stayers': n=1,212,681). Only moves prior to CVD events were included in the analysis. Movers and churners were those individuals with at least two unique Meshblock values during the 34 calendar quarters (27% of the sample had one move recorded, 12.6% had two moves recorded, 5.6% had three moves recorded and 4.6% had 4 or more moves (up to 20 meshblock values) recorded). Churners were assigned the relevant deprivation quintile: Quintile 1 (n=74,560), Quintile 2 (n=42,635), Quintile 3 (n=36,444), Quintile 4 (n=39,548), Quintile 5 (n=62,992). Stayers were also assigned the deprivation level of the Meshblock they resided in: Quintile 1 (n=289,357), Quintile 2 (n=262,831), Quintile 3(n=241,346), Quintile 4 (n=223,593), Quintile 5 (n=195,554).

### Observational time period

We calculated each participant's observed duration in the study as the number of calendar quarters from first enrolment in a PHO to the calendar quarter of first CVD event, or the entire period of enrolment in any PHO if no CVD event occurred (mean observed time [calendar quarters]=26.24, SD=9.98, min=1, max=34). This measure was created to account for the censoring of the data, acknowledging that a longer observation period, and thus a greater opportunity to observe mobility,

would be associated with a lower risk of CVD. Furthermore, a differential number of quarters was observed for participants due to variations in entry time or loss to follow up.

### Analysis

<u>Step 1:</u> We used the STATA plug in 'traj' (Jones and Nagin, 2013) to perform trajectory analysis on the movers (Jones and Nagin, 2007; Jones et al., 2001). This procedure groups individuals who follow similar trajectories across deprivation quintiles in the observed time period. Movers were assigned to trajectory groups based on probability of group membership. Following the example of Jones et al. (2001), we used the change in BIC values between models to determine the optimal number of trajectory groups (Jones et al., 2001). In addition to BIC values, we assessed the model's adequacy according to the following criteria, : 1) a close correspondence between the estimated probability of group membership and the proportion assigned to that group based on the probability of group membership; 2) ensuring that the average of the probabilities of group membership for individuals assigned to each group exceeds a minimum threshold of 0.7; and 3) observing reasonably tight confidence intervals around estimated group membership probabilities (Nagin, 2005).

We started with a single group model, and intended to continue to test solutions until there was no longer a change in BIC value. The Centre for E-research at the University of Auckland provided us with additional computing power for a period of time, in which we were able to test cubic solutions (these were not possible with the sample size on our standard work computers). Linear models, quadratic and cubic solutions were tested for each solution. Likelihood ratio tests were used to compare quadratic to linear models and cubic to quadratic models. For the trajectory analysis, missing data were handled using a Maximum Likelihood (ML) algorithm, which does not fill in the missing values, but uses each case's available data to compute the parameter most likely to have resulted in the observed data (Enders and Bandalos, 2001). Simulation studies show that Maximum Likelihood and Multiple Imputation perform equally well under a range of conditions (Newman, 2003). Here we use Maximum Likelihood, as this is the most efficient and robust technique for estimating trajectory membership.

<u>Step 2</u>: We used a Cox proportional hazard model to examine the relationship between mobility and the risk of CVD event (model 1), and between residential-deprivation mobility groups (trajectory groups for movers, deprivation quintiles for churners and stayers) and risk of CVD event (model 2). We present the results as hazard ratios in tables. Stayers in deprivation quintile 1 (least deprived) were the reference category. We adjusted models for age, age squared, sex, ethnicity, number of

quarters observed (prior to event), and number of moves. We tested higher order polynomials of age (age squared, and age cubed) to account for a nonlinear relationship between age and CVD, age squared was included in the models. We tested interactions between age (and age squared) and residential-deprivation mobility groups. Following significant interactions, results were presented stratified by age groups.

Comparisons between the trajectory analysis approach and taking the first and last observation are presented in appendix 3.

# Results

# Trajectory analysis

There were 949,537 movers eligible for trajectory analysis. A six grouping trajectory was chosen as the best fit, based on BIC values (see appendix 2), the statistical stability of the model, and greater adherence to the criteria for optimal groups. Descriptive names were assigned to each trajectory:

- Trajectory 1 (T1): moves out of least deprived areas
- Trajectory 2 (T2): moves into least deprived areas
- Trajectory 3 (T3): moves from mid into less deprived areas
- Trajectory 4 (T4): moves from mid into more deprived areas
- Trajectory 5 (T5): moves out of most deprived areas
- Trajectory 6 (T6): moves into most deprived areas

There were 16 distinct residential-deprivation mobility groups: 6 trajectories for the movers, 5 deprivation quintiles for the churners, and 5 deprivation quintiles for the stayers.

The estimated trajectories are shown in figure 2. All estimated trajectories were monotonic. An excerpt of the trajectory results are shown in table 1. Individuals are assigned to trajectory groups based on the highest probability of group membership. On average, individuals within trajectory groups had an average probability of >0.94 of being assigned to that trajectory group. For a small number of individuals (0.5%), the probability of being in any trajectory group was <0.5. These individuals had larger amounts of missing data on average (mean number of observed quarters = 9.21). Those movers with no missing information, tended to have more complicated deprivation trajectories such as: highest-, lowest-, highest-, lowest- and mid-levels of deprivation.

As shown in table 1, case 9 represents an example of where taking first and last observation (first=4, last=5) may not provide an accurate summary of experienced deprivation. Further investigation, shown in Appendix 3, demonstrates that taking information from the first and last observation could result in 157,595 (6.5%) individuals being misclassified as remaining within the same deprivation

quintile. A further 109,505 (4.5%) could be classified as moving into areas of increased deprivation, when trajectory analysis suggests decreased deprivation, or classified as moving into decreased deprivation when the trajectory analysis suggests increased deprivation.

### Cox proportional hazards regression

Table 2 shows the results of the logistic regression modelling the odds of a participant in the sample having their first CVD event. The greater the number of quarters observed (up to event for those who have CVD event), the lower the risk of a CVD event (HR=0.88 (0.88-0.88)). Prior to adjustment for mobility groups (model 1) an increasing number of moves resulted in decreased odds of a CVD event (HR=0.80(0.79-0.80)). However, after adjustment for the differential deprivation profiles of these move events (model 2) there was no association between number of moves and odds of a CVD event (HR=0.99 (0.99-1.00).

The results (model 2) show a lower risk of having a CVD event for all movers compared to stayers in the least deprived areas, with the exception of one trajectory group: Those moving into the most deprived areas (T6: HR=0.99 (0.95-1.02)). Churners in NZDep quintiles 1 through 4 had a lower risk of a CVD event than stayers in the least deprived quintile (Churners Q1: HR=0.59 (0.56-0.62), Q2: HR=0.72 (0.69-0.76) Q3: HR=0.80 (0.76-0.84), Q4: HR=0.92 (0.88-0.96). Churners in NZDep quintile 5 had an increased risk of a CVD event compared to stayers in the least deprived quintile (HR=1.16 (1.12-1.20)), but the risks were much lower than for stayers in the most deprived quintile (HR=1.54 (1.51-1.57)).

## Age interactions

First we tested the interaction of age and residential-deprivation mobility group ( $X^2(15)=2761.01$ , p<0.01), and then the interactions between age ( $X^2(15)=48.44$ , p<0.01), age squared ( $X^2(15)=59.66$ , p<0.01), and residential-deprivation mobility groups. Table 3 presents the model stratified by age groups: 30-39, 40-49, 50-59, 60-69, 70-84.

For the youngest age group (30-39) residential deprivation had a larger impact on the relative risk of CVD event than for older age groups. Moving out of low deprivation (T1: HR=0.78(0.65 – 0.95)) was associated with a lower risk of CVD than staying in low deprivation areas. There was no significant difference in risk between moving out of low dep (T2: HR= 1.09 (0.92-1.29)), or moving in and out of mid deprivation (T3: HR=1.15(0.99-1.32), T4: HR=1.11(0.96-1.28)), and a large increase in risk for those moving into and out of areas of high deprivation (T5: HR=1.69(1.48-1.93), T6: HR=1.69 (1.46-

1.96)). Those staying in the most deprived quintile had over the twice the risk of CVD than those staying in the least deprived quintile (Stayer Q5: HR=2.65 (2.34-2.99)).

By contrast, among the oldest age group (70-84) any form of movement trajectory is associated with a decreased risk of CVD compared to staying in the least deprived quintile (T1: HR=0.55 (0.51-0.59), T2: HR=0.67 (0.62-0.73) T3: HR=0.76 (0.72-0.81) T4: HR=0.76 (0.71-0.80) T5: HR=0.70 (0.66-0.75) T6:HR=0.82 (0.76-0.88)). Similarly, churning within any deprivation quintile showed a similar trend (churning Q1: HR=0.64 (0.59-0.69) Q2: HR=0.75(0.69-0.81) Q3: HR=0.70(0.64-0.76) Q4: HR=0.79(0.73-0.86) Q5: HR=0.89 (0.83-0.96)). Staying in the most deprived quintile (stayer Q5: HR=1.21 (1.1-1.24)) was associated with an increase in CVD risk, but this relative difference is much larger for younger age groups

The risk of CVD is much lower in the younger age groups and so relative differences in CVD risk by residential-deprivation mobility group may not translate into absolute differences. Figure 2 presents a graph from the interaction model for three ages, 30, 50 and 70 demonstrating the predicted probability of having an event across the observation period holding all covariates at their observed values. The deprivation gradients appear much stronger for the older age groups, because the difference in the absolute risk is larger, but the relative differences are larger in the younger age groups.

### Discussion

To our knowledge, this is the first use of trajectory analyses to model residential mobility in a health geography context, and the first analysis performed on more than 2 million participants. We found this method produced different classification of individual's deprivation trajectories than taking the first and last observation. We found six mobility groups with distinct patterns of movement between deprivation quintiles. Our main findings were that movers had a lower risk of CVD than stayers. The deprivation characteristics of the move have a larger impact on the relative risk of CVD for younger movers than for older movers. For older movers any move, even to higher deprivation, is associated with a decreased risk of CVD. For movers, churners or stayers there was evidence for a deprivation gradient in CVD risk.

Our findings provide support of the healthy migrant hypothesis: those who move are generally healthier than those who they leave behind (Bentham, 1988; Boyle, 2004; Boyle et al., 1998; Norman et al., 2005). Among older participants any move, even to a more deprived area, was associated with

a decreased risk of CVD event. For younger participants the risk of a CVD event was lower for churners and movers in areas of low deprivation than for stayers' in areas of low deprivation. The healthy migrant effect was also apparent among movers in areas of high deprivation, who had lower odds of a CVD event than stayers in areas of high deprivation.

Reasons for moving vary markedly between high and low mobility groups (DeLuca et al., 2011). Highly mobile populations tend to move across shorter distances, be those in poverty, renters, often experiencing 'involuntary' or 'forced' mobility in response to external forces such as increased rent and housing costs, eviction, and poor housing quality (DeLuca et al., 2011). Higher mobility is therefore more commonly associated with people living in lower socioeconomic circumstances, who are also more likely associated with poorer health. Less frequent movers on the other hand comprise a mixture of renters (often young professionals) and home owners who typically move longer distances, and to improve their situation, such as moving closer to work or to a larger house (Böheim and Taylor, 2002; DeLuca et al., 2011; Morrison and Nissen, 2010). The more socioeconomically advantaged circumstances of groups with higher mobility may explain the unadjusted protective effect of mobility against CVD. However, accounting for the deprivation profile of the move fully accounts for the protective effect of mobility.

The relationship between residential mobility and health is complex, with both the move itself and the area deprivation trajectory of the move being important in respect of health. We found deprivation gradients existed for CVD risk for both movers and stayers. These deprivation gradients may be exacerbated through the influence of selective migration: as healthy people leave deprived areas, unhealthy people move in (Norman et al., 2005). This likely interacts with the existing influence of place on individual health (Stafford and Marmot, 2003), whether through shaping uptake of different health behaviours, by access to local services or even features of the social environment such as the existence of support networks (Bécares et al., 2013).

Indeed, a recent analysis of the causal effect of area-level deprivation on health found health differentials were driven by differential mobility patterns by health, rather than neighbourhood deprivation per se (Jokela, 2015). However, these data do not capture reason for the move or record wider experiences of the social environment or socioeconomic attributes. These unrecorded factors may be important in exploring risk of CVD between movers and stayers. More work is needed to examine whether the consequences for health from place-effects and selective migration varies

between sub-groups in society, e.g. ethnic groups, depending on aspects such as socioeconomic position and history within a country.

### Implications for research/practice

Trajectory modelling resulted in different categorisations of individuals into residential deprivation mobility groups than did taking the first and last observation (appendix 3). However, because of the large sample size, fitting trajectory models was not straightforward. For example, processing time for the chosen quadratic solution with 6 groups was in excess of 3 days. More complex models (higher number of groups, or higher order polynomials) took longer, or did not converge at all. While the trajectory models take advantage of all of the longitudinal deprivation information available, the aim of the analysis is still to provide the simplest model possible to group observations into a smaller number of groups. Trajectory analysis is a flexible approach and can account for nonlinear and nonmonotonic changes over time, however our solution suggested six monotonic trajectory groups. Therefore people with complicated deprivation trajectories, or who move frequently, may not be well accounted for. Indeed, we found lower probabilities of assignment to trajectory groups for those with large amounts of missing information, or for those with complex deprivation trajectories. Where people have non-monotonic trajectories, the trajectory model is most likely to select a trajectory group based on the deprivation quintiles in which the individual spent the most amount of quarters. Consider, a person who lives in a most deprived (i.e. highest deprivation quintile) area for the first 10 quarters, and then moves to the an area of average deprivation for the next 20 quarters, and moves again in the last 4 quarters to the highest deprivation quintile. According to these analyses, they would have a very high probability of being in trajectory group 5 (from most deprived to lower deprivation), and a very low probability of being in trajectory group 6 (from lower deprivation to most deprived areas).

Selecting the appropriate trajectory model has been described by some as an "art" (Ram and Grimm, 2009). It is possible in trajectory modelling to end up with a number of groups that is too large to be practically useful, with the BIC value still decreasing. Therefore some authors suggest model testing and selection should be firmly based on previous research and theory, with researchers hypothesising the number of trajectory groups a-priori, and then testing solutions with +/- 1-2 groups from this hypothesised solution (Ram and Grimm, 2009). In this way, trajectory analysis has potential to test and improve upon theories. This hypothesis-driven method would have been an efficient way to conduct the analysis, as the trajectory group's estimated by the model in this study are similar to those that would have been hypothesised by the authors.

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### Strengths and limitations

We used a longitudinal set of linked anonymised records covering 94% of NZ's adult population. This provided us with adequate statistical power to assess the relationship between residential mobility and CVD event by residential-deprivation mobility groups. These data also allowed us to take account of the ordering of residential moves and CVD events.

There are several limitations to this research: firstly, we only observe individuals across a given time period, we do not know their prior deprivation, health or migration histories, only that they have never had a CVD event. Secondly, we focus on area level deprivation, but there are many other important predictors of CVD that are not included in this modelling, such as smoking, stress and other lifestyle factors. Thirdly due to data availability, we only use one time point to capture area deprivation though we recognise that areas may change their relative level of deprivation over time (Norman, 2010; Norman and Darlington-Pollock, 2017) in part due to the selective migration of people with particular characteristics. Fourthly, and as already discussed, we do not know the housing tenure or reasons for moving. Given these key mechanisms are likely driving the relationship between mobility and CVD risk, further research is required.

Finally, the meshblock information used to measure residential mobility were obtained from the quarterly Primary Health Organisation (PHO) enrolment data. Unfortunately, information regarding how often a patient is asked about their address is not collected in the national collections by the Ministry of Health. While the last consultation date could be used to determine whether the patient was seen during a particular calendar quarter, there is no information available regarding their move date, or when their address information was updated in the PHO registers (Personal communication, Chris Lewis, Ministry of Health 05/04/2018).

#### Conclusion

Trajectory analysis provides a novel and useful way to group, and incorporate repeated measures of area level deprivation into analytic models, where the results are potentially more accurate than taking the first and last observation. However, trajectory models are computationally intensive and can be difficult to implement in large data sets. The deprivation characteristics of the move have a larger impact on the relative risk of CVD for younger movers than for older movers.

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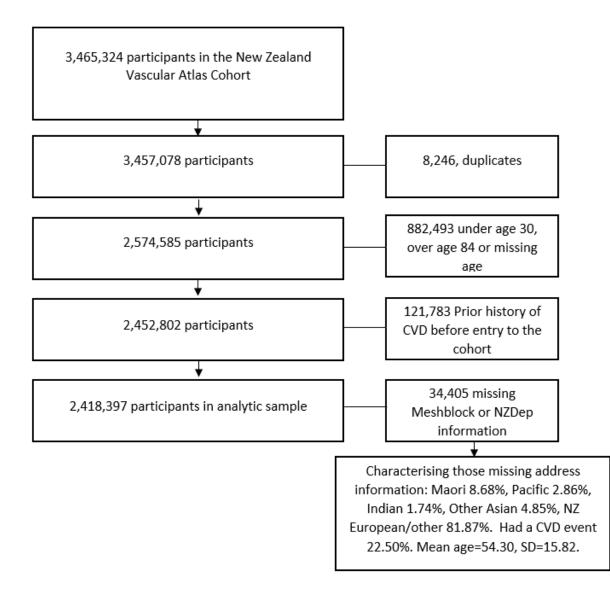
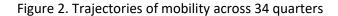
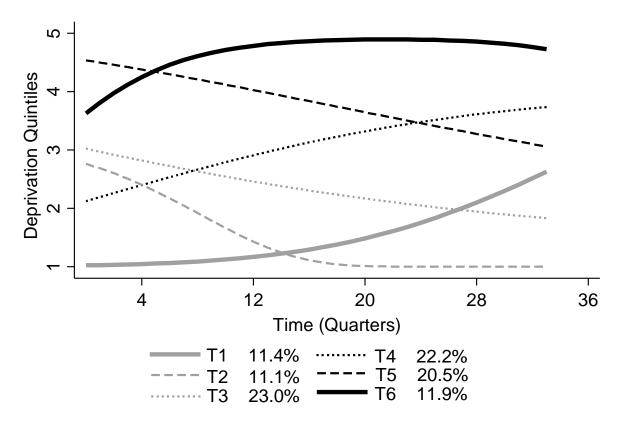


Figure 1. Flowchart describing inclusion criteria for the analytic sample





T1: move from least deprived quintile to higher deprivation,

T2: move from mid deprivation to least deprived areas,

T3: move from mid deprivation to less deprived area,

T4: move from lower mid deprivation to higher deprivation,

T5: move from most deprived to lower deprivation,

*T6: move from lower deprivation into most deprived areas.* 

Table 1. Example of trajectory analysis output.

	assigned		Probability of group assignment					
	Deprivation quintile across 34 quarters	group	T1	T2	Т3	T4	T5	T6
1	55555553333333333333333333333333333333	5	0.00	0.00	0.00	0.00	1.00	0.00
2	113333333333333333333333333333333	4	0.00	0.00	0.00	1.00	0.00	0.00
3	5555555555555555553333333333333333	5	0.00	0.00	0.00	0.00	1.00	0.00
4	3311111111111111111111111111111111111	3	0.00	0.00	1.00	0.00	0.00	0.00
5	33333333331111111144444444444444	4	0.00	0.00	0.00	1.00	0.00	0.00
6	4411111111111	3	0.15	0.00	0.85	0.00	0.00	0.00
7		2	0.07	0.92	0.00	0.00	0.01	0.00
8	222222222222333331222222222221111	2	0.00	1.00	0.00	0.00	0.00	0.00
9	44444444433333332333335	5	0.00	0.00	0.00	0.03	0.97	0.00
10	4444444554255555333333333333333333	5	0.00	0.00	0.00	0.00	1.00	0.00

*Note:* 1= *lowest deprivation quintile and* 5=*lowest deprivation quintile. The "." denotes a missing value for deprivation in that quarter.* 

*T1: move from least deprived quintile to higher deprivation,* 

T2: move from mid deprivation to least deprived areas,

T3: move from mid deprivation to less deprived area,

T4: move from lower mid deprivation to higher deprivation,

T5: move from most deprived to lower deprivation,

*T6: move from lower deprivation into most deprived areas.* 

Table 2. Cox proportional hazards model of the relationship between trajectory mobility groups and risk of CVD event

	Model 1	Model 2
Number of moves	0.80	0.99
	[0.79 -0.80]	[0.98 - 1.00]
quarters observed	0.88	0.88
	[0.88 - 0.88]	[0.88 - 0.88]
Mover T1: from least deprived quintile to higher deprivation		0.55
		[0.53 - 0.57]
Mover T2: from mid deprivation to least deprived areas		0.75
		[0.72 - 0.78]
Mover T3: from mid deprivation to less deprived area		0.77
		[0.75 - 0.80]
Mover T4: from lower mid deprivation to higher deprivation		0.78
		[0.76 – 0.80]
Mover T5: from most deprived to lower deprivation		0.89
		[0.86 – 0.92]
Mover T6: from lower deprivation into most deprived area		0.99
		[0.95 - 1.02]
Churner Q1 (least deprived)		0.59
		[0.56 - 0.62]
Churner Q2		0.72
		[0.69 - 0.76]
Churner Q3		0.80
		[0.76 - 0.84]
Churner Q4		0.92
		[0.88 – 0.96]
Churner Q5 (most deprived)		1.16
(taura 01 (laget densities d))		[1.12 - 1.20]
Stayer Q1 (least deprived)		ref
Stayer Q2		1.12
		[1.10 - 1.14]
Stayer Q3		1.29
		[1.26 - 1.31]
Stayer Q4		1.47
		[1.44 - 1.50]
Stayer Q5 (most deprived)		1.54
, · · · · · /		[1.51 - 1.57]
Log likelihood	-2157076.6	-2153802.9
N	2,400,904	2,400,904

Model 1 considers the relationship between number of moves observed and odds of a CVD event, Model 2 considers mobility groups (trajectory groups, churners, and stayers).

Models also adjusted for age, age squared, gender, and ethnicity.

n=17349 are only observed for one time period and are excluded from the model

Trajectory analysis conducted on Movers (those who move to a different deprivation quintile)

	30-39	40-49	50-59	60-69	70-84
Number of moves	1.04	1.01	1.00	0.96	0.83
	(1.02 - 1.07)	(0.99 - 1.03)	(0.98 - 1.02)	(0.93 - 0.98)	(0.81 - 0.86)
quarters observed	0.87	0.87	0.88	0.88	0.88
	(0.87 - 0.87)	(0.87 - 0.87)	(0.88 - 0.88)	(0.88 - 0.88)	(0.88 - 0.88)
Mover T1: from least deprived quintile to higher deprivation	0.78	0.66	0.66	0.63	0.55
	(0.65 - 0.95)	(0.59 - 0.75)	(0.60 - 0.71)	(0.58 - 0.69)	(0.51 - 0.59)
Mover T2: from mid deprivation to least deprived areas	1.09	0.99	0.95	0.89	0.67
	(0.92 - 1.29)	(0.89 - 1.10)	(0.88 - 1.03)	(0.82 - 0.96)	(0.62 - 0.73)
Mover T3: from mid deprivation to less deprived area	1.15	1.11	0.90	0.84	0.76
	(0.99 - 1.32)	(1.02 - 1.21)	(0.84 - 0.97)	(0.79 - 0.90)	(0.72 - 0.81)
Mover T4: from lower mid deprivation to higher deprivation	1.11	1.07	0.90	0.90	0.76
	(0.96 - 1.28)	(0.99 - 1.16)	(0.84 - 0.96)	(0.85 - 0.96)	(0.71 - 0.80)
Mover T5: from most deprived to lower deprivation	1.69	1.40	1.13	0.95	0.70
	(1.48 - 1.93)	(1.30 - 1.51)	(1.06 - 1.21)	(0.90 - 1.02)	(0.66 - 0.75)
Mover T6: from lower deprivation into most deprived area	1.69	1.41	1.26	1.09	0.82
	(1.46 - 1.96)	(1.29 - 1.54)	(1.17 - 1.36)	(1.01 - 1.17)	(0.76 - 0.88)
Churner Q1 (least deprived)	0.68	0.72	0.67	0.63	0.64
	(0.54 - 0.86)	(0.63 - 0.81)	(0.61 - 0.74)	(0.57 - 0.69)	(0.59 - 0.69)
Churner Q2	1.12	0.92	0.84	0.71	0.75
	(0.90 - 1.40)	(0.80 - 1.05)	(0.75 - 0.94)	(0.64 - 0.80)	(0.69 - 0.81)
Churner Q3	1.06	1.19	1.01	0.92	0.70
	(0.83 - 1.35)	(1.03 - 1.37)	(0.90 - 1.14)	(0.83 - 1.02)	(0.64 - 0.76)
Churner Q4	1.55	1.32	1.16	1.04	0.79
	(1.28 - 1.89)	(1.17 - 1.49)	(1.05 - 1.28)	(0.95 - 1.14)	(0.73 - 0.86)
Churner Q5 (most deprived)	2.13 (1.84 - 2.46)	1.74	1.46	1.13	0.89
Stayer Q1 (least deprived)	(1.84 - 2.46) ref	(1.60 - 1.90) ref	(1.35 - 1.57) ref	(1.04 - 1.22) ref	(0.83 - 0.96) ref
Stayer QI (least deprived)	rei	Ter	Tel	Ter	Ter
Stayer Q2	1.24	1.14	1.17	1.14	1.06
Stayer Q2	(1.08 - 1.41)	(1.07 - 1.22)	(1.12 - 1.22)	(1.10 - 1.18)	(1.04 - 1.09)
Stayer Q3	1.69	1.37	1.36	1.37	1.13
	(1.48 - 1.92)	(1.29 - 1.46)	(1.31 - 1.43)	(1.33 - 1.42)	(1.10 - 1.17)
Stayer Q4	2.15	1.82	1.69	1.55	1.23
,	(1.89 - 2.43)	(1.71 - 1.93)	(1.62 - 1.77)	(1.49 - 1.60)	(1.20 - 1.27)
Stayer Q5 (most deprived)	2.65	2.23	1.97	1.58	1.21
	(2.34 - 2.99)	(2.10 - 2.37)	(1.88 - 2.05)	(1.53 - 1.64)	(1.17 - 1.24)
Loglikelihood	-80,663.07	-229,047.52	-379,885.80	-479,790.64	-746,293.78
N	700,724	660,959	501,218	309,674	228,329

Table 3. Cox proportional hazards model of the relationship between trajectory mobility groups and risk of CVD event stratified by age group.

Models also adjusted for age, age squared, gender, and ethnicity.

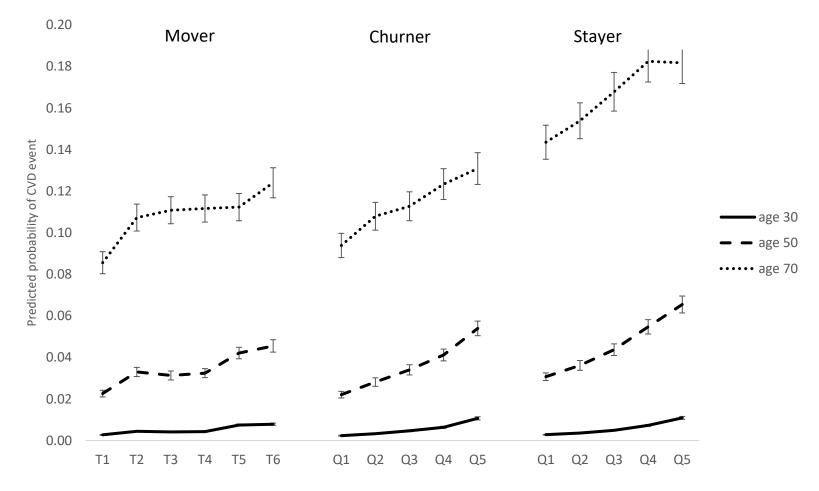


Figure 3. Predicted probability of having a CVD event by age and residential-deprivation mobility group. Error bars represent 95% confidence Intervals.

T1: move from least deprived quintile to higher deprivation, T2: move from mid deprivation to least deprived areas, T3: move from mid deprivation to less deprived area, T4: move from lower mid deprivation to higher deprivation, T5: move from most deprived to lower deprivation, T6: move from lower deprivation into most deprived areas. Q1 = least deprived quintile, and Q5 = most deprived quintile.

# Appendix 1: ICD-10-AM codes for defining CVD events

Supplementary table 1 provides the ICD-10-AM codes used to define first major CVD event in this research paper. It relates to a broad definition of CVD events. Prior history of CVD events was defined using the same set of codes with the exception of code I461, referring to sudden cardiac death.

Supplementary table 1. Definition of first CVD event

Clinical Code	Description	
1210	Acute transmural myocardial infarction of anterior wall	
1211	Acute transmural myocardial infarction of inferior wall	
1212	Acute transmural myocardial infarction of other sites	
1213	Acute transmural myocardial infarction of unspecified site	
1214	Acute subendocardial myocardial infarction	
1219	Acute myocardial infarction, unspecified	
1220	Subsequent myocardial infarction of anterior wall	
1221	Subsequent myocardial infarction of inferior wall	
1228	Subsequent myocardial infarction of other sites	
1229	Subsequent myocardial infarction of unspecified site	
E1050	Insulin-dependent diabetes mellitus with peripheral circulatory complications, not stated as uncontrolled	
E1051	Insulin-dependent diabetes mellitus with peripheral circulatory complications, stated as uncontrolled	
E1052		
E1059		
E1150	Non-insulin-dependent diabetes mellitus with peripheral circulatory complications, not stated as uncontrolled	
E1151	Non-insulin-dependent diabetes mellitus with peripheral circulatory complications, stated as uncontrolled	
E1152		
E1159		
E1451	Unspecified diabetes mellitus with peripheral circulatory complications, stated as uncontrolled	
E1452		
E1459		
1250	Atherosclerotic cardiovascular disease, so described	
12510	Atherosclerotic heart disease, of unspecified vessel	
12511	Atherosclerotic heart disease, of native coronary artery	
I2512	Atherosclerotic heart disease, of autologous bypass graft	
12513	Atherosclerotic heart disease, of nonautologous biological bypass graft	
1258	Other forms of chronic ischaemic heart disease	
1259	Chronic ischaemic heart disease, unspecified	
1469	Cardiac arrest, unspecified	
3270000	Carotid bypass using vein	
3270001	Carotid-carotid bypass using vein	
3270002	Carotid-subclavian bypass using vein	
3270003	Carotid-vertebral bypass using vein	

3270004Aorto-subclavian-carotid bypass using vein3270005Carotid bypass using synthetic material3270006Carotid-carotid bypass using synthetic material3270007Carotid-vertebral bypass using synthetic material3270008Carotid-subclavian bypass using synthetic material3270010Aorto-carotid bypass using synthetic material3270010Aorto-carotid-brachial bypass using synthetic material3270111Aorto-carotid-brachial bypass using synthetic material3270800Resection of carotid artery with re-anastomosis3270800Aorto-femoral bypass using synthetic material3270801Aorto-femoral bypass using synthetic material3270802Aorto-filco bypass using synthetic material3270803Aorto-ilic bypass using synthetic material3271200Illio-femoral bypass using synthetic material3271201Subclavian-femorol bypass using synthetic material3271201Subclavian-femoral bypass using synthetic material3271501Subclavian-femoral bypass using synthetic material3271502Axillo-femoral bypass using synthetic material3271503Axillo-femoral bypass using synthetic material3271504Axillo-femoral crossover bypass3273000Mesenteric bypass using synthetic material3271801Femoro-femoral crossover bypass3273000Mesenteric bypass using synthetic material, single vessel3273300Mesenteric bypass using synthetic material, multiple vessels3273300Mesenteric bypass using synthetic material, multiple vessels3273300 <th></th>	
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3274800 Femoral artery bypass using vein, within 5cm of ankle	,
3275100 Femoral artery bypass using synthetic material, above knee	
3275101 Femoral artery bypass using synthetic material, below knee	
3275102 Femoral artery bypass using synthetic material, to tibio-peroneal trunk, tibial or	
peroneal artery	
3275103 Femoral artery bypass using synthetic material, within 5 cm of ankle	
3275400 Femoro-femoral bypass using composite graft	
3275401 Femoro-popliteal bypass using composite graft	
3275402	
3275700 Femoral artery sequential bypass using vein	
3275701 Femoral artery sequential bypass using synthetic material	
3276300 Other arterial bypass using vein	
3276301 Other arterial bypass graft using synthetic material	
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3276311	
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3305000	Replacement of popliteal aneurysm using vein
3305500	Replacement of popliteal aneurysm using synthetic graft
3307500	Repair of aneurysm in neck
3308000	Repair of intra-abdominal aneurysm
3310000	Replacement of carotid artery aneurysm with graft
3311200	Replacement of suprarenal abdominal aorta aneurysm with graft
3311500	Replacement of infrarenal abdominal aortic aneurysm with tube graft
3311300	Replacement of infrarenal abdominal aortic aneurysm with bifurcation graft to iliac
5511800	arteries
3312100	Replacement of infrarenal abdominal aortic aneursym with bifurcation graft to
	femoral arteries
3312400	Replacement of iliac artery aneurysm with graft, unilateral
3312700	Replacement of iliac artery aneurysm with graft, bilateral
3313000	Excision and repair of visceral artery aneurysm with direct anastomosis
3315100	Replacement of ruptured suprarenal abdominal aortic aneurysm with graft
3315400	Replacement of ruptured infrarenal abdominal aortic aneurysm with tube graft
3315700	Replacement of ruptured infrarenal aortic aneurysm with bifurcation graft to iliac
	arteries
3316000	Replacement of ruptured infrarenal abdominal aortic aneurysm with bifurcation
	graft to femoral arteries
3316300	Replacement of ruptured iliac artery aneurysm with graft
3317800	Repair of ruptured aneurysm in neck
3318100	Repair of ruptured intra-abdominal aneurysm
3350000	Carotid endarterectomy
3350600	Innominate endarterectomy
3350601	Subclavian endarterectomy
3350900	Aorta endarterectomy
3351200	Aorto-iliac endarterectomy
3351500	Aorto-femoral endarterectomy
3351501	Ilio-femoral endarterectomy, bilateral
3351800	Iliac endarterectomy
3352100	Ilio-femoral endarterectomy, unilateral
3352400	Renal endarterectomy, unilateral
3352700	Renal endarterectomy, bilateral
3353000	Coeliac endarterectomy
3353001	Superior mesenteric endarterectomy
3353300	Coeliac and superior mesenteric endarterectomy
3353600	Inferior mesenteric endarterectomy
3353900	Endarterectomy of extremities
3354200	Extended endarterectomy of deep femoral artery
3354800	Patch graft of artery using vein
3334000	Patch graft of artery using synthetic material

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3354802	Patch graft of vein using vein		
3354803	Patch graft of vein using synthetic material		
3355100	Procurement of vein from limb for patch graft		
3355400	Endarterectomy in conjunction with arterial bypass to prepare site for anastomosis		
3530306			
3530307			
3530400	Percutaneous transluminal balloon angioplasty of 1 coronary artery		
3530401	Open transluminal balloon angioplasty of 1 coronary artery		
3530500	Percutaneous transluminal balloon angioplasty of 2 or more coronary arteries		
3530501	Open transluminal balloon angioplasty of 2 or more coronary arteries		
3530906			
3530907			
3530908			
3530909			
3531000	Percutaneous insertion of 1 transluminal stent into single coronary artery		
3531001	Percutaneous insertion of 2 or more transluminal stents into single coronary artery		
3531002	Percutaneous insertion of 2 or more transluminal stents into multiple coronary		
	arteries		
3531003	Open insertion of 1 transluminal stent into single coronary artery		
3531004	Open insertion of 2 or more transluminal stents into single coronary artery		
3531005	Open insertion of 2 or more transluminal stents into multiple coronary arteries		
3531200	Percutaneous peripheral artery atherectomy		
3531201	Open peripheral artery atherectomy		
3531500	Percutaneous peripheral laser angioplasty		
3531501	Open peripheral laser angioplasty		
3845619	Other intrathoracic procedures on arteries of heart without cardiopulmonary bypass		
3849700	Coronary artery bypass, using 1 saphenous vein graft		
3849701	Coronary artery bypass, using 2 saphenous vein grafts		
3849702	Coronary artery bypass, using 3 saphenous vein grafts		
3849703	Coronary artery bypass, using 4 or more saphenous vein grafts		
3849704	Coronary artery bypass, using 1 other venous graft		
3849705	Coronary artery bypass, using 2 other venous grafts		
3849706	Coronary artery bypass, using 3 other venous grafts		
3849707	Coronary artery bypass, using 4 or more venous grafts		
3850000	Coronary artery bypass, using 1 LIMA graft		
3850001	Coronary artery bypass, using 1 RIMA graft		
3850002	Coronary artery bypass, using 1 radial artery graft		
3850003	Coronary artery bypass, using 1 epigastric artery graft		
3850004	Coronary artery bypass, using 1 other arterial graft		
3850300	Coronary artery bypass, using 2 LIMA grafts		
3850301	Coronary artery bypass, using 2 RIMA grafts		
3850302	Coronary artery bypass, using 2 radial artery grafts		
3850303	Coronary artery bypass, using 2 epigastric artery grafts		
3850304	Coronary artery bypass, using 2 or more other arterial grafts		
3850500	Open coronary endarterectomy		
3850700	Left ventricular aneurysmectomy		
3850800	Left ventricular aneurysmectomy with patch graft		
3850900	Repair of ventricular septal rupture		
3863700	Re-operation for reconstruction of occluded coronary artery		

9020100	Coronary artery bypass, using 1 other material graft, not elsewhere classified			
9020100	Coronary artery bypass, using 2 other material grafts, not elsewhere classified			
9020102	Coronary artery bypass, using 3 other material grafts, not elsewhere classified			
9020103	Coronary artery bypass, using 4 or more other material grafts, not elsewhere			
	classified			
9022900	Other endarterectomy			
9023000	Embolectomy or thrombectomy of other artery			
G450	Vertebro-basilar artery syndrome			
G451	Carotid artery syndrome (hemispheric)			
G452	Multiple and bilateral precerebral artery syndromes			
G453	Amaurosis fugax			
G458	Other transient cerebral ischaemic attacks and related syndromes			
G459	Transient cerebral ischaemic attack, unspecified			
G460	Middle cerebral artery syndrome (I66.0+)			
G461	Anterior cerebral artery syndrome (I66.1+)			
G462	Posterior cerebral artery syndrome (I66.2+)			
G463	Brain stem stroke syndrome (I60-I67+)			
G464	Cerebellar stroke syndrome (160-167+)			
G465	Pure motor lacunar syndrome (160-167+)			
G466	Pure sensory lacunar syndrome (I60-I67+)			
G467	Other lacunar syndromes (I60-I67+)			
G468	Other vascular syndromes of brain in cerebrovascular diseases (I60-I67+)			
1110	Hypertensive heart disease with heart failure			
1130	Hypertensive heart and renal disease with both (congestive) heart failure and renal			
	failure			
1132	Hypertensive heart and renal disease with both (congestive) heart failure and renal			
1200	failure			
1200	Unstable angina			
1201	Angina pectoris with documented spasm			
1208	Other forms of angina pectoris			
1209	Angina pectoris, unspecified			
1230	Haemopericardium as current complication following acute myocardial infarction			
1231	Atrial septal defect as current complication following acute myocardial infarction			
1232	Ventricular septal defect as current complication following acute myocardial infarction			
1233	Rupture of cardiac wall without haemopericardium as current complication following			
	acute myocardial infarction			
1234	Rupture of chordae tendineae as current complication following acute myocardial infarction			
1235	Rupture of papillary muscle as current complication following acute myocardial			
1233	infarction			
1236	Thrombosis of atrium, auricular appendage, and ventricle as current complications			
	following acute myocardial infarction			
1238	Other current complications following acute myocardial infarction			
1240	Coronary thrombosis not resulting in myocardial infarction			
1248	Other forms of acute ischaemic heart disease			
1249	Acute ischaemic heart disease, unspecified			
	Old myocardial infarction			
1252				
1252 1253	Aneurysm of heart			

1255	Ischaemic cardiomyopathy
1255	Silent myocardial ischaemia
1250	Cardiac arrest with successful resuscitation
1400	Heart failure
1500	congestive heart failure
1500	Left ventricular failure
1501	Heart failure unspecified
1600	
1601	Subarachnoid haemorrhage from carotid siphon and bifurcation Subarachnoid haemorrhage from middle cerebral artery
1601	Subarachnoid haemorrhage from anterior communicating artery
1602	Subarachnoid haemorrhage from posterior communicating artery
1603	Subarachnoid haemorrhage from basilar artery
1604	
1605	Subarachnoid haemorrhage from vertebral artery
1608	Subarachnoid haemorrhage from other intracranial arteries
	Subarachnoid haemorrhage from intracranial artery, unspecified
1608	Other subarachnoid haemorrhage
1609	Subarachnoid haemorrhage, unspecified
1610	Intracerebral haemorrhage in hemisphere, subcortical
1611	Intracerebral haemorrhage in hemisphere, cortical
1612	Intracerebral haemorrhage in hemisphere, unspecified
1613	Intracerebral haemorrhage in brain stem
1614	Intracerebral haemorrhage in cerebellum
1615	Intracerebral haemorrhage, intraventricular
1616	Intracerebral haemorrhage, multiple localized
1618	Other intracerebral haemorrhage
1619	Intracerebral haemorrhage, unspecified
1630	Cerebral infarction due to thrombosis of precerebral arteries
1631	Cerebral infarction due to embolism of precerebral arteries
1632	Cerebral infarction due to unspecified occlusion or stenosis of precerebral arteries
1633	Cerebral infarction due to thrombosis of cerebral arteries
1634	Cerebral infarction due to embolism of cerebral arteries
1635	Cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries
1636	Cerebral infarction due to cerebral venous thrombosis, nonpyogenic
1638	Other cerebral infarction
1639	Cerebral infarction, unspecified
164	Stroke, not specified as haemorrhage or infarction
1650	Occlusion and stenosis of vertebral artery
1651	Occlusion and stenosis of basilar artery
1652	Occlusion and stenosis of carotid artery
1653	Occlusion and stenosis of multiple and bilateral precerebral arteries
1658	Occlusion and stenosis of other precerebral artery
1659	Occlusion and stenosis of unspecified precerebral artery
1660	Occlusion and stenosis of middle cerebral artery
1661	Occlusion and stenosis of anterior cerebral artery
1662	Occlusion and stenosis of posterior cerebral artery
1663	Occlusion and stenosis of cerebellar arteries
1664	Occlusion and stenosis of multiple and bilateral cerebral arteries
1668	Occlusion and stenosis of other cerebral artery
1669	Occlusion and stenosis of unspecified cerebral artery
1670	Dissection of cerebral arteries, nonruptured

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1672	Cerebral atherosclerosis
1690	Sequelae of subarachnoid haemorrhage
1691	Sequelae of intracerebral haemorrhage
1693	Sequelae of cerebral infarction
1694	Sequelae of stroke, not specified as haemorrhage or infarction
1698	Sequelae of other and unspecified cerebrovascular diseases
1700	Atherosclerosis of aorta
1701	Atherosclerosis of renal artery
17020	Atherosclerosis of arteries of extremities, unspecified
17021	Atherosclerosis of arteries of extremities with intermittent claudication
17022	Atherosclerosis of arteries of extremities with rest pain
17023	Atherosclerosis of arteries of extremities with ulceration
17024	Atherosclerosis of arteries of extremities with gangrene
1708	Atherosclerosis of other arteries
1709	Generalized and unspecified atherosclerosis
17100	Dissection of aorta, unspecified site
17101	Dissection of thoracic aorta
17102	Dissection of abdominal aorta
17103	Dissection of thoracoabdominal aorta
1711	Thoracic aortic aneurysm, ruptured
1713	Abdominal aortic aneurysm, ruptured
1714	Abdominal aortic aneurysm, without mention of rupture
1715	Thoracoabdominal aortic aneurysm, ruptured
1718	Aortic aneurysm of unspecified site, ruptured
1739	Peripheral vascular disease, unspecified
1740	Embolism and thrombosis of abdominal aorta
1741	Embolism and thrombosis of other and unspecified parts of aorta
1742	Embolism and thrombosis of arteries of upper extremities
1743	Embolism and thrombosis of arteries of lower extremities
1744	Embolism and thrombosis of arteries of extremities, unspecified
1745	Embolism and thrombosis of iliac artery
1748	Embolism and thrombosis of other arteries
1749	Embolism and thrombosis of unspecified artery
Z951	Presence of aortocoronary bypass graft
Z955	Presence of coronary angioplasty implant and graft
Z958	Presence of other cardiac and vascular implants and grafts
Z959	Presence of cardiac and vascular implant and graft, unspecified
1461	Sudden cardiac death, so described

Appendix 2: Model fit for trajectory analysis.

Number of groups	BIC	ΔBIC
2	-40224001	
3	-37524013	-2699988
4	-36049005	-1475008
5	-34975401	-1073605
6	-33880744	-1094657
7 <sup>a</sup>	-33362004	-518740

<sup>a</sup> variance matrix is nonsymmetric or highly singular suggesting insufficient portioning of the variance between groups.

### Appendix 3: Comparison of first and last observation and trajectory analysis

Supplementary table 3 shows the deprivation quintiles of the first and last observations. By using this information in addition to whether they recorded a move over the period we classified individuals with varying levels of detail into movers and stayers and compared this with the results of trajectory analysis.

	Last observed deprivation quintile								
First observed deprivation									
quintile	1	2	3	4	5	Total			
1	396,659	57,709	41,031	28,514	13,764	537,677			
2	67 <i>,</i> 536	336,148	48,068	36,809	20,488	509,049			
3	50,969	51,827	307,597	45,372	28,881	484,646			
4	36,928	41,169	48,073	295,194	45,609	466,973			
5	19,602	25,369	33,348	50,876	290,857	420,052			
Total	571,694	512,222	478,117	456,765	399,599	2,418,397			

Supplementary table 3: First and last observed deprivation quintile.

The simplest classification was: stays in Quintile 1, stays in Quintile 2, stays in Quintile 3, stays in Quintile 4, stays in Quintile 5, increasing dep, and decreasing dep. The most detailed version would be to use an indicator of whether they moved. The most detailed classification included information on whether they moved during the period and classified individuals into 16 groups: Stayers Q1-Q5 (5 groups), churners Q1-Q5 (5 groups), increasing deprivation by 1 quintile, increasing deprivation by 2 quintiles, increasing deprivation by 3/4 quintiles, decreasing deprivation by 1 quintile, decreasing deprivation by 2/4 quintiles.

A comparison of the simplest classification with the mobility trajectory groups used in the paper is shown in supplementary table 4. In total 157,595 would be classified as staying in Q1-Q5 when they actually changed deprivation quintiles over the course of the observation period. A further 109,505

would be classified as moving into areas of increased deprivation, when the trajectory analysis suggests decreased deprivation, or classified as moving into decreased deprivation when the trajectory analysis suggests increased deprivation. If we didn't account for churning, A total of 256,179 people would be classified as staying in Q1-Q5 when they actually churned in Q1-Q5. Taking account of the churners is important as they differ from the stayers in terms of their relative risks for health outcomes. This is fairly easy to account for if we look at the minimum and maximum deprivation score observed across the period and count people as churners where they move, and the deprivation quintile does not change.

A comparison of the detailed classification with the mobility trajectory groups used in the paper is shown in supplementary table 5. In this more detailed classification 157,595 are incorrectly classified as churners based on first and last observation of deprivation. These people change deprivation score over the course of the observation period, but the first and last observed deprivation quintiles are the same. The magnitude of the change in deprivation based on first and last quintile is captured. There is a substantial amount of disagreement between first and last observation classifications of deprivation-mobility and trajectory groupings of deprivation-mobility.

Trajectory		Circu I	t first and l		: <b>f</b> : :	_		
groupings	Simplest first and last observation classification							
	Stayer Q1	Stayer Q2	Stayer Q3	Stayer Q4	Stayer Q5	Increasing deprivation	Decreasing deprivation	Total
(T1): moves out of								
least deprived areas	12,879	2,687	753	277	48	87,293	4,096	108,03
(T2): moves into least	-							
deprived areas	12,599	197	51	4	4	145	92,256	105,25
(T3): moves from mid	-							
into less deprived								
areas	5,169	21,758	7,902	2,753	492	37,141	142,349	217,56
(T4): moves from mid								
into more deprived								
areas	1,753	4,811	16,193	7,064	1,402	158,668	21,221	211,11
(T5): moves out of	-							
most deprived areas	254	932	4,056	18,387	9,300	21,346	140,219	194,49
moves into most								
deprived areas	88	297	852	3,568	21,065	61,652	25,556	113,07
Churner Q1	74,560	0	0	0	0	0	0	74,56
Churner Q2	0	42,635	0	0	0	0	0	42,63
Churner Q3	0	0	36,444	0	0	0	0	36,44
Churner Q4	0	0	0	39,548	0	0	0	39,54
Churner Q5	0	0	0	0	62,992	0	0	62,99
Stayer Q1	289,357	0	0	0	0	0	0	289,35
Stayer Q2	0	262,831	0	0	0	0	0	262,83
Stayer Q3	0	0	241,346	0	0	0	0	241,34
Stayer Q4	0	0	0	223,593	0	0	0	223,59
Stayer Q5	0	0	0	0	195,554	0	0	195,55
Total	396,659	336,148	307,597	295,194	290,857	366,245	425,697	2,418,39

Supplementary table 4. Comparison of mobility groups based on trajectory analysis and simple classification of first and last observation

Trajectory											
groupings				lost detai	led classi	fication fro	m first and	last obser	vation		
	Churner					Mover					
	Q1	Q2	Q3	Q4	Q5	Increase	Increase	Increase	Decrease	Decrease	Decrease
	QI	QZ	43	4	45	+1	+2	+3	-1	-2	-3
(T1): moves out											
of least deprived											
areas	12,879	2,687	753	277	48	45,512	24,263	17,518	2,659	1,035	402
(T2): moves into											
least deprived	12,599	197	51	4	4	125	19	1	40,399	26,745	25,112
areas											
(T3): moves from											
mid into less											
deprived areas	5,169	21,758	7,902	2,753	492	28,429	6,922	1,790	72,865	47,244	22,240
(T4): moves from											
mid into more	1,753	4,811	16,193	7,064	1,402	72,276	56,102	30,290	16,549	4,183	489
deprived areas											
(T5): moves out											
of most deprived											
areas	254	932	4,056	18,387	9,300	17,189	3,258	899	70,877	40,331	29,011
(T6): moves into											
most deprived											
areas	88	297	852	3,568	21,065	33,227	16,157	12,268	14,963	5,948	4,645
Churner Q1	74,560	0	0	0	0	0	0	0	0	0	0
Churner Q2	0	42,635	0	0	0	0	0	0	0	0	0
Churner Q3	0	0	36,444	0	0	0	0	0	0	0	0
Churner Q4	0	0	0	39,548	0	0	0	0	0	0	0
Churner Q5	0	0	0	0	62,992	0	0	0	0	0	0
Total	107,302	73,317	66,251	71,601	95,303	196,758	106,721	62,766	218,312	125,486	81,899

Supplementary table 5. Comparison of mobility groups based on trajectory analysis and detailed classification of first and last observation

Note stayers are not included in this table, this would be a duplication of the information shown in supplementary table 4. For the first and last observations moves are broken down into increasing or decreasing deprivation based on changing by 1,2 or 3+ deprivation quintiles. Increase +1 for example refers to an increase in deprivation quintile, from say Quintile 1 to Quintile 2. Whereas increase +2 refers to a change in deprivation of two quintiles, from say Quintile 1 to Quintile 3.