Introduction

Residential mobility may be an important determinant of cardiovascular disease (CVD) in New Zealand (NZ) as residentially mobile adults, 'movers', exhibit a higher risk of CVD than their immobile peers, 'stayers' (Exeter et al. 2015; Darlington-Pollock et al. 2016). International literature demonstrates that whilst most mobile groups are younger and in better health than their immobile peers (Bentham 1988; Norman et al. 2005; Martikainen et al. 2008), poorer health may precipitate a move in older ages or, be associated with moves across shorter distances within and between disadvantaged socioeconomic contexts (Boyle et al. 2002; Larson et al. 2004). However, previous studies examining the relationship between risk of CVD and residential mobility (noted above) consistently find a heightened risk of CVD for mobile groups, irrespective of age or the socioeconomic direction of a move. As ethnic inequalities in CVD are marked in NZ (Blakely et al 2004; Riddell et al. 2007; Kerr et al. 2008; Grey et al 2010; Mehta et al. 2014; Wells et al. 2015), there are important policy implications in establishing whether mobile groups have a higher risk of CVD than immobile groups; and whether this varies between ethnic groups already differentiated by socioeconomic position (SEP). Existing studies only reveal an association between heightened risk of CVD for groups who experienced residential mobility during the study period compared to those who have not, rather than demonstrating whether the heightened risk is associated with the move itself.

Of particular importance for CVD interventions is establishing whether the association between residential mobility and risk of CVD is driven by the individual-level characteristics of the mobile groups, or by the mobility event itself. Ethnic groups in NZ are socioeconomically differentiated (Blakely et al. 2004), exacerbated by marked disparities in residential deprivation, with Māori and Pacific populations concentrated in NZ's most deprived areas (Ministry of Health, 2010). To identify whether movers, differentiated both by ethnicity and socioeconomic experience, vary in risk of CVD relative to their immobile peers, we must compare risk of CVD for those who move *before* their first CVD event with risk of CVD for those who do not move. Using longitudinal data, it is possible to determine whether the CVD event, amongst movers, occurred before or after the first move. We can therefore compare differences in the relationship between residential mobility and subsequent risk of CVD.

As individual measures of SEP (e.g. income, occupation or educational attainment) are not routinely collected in the national health databases, in this study we use area deprivation as a proxy for socioeconomic position, and address two research questions:

1) Do movers have a higher risk of CVD event than stayers when the first move precedes the first CVD event?

2) Does the relationship between residential mobility and CVD vary according to the nature of the move or by ethnic group?

We distinguish between mover types according to both the frequency of moves, and the relationship with changes in area deprivation. In answering these questions, we can reflect on whether risks are associated with a residential mobility event, or unobserved compositional attributes of the sample population.

Methods

Our sample was identified using a unique health identifier assigned to NZ residents at their first health service contact (n = 2 068 360). The construction of this cohort (Wells et al. 2015) and the derivation of this sample (Darlington-Pollock et al. 2016) have been described elsewhere. The eligible population for this study was NZ residents enrolled in any Primary Health Organisation (approximately 97% of NZ population (Ministry of Health 2016) during at least one of the 34 calendar quarters between 1st January 2006 to 30th June 2014; aged between 30 and 84; had complete demographic information; and no prior history of CVD upon entry into the study cohort. We excluded participants aged <30 who have low risk of CVD, and those ≥85 due to differences in their CVD risk profile, patterns of residential mobility and their higher likelihood of comorbidities.

Age at 1/1/2006 was categorised into five groups (30-44; 45-54; 55-64; 65-74; 75-84). Following previous studies of CVD, ages 55-64 are the reference group (Exeter et al. 2015; Grey et al. 2014; Warin et al. 2016). Ethnic groups were defined using the 'prioritised output' of national ethnicity coding protocols in NZ (Ministry of Health, 2004), distinguishing between Māori, Pacific, Indian, Other Asian and NZ European and Other ethnicities combined (NZEO). Indian are separately categorised from Other Asian due to their increased risk of CVD. Participants' residences are recorded at each calendar quarter by their Census Meshblock (MB) which we use to derive residential mobility status and area deprivation information. Movers were first identified as any participant who changed their MB at least once during the study period, contrasting with immobile stayers. Deprivation quintiles were assigned based on NZDep2006 scores, a measure of area level socioeconomic deprivation based on nine variables from the 2006 Census (Salmond et al. 2007). We identified deprivation change as the differences between deprivation quintiles for the first recorded MB and the first new recorded MB after a change of address. Using deprivation quintiles (Q1–least deprived; Q2; Q3; Q4; and Q5–most deprived), we determine whether participants who move become more deprived, churn within the same deprivation quintile, or become less deprived during their first recorded move. Frequent movers may experience more complex deprivation trajectories, but the restricted time-frame of our study means it is unlikely that such varied trajectories will markedly impact the results of this analysis.

We define a CVD event as any hospitalisation or procedure related to acute coronary syndrome, ischaemic and haemorrhagic stroke, peripheral arterial disease or for congestive heart failure (Wells et al. 2015). Our cohort was constructed through the record linkage of key routine health databases, which capture patient journeys through the publically-funded health system in New Zealand. Individual-level clinical risk factors for CVD, such as BMI, blood pressure and smoking status, are not captured in routine health datasets, and we did not have access to information reported in a patient's electronic health record maintained by their general practitioner. We use the Cox proportional regression method of survival analysis to compare the risk of CVD between movers and stayers. Survival analysis is typically concerned with the time between a starting point and a terminating event, although the terminating event will not have occurred for all cases by the end of the study period (Bradburn et al. 2003). Here we are interested in time to CVD event, and whether this varies between movers and stayers: shorter 'survival' times are associated with a higher risk of CVD.

In this type of analysis, it is important to consider the bias introduced by 'immortal person time' (Levesque et al. 2008; Mi et al. 2013; Yang et al. 2014). Movers may be 'immortal' upon entry into the cohort until the point at which they move. This may downwardly bias results for mobile groups, suggesting they survive longer than stayers. To address this, one approach removes 'immortal person time', by counting time to a CVD event for movers from the point at which they move, rather than entry into the cohort. However, residential mobility is not a unique or homogenous type of 'exposure' that participants in our cohort will experience. Nor can we assume that our immobile 'stayers' have not moved previously. Arbitrarily censoring data in this way may therefore introduce more bias than it eliminates. We adopt an alternative approach that is more appropriate for a population-based observational study. In this analysis, we are interested in differences between those who move before their first CVD event and those who either do not move, or those who have a CVD event before their first move. If a participant moves *after* their first CVD event, they are considered at risk of a CVD event as stayers rather than as movers. Table 1 summarises the study population by mover status and ethnic group. For movers, this group are defined as a) those who change their MB during the study period without a CVD event, and b) those who change their MB during the study period before their first CVD event. Stayers are those who do not change their MB during the study period.

Table 1 here.

Our baseline models adjust for age, sex, ethnicity and either: (a) residential mobility status (mover/stayer); (b) mover type by frequency of moves; or (c) mover type by change in deprivation quintile. To explore whether the relationship between residential mobility and CVD varies between ethnic groups, we stratify the population by ethnic group and repeat each of the three models by ethnicity. In preliminary modelling, we also stratified the baseline models by gender: there were no observed differences in the results so this was discontinued. Results are presented as Hazard Ratios

(HR) with 95% confidence intervals, by mover status and mover type in the three baseline models and for each ethnic group. A HR > 1 suggests that this group have a higher risk of CVD (e.g. poorer 'survival' time) relative to the reference group. Given the large sample sizes used in this study, caution must be taken when interpreting narrow confidence intervals. These results may be an artefact of sample size. Throughout the interpretation of the results, we focus on the magnitude of the estimated effect size, rather than whether the confidence intervals indicate statistical significance.

Results

The patterns revealed in Table 1 broadly reflect those reported in the literature on the selectivity of migration (Norman et al. 2005; Exeter et al. 2011): movers are more likely to be in better health (lower proportions of movers with CVD than for stayers); younger (greatest proportion of movers at ages 30-44); and there are marginal differences between sexes (similar proportions of movers and stayers by gender, though greater differences for Other Asian populations which may reflect cultural differences in migration propensity as suggested by a UK based study (Finney 2011)). Differences are apparent when comparing the nature of a residential mobility event between ethnic groups. Māori and Pacific movers are more likely to move more frequently (≥4) than the other ethnic groups, 30.7% for Māori and 21.3% of Pacific movers. While Indian movers are more likely to move to a less deprived area (accounting for 40.0% of their moves), all other ethnic groups are generally more likely to move within the same level of deprivation. Moving to a more deprived area accounts for the smallest proportion of moves for all ethnic groups.

Table 2 summarises the HRs and 95% confidence intervals for each of the mobility covariates included in the model. Given the large sample sizes (Table 1) it is not surprising that all results return a p-value of < 0.05. In the baseline model, movers consistently have lower CVD event risks relative to stayers, whether defined by mover status, frequency of move, or deprivation change. The lowest risk of a CVD event is for frequent movers (≥4 moves during the study period): HR 0.47 (0.46-0.49) compared to HR 0.66 (0.66-0.67) for those moving 1-3 times. There are some differences by deprivation change: those moving to a less deprived area have a higher risk of a CVD event (HR 0.64 (0.63-0.65)) than either those moving within the same level of deprivation (HR: 0.63 (0.63-0.64)) or those moving to more deprived areas (HR: 0.63 (0.63-0.64)).

Table 2 here.

Explanations for these counter-intuitive results are discussed below. The models stratified by ethnicity similarly show that movers have a lower risk of CVD than their peers who remain in their original MB (Māori: HR 0.59 (0.58-0.61), Pacific: HR 0.66 (0.63-0.69), Indian: HR 0.65 (0.61-0.70), Other Asian: HR 0.63 (0.60-0.68), and NZEO: HR 0.64 (0.63-0.65). Across each ethnic group, higher frequencies of moves are associated with a greater decrease in the risk of CVD events relative to stayers than observed

for less frequent movers. Results by deprivation change did not differentiate risk of CVD for the different ethnic groups. Overlapping confidence intervals suggest that risk of a CVD event does not change by deprivation change.

Discussion

We examined whether movers had a higher risk of CVD after they moved than stayers, and whether there are differences by ethnic group or their experiences of residential mobility (defined by frequency of moves and experience of deprivation change). Previous studies (Exeter et al. 2015; Darlington-Pollock et al. 2016) found residential mobility to be a determinant of CVD in NZ as movers have a higher risk of CVD than stayers. Here we sought to examine whether a residential mobility event influenced subsequent risk of CVD for movers, and if that varied from CVD risk among stayers. We find that for those who experienced CVD, the survival time was longer for mobile groups than for stayers. This is indicative of a short-term 'healthy migrant effect' comparable to that observed in international studies of migrant flows (Razum et al. 2000) and more generally reflective of literature finding that migrants tend to be healthier than their immobile peers. Movers may temporarily experience relatively lower risks of poor health, here defined by a risk of CVD, given that these mobile groups are those *able* to make a move. While they may have been marginalised and disadvantaged, their socioeconomic resources were sufficient to enable a change of address.

Within mobile groups, there are some differences in the risk of a CVD event according to either frequency of move or experience of deprivation change. All mobile groups have a lower risk relative to stayers, however, the resilience of mobile groups increases with increasing moves. It is possible that our research design masks the complexities of the health-migration relationship for those moving multiple times in such a short period. Future work will extend these analyses to examine the ordering of events for multiple movers to thereby assess whether risk of CVD varies according to more detailed longitudinal deprivation trajectories.

There are some interesting differences by deprivation change for the movers. We might anticipate that movement towards more deprived areas will have a negative effect on health outcomes, whilst movement away from deprivation will benefit health. This hypothesis drives theories of selective migration and their influence on changing health gradients. Norman et al. (2005) found strong evidence to support this over a 20-year study period. During this time, the health (dis)advantages of differently deprived areas accrued such that it appeared to influence population-level health. In our shorter study period, moving to a more deprived area was *not* associated with a relatively higher risk of CVD than moving to a less deprived area: indeed, the baseline models found movers in this direction experience to have significantly lower risk of CVD relative to their immobile peers. It seems likely that those moving to a less deprived area take the health disadvantage of their previous residence with them, whilst

those who move to a more deprived area enjoy some protective effects from their previously more advantaged residence (Exeter et al. 2015; Darlington-Pollock et al. 2016). However, marginal differences in HRs when stratified by ethnic group suggest that the effects of deprivation change, if any are to occur, have not yet accrued during this time-period for mobile groups.

Although time may be an important factor explaining the differences between this study and Norman et al's (2005) research, the health outcomes vary. We used an objective measure of ICD-coded hospitalisation events whereas Norman et al. used self-reported health status, which may influence the observed results. Future research must explore whether the contrasting results for the mobile groups are a product of time or health outcome. Further, research should consider whether individual-level rather than area-level measures of deprivation would yield similar results to those presented here. While an area may be deprived, not *all* individuals' resident in that area will also be deprived. The motivations for residential mobility will vary by individual-level SEP which may have different associations with changing health status. For example, individually socioeconomically advantaged groups may, for various reasons, live in more deprived areas. However, declining health may prompt a move to a less pathogenic environment which, should a CVD event occur, be more conducive for recovery and rehabilitation. This may heighten risk of a CVD event for the upwardly mobile groups in these data.

We began this paper by asking whether policies should focus on vulnerable residentially mobile groups already with a heightened risk of CVD (Darlington-Pollock et al. 2016), or whether observed associations between residential mobility and CVD were compositional rather than related to the mobility event itself. Our results suggest that movers are, at least in the short-term, likely to have a lower risk of a CVD event than stayers. Associations between residential mobility and CVD reported in previous studies likely reflect wider risk factors predisposing some groups both to a heightened risk of CVD, and in some cases, a heightened risk of unfavourable residential mobility. Future research must examine the experiences of frequently mobile groups and their individual-level characteristics, both in terms of clinical and behavioural risk factors and wider socioeconomic status. Should data permit, questioning the extent to which individual-level characteristics of certain groups are associated with both a higher propensity to change address and higher risk of CVD will be informative.

The strengths of this paper rest in the dataset used: a longitudinal set of linked anonymised records for approximately 97% of NZ's adult population with the ability to analyse the ordering of CVD and residential mobility events. We are therefore able to extend existing work in this area and examine whether movers themselves have a higher risk of a CVD event, contributing to efforts to disentangle the complexities of the health-migration relationship. However, there are limitations. We do not have information on individual level socioeconomic circumstances, a key risk factor for CVD and residential mobility, as they are not collected in national health datasets. Similarly, we are unable to report on wider clinical-risk factors which may contribute to differences between ethnic groups; differences in health-

related behaviours, factors motivating a residential mobility event, or international migrant status. For example, smoking varies by ethnic group and also by deprivation in NZ but it is not possible to account for these factors within the parameters of the available data. Further work must also examine the extent to which the relationship between health and migration varies between established populations in a country and more recent migrants and their offspring. International migration may both act as a marker of risk for CVD through different clinical or behavioural-risk factors, and interact with experiences of residential mobility.

Area-level deprivation is assumed to adequately describe the circumstances of individuals' resident in each deprivation quintile. While correlations between area-level and individual-level deprivation are moderate, given that NZDep incorporates individual and household level measures of socioeconomic position, understanding the variability in mobility patterns of those with differential socioeconomic circumstances within areas of high and low deprivation is vital for untangling the relationship between deprivation, mobility and CVD. The selective migration literature demonstrates that socioeconomically advantaged groups, who are often in better health, move away from more deprived areas over time (Norman et al. 2005), therefore our results are likely to be underestimating the relationship between deprivation and CVD. A clearer picture would be revealed should linking patient records to individual-level socioeconomic attributes be possible. Future work may also enhance this data by qualitatively examining differences in motivations for residential mobility between ethnic groups and by health status. Further, identifying the length of residency in NZ for migrant populations would provide more insights into the differences between ethnic groups as experience of marginalisation or assimilation has important implications for differences in health outcomes between migrant groups. The Integrated Data Infrastructure (IDI) Statistics New Zealand's database (Stats NZ 2017), containing microdata about people and households from routine administrative sources, provides an opportunity to explore these limitations in depth.

Notwithstanding these limitations, the results are important. We have shown that while mobile groups may have a higher risk of CVD, this should not direct policy attention to the move itself. Rather, policies designed to reduce inequalities in CVD within and between ethnic groups in NZ must focus on the vulnerable and marginalised groups. This paper also highlights that research into migration and health must not fall back on cross-sectional associations. The complexities of the relationship can better be revealed by detailed longitudinal analyses making use of the temporal detail available.

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