SSM - Population Health 5 (2018) 48–54

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: www.elsevier.com/locate/ssmph

Article

Does selective migration alter socioeconomic inequalities in mortality in Wales?: a record-linked total population e-cohort study☆

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ARTICLE INFO

Keywords:
Inequalities
Selective migration
Mortality
Socioeconomic gradient

ABSTRACT

Recent studies found evidence of health selective migration whereby healthy people move to less deprived areas and less healthy people move to or stay in more deprived areas. There is no consensus, however, on whether this influences health inequalities. Measures of socio-economic inequalities in mortality and life expectancy are widely used by government and health services to track changes over time but do not consider the effect of migration. This study aims to investigate whether and to what extent migration altered the observed socio-economic gradient in mortality. Data for the population of Wales (3,136,881) registered with the National Health Service on 01/01/2006 and follow-up for 24 quarters were individually record-linked to ONS mortality files. This included moves between lower super output areas (LSOAs), deprivation quintiles and rural-urban class at each quarter, age, sex, and date of death. Cox regression models were used to estimate the hazard ratios for the deprivation quintiles in all-cause mortality, as well as deprivation change between the start and end of the study. We found evidence of health selective migration in some groups, for example people aged under 75 leaving the most deprived areas having a higher mortality risk than those they left behind, suggesting widening inequalities, but also found the opposite pattern for other migration groups. For all ages, those who lived in the most deprived quintile had a 57% higher risk of death than those in the least deprived quintile, allowing deprivation to vary with moves over time. There was little change in this risk when people were artificially kept in their deprivation quintile of origin (54% higher). Overall, migration during the six year window did not substantially alter the deprivation gradient in mortality in Wales between 2006 and 2011.

1. Introduction

Migration is known to be selective, based on socioeconomic, demographic or health factors (Boyle & Norman, 2009). Several studies reported evidence of health selective migration whereby healthier people tend to move to less deprived areas and less healthy people move to or stay in more deprived areas (Boyle & Norman, 2009; Green, Subramanian, Vickers, & Dorling, 2015; Pearce & Dorling, 2010; Popham, Boyle, O'Reilly, & Leyland, 2011). There is no consensus, however, on whether or to what extent health selective migration alters, or exaggerates, socioeconomic inequalities in health or mortality. This is important as measures of inequalities in mortality or life expectancy continue to be widely used by Government and health services in many countries to track progress towards policy aims of reducing inequalities. Following the influential Marmot Review of inequalities (Marmot et al., 2010) the Marmot indicators for England (Public Health England, 2015) were developed for this purpose including inequalities in life expectancy. Similar measures are used in the Public Health Outcomes Framework for Wales (Welsh Government, 2017) supporting the Wellbeing of Future Generations (Wales) Act 2015 Welsh Government (2015) or in a report comparing European countries commissioned by the European Union (Mackenbach, 2006).

Some of the reasons for the differences in study findings includes the variation in their study design, study setting, geographical scale, data sources and outcome measures. Many investigate health status, including self-reported limiting long-term illness, general or mental health (Brown et al., 2012; Tunstall, Pearce, Shortt, & Mitchell, 2015; Jongeneel-Grimen et al., 2013, Darlington-Pollock, Norman, & Ballas, 2017) and it is likely that migration influences the relationship between deprivation and these measures differently compared to mortality.

☆ All authors have reviewed and approved the final manuscript.

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https://doi.org/10.1016/j.ssmph.2018.05.004
Received 31 January 2018; Received in revised form 8 May 2018; Accepted 9 May 2018

Age patterns are also important, as exaggerations of inequalities in mortality and self-reported health in England and Wales appear to be driven by movers in mid-life from more to less deprived areas (Norman & Boyle, 2014). Migration contributed to some of the increased inequalities in mortality in England and Wales during the 1990s in those aged under 75, whilst it had the opposite effect in people aged 75 and over and for all ages there was little evidence for a contribution (Connolly, O'Reilly, & Rosato, 2007). This seems logical as people move for different reasons and at different times of their lives. Younger people may move for work or study, or to set up a family home, and tend to be healthier. Older people may move to live nearer family or to access care due to poor health. A recent study found that when considering an individual's health before a move there was little evidence of an association between neighbourhood type (based on median house price) and the risk of poor health on follow-up, suggesting that health selective migration helped to explain this relationship (Green, Arcaya, & Subramanian, 2017).

Some studies have used shorter follow-up time periods of one or two years. Brown et al. (2012) suggested that while the relationship between migration and socioeconomic circumstances is immediately measurable, the relationship between migration and health could take longer to take effect. If indeed moves in mid-life to less deprived areas were exaggerating health inequalities, and presumably made by healthier individuals, then studies with shorter follow-up periods might not capture all changes in inequalities in health conditions that develop in older age and therefore years after their move. More pronounced effects might therefore be observed with a longer follow-up (Connolly, Rosato, & O'Reilly, 2011; Tunstall et al., 2015). The small number of movers is another common limitation and several studies suggest that further research should be conducted using larger datasets (Jongeneel-Grimen et al., 2013; Martikainen, Sipilä, Blomgren, & Van Lenthe, 2008; Tunstall et al., 2015).

Broadly, for migration to alter the observed inequalities the group of people who leave or join the most and least deprived areas would have to be different in their mortality risk to the group they left and/or joined. This could lower the mortality risk in the least deprived areas or raise it in the most deprived quintiles increasing the difference between the two and thus the measure of inequalities in the population. These patterns of deprivation change could also maintain inequalities over time that would otherwise have decreased, and would also be of concern.

In our cohort study we analysed the entire population of Wales considering quarterly moves and using individual record-linkage to determine whether and to what extent migration altered the observed deprivation gradient in mortality during the 6-year study period. We used all-cause mortality as it is a well-established measure of population health and the basis for routine measures of inequalities, which could be biased by migration.

2. Data and methods

2.1. Cohort description

The cohort is based on a previously defined cohort including its entire population (Fone et al., 2016). It is an electronic record-linked dataset that includes all individuals registered with a GP in Wales on 1st January 2006 with six years of follow-up (3,136,881 people). It is based on the Welsh Demographic Service (WDS) dataset that is held and managed by the NHS Wales Informatics Service (NWIS), and used as the population register within the SAIL Databank (see: https://saildatabank.com/) (Ford et al., 2009; Lyons et al., 2009). A unique identifier was used to securely link individuals to the mortality database provided by the Office for National Statistics (ONS), which provided a date of death for individuals in the cohort who died during the time period. To account for moves within Wales, each individual's lower super output area (LSOA, approximately 1500 people) code of residence was recorded at the start of each quarterly time-period for each of the 24 quarters over the six-year period. Individuals who moved out of Wales (219,470; 7%) and back in at a later stage (3297; 0.1%) were included in the dataset for all the time-periods they lived in Wales. Migration is therefore defined as the moves between LSOAs at each quarter for all individuals included in the cohort, censored for death and moving out of Wales (allowing moves back in). People who have moved into Wales since the start of the study period are not included in the cohort.

2.2. Area-level deprivation

We measured LSOA deprivation using the Welsh Index of Multiple Deprivation (WIMD) 2008 (Welsh Government, 2009) and created deprivation quintiles based on the published ranks. The deprivation quintiles were then linked to the cohort data using the LSOA code at each quarter. We coded deprivation change for those in the most deprived and the least deprived quintile at the start of the study and the quintile they were in at the end of the study as well as the opposite direction for those who were in the most and least deprived quintile at the end of the study and their quintile of origin at the start.

2.3. Rural-urban definition

We defined rural-urban settlement type by grouping the six classes in the 2001 rural urban classification (RUC) published by ONS (ONS, 2005) into three groups: 'urban' for settlements with more than 10,000 people, rural 'town and fringe' areas, and rural 'village and dispersed' areas, whether they were in a "sparse" or "less sparse" regional setting. These three classes were then linked to the cohort for every quarter using the LSOA code.

2.4. Analyses

All analyses were performed in the secure SAIL gateway using the statistical package R (R Core Team, 2015). We described the percentage of people who moved and the incidence of first move per 100,000 person-years at risk, either within Wales or out of Wales, broken down by age group, sex, deprivation quintile and rural-urban classification. We also described the number of deaths, and incidence of death per 100,000 person-years at risk to provide an overview of the cohort data.

To investigate factors associated with the risk of (1) moving within Wales or (2) moving out of Wales, (time to first migration), two separate Cox regression models were fitted, censored for death. The event variable was a move, censored for death, using the explanatory variables of age group, sex, deprivation quintile and rural-urban classification. Age groups for these analyses were defined as those aged < 15, 15–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, 85+.

To estimate the risk of mortality, further Cox regression models were fitted with death as the event, censoring for moving out of Wales (i.e. leaving the cohort). Model A included the covariates age group, sex, deprivation quintile and rural-urban class where age group, deprivation quintile and rural-urban class were treated as time-varying covariates, i.e. considered at each quarter over time. Age groups for these analyses were defined as those aged < 18, 18–24, 25–44, 45–64 (ref), 65–74, 75+ to allow sufficient number of events in each group (those aged 75–84 and aged 85+ had to be combined).

We also fitted a model (Model B) with the same variables as Model A but counterfactually assuming no migration followed by artificially returning individuals to the deprivation quintile of origin at the start of the study. We compared the hazard ratios for mortality in the most deprived quintile relative to the least deprived quintile in Model A, allowing deprivation to vary, and Model B, returning people to the quintile of their origin. This allowed us to test whether and to what extent moves in Model A, specifically those changing deprivation quintile, had redistributed people in a way that changed the mortality risk for the deprivation quintiles and resulted in different hazard ratios in the two models. Any difference between the hazard ratios in the two models represented the size of the effect of migration on the mortality gradient. Model C included an additional binary variable 'moved', set to TRUE for time periods following a move, and interactions between age group and 'moved'. An interaction term was used because the relationship between migration and mortality differed by age group. The estimates for the interaction between each age group and 'moved' denote the effect over and above those of the age groups generally for those who moved compared to those who have not moved.

Model D investigated the direction of deprivation change for those who stayed in, moved to or from the most and least deprived quintiles between the start and the end of the study. We performed separate Cox regression analyses for the four groups who started or ended in the most or least deprived quintile estimating the risk of death for the direction of change (e.g. moved from the most deprived to quintile 2) and sex, separately for people aged under 75 years and those aged 75 years and over. We stratified the analysis for those aged under 75 by age group (< 18, 18–24, 25–44, 45–64, 65–74). These analyses allowed us to examine health selective migration by comparing the risk of death in deprivation change groups with those who remained in their fifth of origin or those they joined, whether they had moved within the quintile or not. This gives an indication of the contribution each deprivation change group has made to inequalities, i.e. whether the change may have had a widening or narrowing effect.

We tested the proportional hazards assumption using standard procedures and the assumption was discernibly violated only for the covariate "age group". To address this we used a Cox model stratified by age group allowing the underlying hazard function to vary across age groups. The results for the stratified model were very similar to the model without stratification. We assume that underlying mortality rates did not vary substantially during our six-year study period and for simplicity we have used the models without stratification with the exception of the deprivation change model (Model D).

3. Results

3.1. Characteristics associated with moves in the cohort

Overall, nearly 30.6% of people moved during the six years, whether within Wales or out of Wales (Table 1). Slightly more females had moved with nearly 31.3% compared to 29.9% of males. Around 50% of young people aged 15–34 years had moved compared to 12–34% in the other age categories.

Amongst people living in most deprived areas (Table 1) nearly 33% have moved, compared with 29–31% in the other deprivation quintiles. Of people living in an urban area in 2006, nearly 33% moved, more than 28% of those living in 'town and fringe' areas or 26% in 'village and dispersed' areas. The same patterns are reflected in the incidence of the first move per 1000 person-years at risk.

Although not shown in the table, there is a slight net increase in movers from the most deprived areas to less deprived areas (0.3% away from most deprived) between the start of the study and the last known residence of each individual, whether they left Wales, died or still lived in Wales at the end of the study.

To investigate the characteristics of people most likely to move or

Table 2
Risk of moving within and out of Wales (time to first move).
Source: CHALICE dataset (SAIL databank), WIMD 2008 (WG), 2001 RUC (ONS)

	Within Wales				Out of Wales			
	HR	95% CI		p-value	HR	95% CI		p-value
Male (ref)								
Female	1.14	1.13	1.14	< 0.001	1.01	1.00	1.02	0.01
< 15	1.91	1.89	1.93	< 0.001	1.41	1.38	1.44	< 0.001
15–24	3.26	3.23	3.28	< 0.001	4.62	4.54	4.71	< 0.001
25–34	2.88	2.86	2.91	< 0.001	3.24	3.18	3.31	< 0.001
35–44	1.55	1.53	1.56	< 0.001	1.44	1.41	1.47	< 0.001
45–54 (ref)								
55–64	0.73	0.72	0.74	< 0.001	1.08	1.06	1.11	< 0.001
65–74	0.58	0.57	0.59	< 0.001	0.80	0.78	0.83	< 0.001
75–84	0.93	0.92	0.95	< 0.001	0.93	0.90	0.96	< 0.001
85 +	2.10	2.06	2.13	< 0.001	1.77	1.69	1.84	< 0.001
Least deprived (ref)								
2	1.04	1.03	1.05	< 0.001	0.85	0.84	0.86	< 0.001
3	1.09	1.08	1.10	< 0.001	0.68	0.67	0.69	< 0.001
4	1.12	1.11	1.12	< 0.001	0.59	0.58	0.59	< 0.001
Most deprived	1.17	1.16	1.18	< 0.001	0.46	0.46	0.47	< 0.001
Urban (ref)								
Town	0.85	0.85	0.86	< 0.001	0.86	0.85	0.87	< 0.001
Village	0.79	0.79	0.80	< 0.001	1.04	1.02	1.05	< 0.001

HR: hazard ratio; 95%CI: 95% confidence interval

Table 1
Overview of cohort, migration and deaths by age group, sex, rural-urban class and deprivation quintile at the start of the study, univariate, Wales, 2006–2011.
Source: CHALICE dataset (SAIL databank), WIMD 2008 (WG), 2001 RUC (ONS)

	Total cohort	Count moved	% moved	Incidence of first move per 1000 person-years at risk	Count of deaths	Incidence of death per 1000 person-years at risk
All	3,136,881	959,622	30.6	64.1	184,247	10.5
Male	1,557,378	465,166	29.9	62.1	88,937	10.2
Female	1,579,503	494,456	31.3	66.2	95,310	10.8
< 15	527,880	177,567	33.6	69.5	456	0.1
15–24	429,303	235,246	54.8	135.6	1141	0.5
25–34	393,063	189,626	48.2	114.2	1888	0.9
35–44	459,824	132,820	28.9	58.3	4456	1.7
45–54	404,208	80,193	19.8	37.7	9045	3.9
55–64	392,415	62,197	15.8	29.7	21,412	9.5
65–74	277,782	33,859	12.2	23.3	38,598	25.2
75–84	187,087	30,804	16.5	36.1	64,622	71.0
85 +	65,319	17,310	26.5	82.4	42,629	179.6
Least deprived	627,314	190,453	30.4	63.3	30,866	8.9
2	629,674	184,826	29.4	60.8	34,745	9.9
3	632,839	185,935	29.4	61.1	38,943	11.0
4	623,817	194,787	31.2	66.0	38,807	11.1
Most deprived	623,237	203,621	32.7	69.8	40,886	11.6
Urban	2,061,144	669,939	32.5	69.3	119,261	10.3
Town and fringe	550,314	152,517	27.7	56.8	34,392	11.1
Village and dispersed	525,423	137,166	26.1	52.6	30,594	10.4

HR: hazard ratio; 95%CI: 95% confidence interval stay, we analysed the risk of moving (time to first migration) by age group, deprivation quintile and rural-urban class (Table 2). People aged under 45, and aged 85 and over, were more likely to move within Wales. People aged 15–24 were over three times more likely to move compared to the reference group aged 45–54. People aged 55 to 84 were less likely to move in comparison to the reference group. This pattern was similar for moving out of Wales. Young people aged 15–24 were over four-times as likely, and people aged over 85 nearly twice as likely to move out of Wales compared to the reference group. The higher likelihood of moves in younger age groups is possibly explained by the student population or by young people moving for work within this group. Females were more likely than males to move within Wales (HR 1.14, Table 2), but equally likely to move out of Wales as males.

There were also differences in migration in and out of Wales by deprivation quintile. People living in the most deprived areas were more likely to move internally (HR 1.17, Table 2). However, people in most deprived areas were less than half as likely to move out of Wales (HR 0.46, Table 2) than people living in least deprived areas.

People living in urban areas were most likely to move within Wales, with the 'town and fringe' areas and 'village and dispersed' areas having lower hazard ratios of 0.85 and 0.79, respectively, than the urban reference group (Table 2). For migration out of Wales, the likelihood of moving in 'village and dispersed' areas was similar to urban areas, while people in the 'town and fringe' areas were less likely to move out (HR 0.86, Table 2).

3.2. Patterns in the risk of death

In these analyses we compared the risk of death in subjects who moved with those who had not moved. Model A (Table 3) included the covariates sex, age groups, the deprivation quintiles and rural-urban categories and allows deprivation to vary with every move during the study period.

Model C (Table 3) included the same variables and additionally an adjustment for moving using an interaction term between moving and each of the age groups. This allowed a more flexible investigation of the relationships between age, moving and mortality. There was a higher risk of death (hazard ratio 1.55) following a move during the study period compared to those who had not moved (see Table 3).

The relationship between migration and the risk of death is not uniform across all age groups but increases with age. Following a move, people aged 65 and over had an increased risk of death (HR 1.20 aged 65–74, HR 2.04 aged 65–74, Table 3) compared to the reference group of 45–64 year olds. Following a move, people aged under 45 had a lower risk of death than the comparison group. There was strong evidence for the interaction between age groups and migration for those aged 18 and over, whilst it was weaker for people aged under 18.

3.3. Effect of migration on inequalities in mortality

People living in the most deprived areas had a risk of death, which was 1.57 times higher (Table 3) than people living in least deprived areas. In order to assess whether migration had altered the deprivation gradient in mortality during the study period, we compared the hazard ratio for the most deprived quintile between different models.

We fitted a model (Model B, Table 3) that ignored deprivation change by counterfactually returning individuals to the deprivation quintile of origin at the start of the study. The hazard ratio for people living in most deprived areas compared to least deprived was 1.55 (CI 1.53–1.57, p-value < 0.001; Table 3). This was similar to the hazard ratio of 1.57 in our previous analysis using Model A (Table 3), allowing deprivation to vary with moves. The differences are similar for the other deprivation quintiles and so affect the entire gradient and not only the difference between the most and least deprived quintile. We therefore concluded that migration did not have a substantial effect on the deprivation gradient of mortality during the time period considered.

Model D investigated the direction of deprivation change for those who moved to or from the most or least deprived quintile (Table 4). The model estimated the risk of death for the direction of change, separately for those aged under 75 years and aged 75 and over. This allowed us to investigate health selective migration by comparing the risk of death for the groups who moved "up" or "down" to the other four quintiles with

Table 3
Risk of death, model results for Model A, allowing deprivation to vary over time, Model B, returning people to their origin, and Model C including interaction between age group and moves (fully adjusted).
Source: CHALICE dataset (SAIL databank), WIMD 2008 (WG), 2001 RUC (ONS)

	Model A, varying deprivation				Model B, origin deprivation				Model C, interaction			
	HR	95% CI		p-value	HR	95% CI		p-value	HR	95% CI		p-value
Male (ref)												
Female	0.81	0.80	0.81	< 0.001	0.81	0.80	0.81	< 0.001	0.79	0.78	0.79	< 0.001
< 18	0.03	0.03	0.03	< 0.001	0.03	0.03	0.03	< 0.001	0.03	0.03	0.03	< 0.001
18–24	0.09	0.09	0.10	< 0.001	0.09	0.09	0.10	< 0.001	0.09	0.09	0.10	< 0.001
25–44	0.20	0.19	0.21	< 0.001	0.20	0.19	0.21	< 0.001	0.20	0.19	0.20	< 0.001
45–64 (ref)												
65–74	3.69	3.63	3.75	< 0.001	3.69	3.63	3.75	< 0.001	3.70	3.64	3.77	< 0.001
75+	15.9	15.7	16.1	< 0.001	15.9	15.7	16.1	< 0.001	14.62	14.40	14.84	< 0.001
Least deprived (ref)												
2	1.20	1.18	1.22	< 0.001	1.15	1.13	1.17	< 0.001	1.18	1.16	1.20	< 0.001
3	1.28	1.26	1.30	< 0.001	1.25	1.23	1.27	< 0.001	1.27	1.25	1.29	< 0.001
4	1.41	1.39	1.43	< 0.001	1.39	1.37	1.41	< 0.001	1.39	1.37	1.41	< 0.001
Most deprived	1.57	1.55	1.60	< 0.001	1.55	1.52	1.57	< 0.001	1.54	1.52	1.56	< 0.001
Urban (ref)												
Town and fringe	1.00	0.99	1.02	0.48	1.01	0.99	1.02	0.37	1.01	1.00	1.02	0.102
Village and dispersed	0.90	0.89	0.92	< 0.001	0.91	0.90	0.92	< 0.001	0.92	0.91	0.93	< 0.001
Not moved (ref)												
Moved									1.55	1.50	1.61	< 0.001
< 18: Moved									0.68	0.53	0.87	0.003
18–24: Moved									0.69	0.59	0.82	< 0.001
25–44: Moved									0.83	0.77	0.89	< 0.001
45–64: Moved (ref)												
65–74: Moved									1.20	1.14	1.27	< 0.001
75+: Moved									2.04	1.96	2.12	< 0.001

HR: hazard ratio; 95%CI: 95% confidence interval

Table 4
Risk of death, model results for deprivation change between the start and end of the study, adjusted for age and sex (Model D, four separate models).
Source: CHALICE dataset (SAIL databank), WIMD 2008 (WG), 2001 RUC (ONS)

Start deprivation	End deprivation	< 75 Pop (n)	HR	95% CI		p-value	75+ Pop (n)	HR	95% CI		p-value
Least	Least (ref)	8250	1				18,999	1			
Least	2	221	0.88	0.77	1.00	0.05	988	1.58	1.49	1.69	< 0.001
Least	3	158	0.91	0.77	1.06	0.22	705	1.67	1.55	1.80	< 0.001
Least	4	157	1.05	0.90	1.23	0.53	643	1.62	1.50	1.75	< 0.001
Least	Most	156	1.37	1.17	1.60	< 0.001	589	1.70	1.56	1.84	< 0.001
Most	Least	157	0.56	0.48	0.66	< 0.001	440	1.19	1.08	1.30	< 0.001
Most	2	222	0.67	0.59	0.77	< 0.001	695	1.31	1.22	1.41	< 0.001
Most	3	357	0.75	0.67	0.83	< 0.001	841	1.20	1.12	1.28	< 0.001
Most	4	545	0.79	0.72	0.86	< 0.001	1135	1.20	1.13	1.27	< 0.001
Most	Most (ref)	14,964	1				21,530	1			
Least (ref)	Least	8250	1				18,999	1			
2	Least	202	0.78	0.68	0.89	< 0.001	751	1.39	1.29	1.50	< 0.001
3	Least	187	0.95	0.83	1.10	0.53	607	1.43	1.32	1.55	< 0.001
4	Least	170	1.05	0.90	1.22	0.55	538	1.60	1.47	1.74	< 0.001
Most	Least	157	1.25	1.07	1.47	0.01	440	1.65	1.50	1.82	< 0.001
Least	Most	156	0.62	0.53	0.72	< 0.001	589	1.21	1.12	1.32	< 0.001
2	Most	211	0.71	0.62	0.82	< 0.001	535	1.09	1.00	1.19	0.04
3	Most	338	0.75	0.67	0.83	< 0.001	817	1.14	1.06	1.22	< 0.001
4	Most	566	0.84	0.77	0.91	< 0.001	1034	1.12	1.05	1.19	< 0.001
Most (ref)	Most	14,964	1				21,530	1			

HR: hazard ratio; 95%CI: 95% confidence interval

those they left or joined. It also gives an indication of a widening or narrowing effect on inequalities by lowering or raising the risk of death in the group they left or joined, although this would also depend on the number in each migration group. People aged under 75 years who left the most deprived quintile had a lower risk of death compared to those who remained in the most deprived quintile. Conversely, those aged 75 years and over who left the least deprived areas had a higher risk of mortality than those they left. For these groups this provided some evidence of health selective migration as described in the literature, whereby “healthier” people moved to less deprived areas and “less healthy” people moved to or stayed in more deprived areas. It suggests that these deprivation change groups could have a widening effect on inequalities by raising the risk of mortality in the most deprived quintile who stayed or lowering the risk of mortality in the least deprived group respectively. We found the opposite pattern, however, for the older age group (75+) who left the most deprived quintile or joined the least deprived quintile or the younger age group who joined the most deprived quintile, suggesting they could have a narrowing effect on inequalities. For some of the groups there are mixed results depending how many quintiles they move up or down and no clear direction for an effect on inequalities (Table 4). For all ages and the entire cohort, as reported in our previous analysis (Model A and Model B), we found no evidence that migration had altered inequalities in mortality.

4. Discussion

Our study builds on existing evidence by using a large record-linked total population cohort and small area-level quarterly migration for six years. To our knowledge it is the largest longitudinal study on this topic in the UK, benefitting from advanced linkage infrastructure in Wales. Our main aim was to investigate whether and to what extent migration altered inequalities in mortality in Wales in 2006–2011. We found evidence of health selective migration, in which healthier people moved to less deprived areas and less healthy people stayed in or moved to more deprived areas, but also the opposite pattern for some deprivation change groups. We found little evidence, however, that migration overall altered the mortality gradient during the six years. This is important, as routine cross-sectional measures of the gap in life expectancy and all-cause mortality are widely used by government and health services across the UK and elsewhere. These serve to assess progress over time towards policy aims of reducing inequalities, such as the Marmot indicators for England (Public Health England, 2015) including repeated measures of inequalities in life expectancy, similar measures in indicator sets for Wales (Welsh Government, 2017) or those comparing between European countries (Mackenbach, 2006). We found no evidence that these routine measures of inequalities in mortality were biased by migration during the six year study period.

Our results are in keeping with previous UK studies (Connolly et al., 2011; Maheswaran et al., 2014; Popham et al., 2011; Brimblecombe, Dorling, & Shaw, 2000) who also found no substantial effect on the mortality gradient. Maheswaran et al. (2014) and Popham et al. (2011) examined smaller populations of Sheffield and the Scottish Longitudinal study respectively. Connolly et al. (2011) examined the effect of population movement in Northern Ireland over one year and suggested that longer follow-up might have shown stronger effects of migration. Brimblecombe (2000) found that inequalities in mortality in British Household Panel Survey participants between 1991 and 1996 were largely accounted for by migration patterns and advantage in men. A study in Finland also found no evidence for an overall effect of migration on mortality based on the proportion of manual workers in an area rather than area-based deprivation, likely due to small migratory flows (Martikainen et al., 2008). Despite agreement in results it is unclear whether these studies are directly comparable to ours.

Our finding is contrary to results from a study in England and Wales which found that migration had increased inequalities in health between 1971 and 1991 although the effect was weaker for mortality than for ill-health (Norman, Boyle, & Rees, 2005). It used the ONS Longitudinal Study and subjects who died in the study period were excluded, and this undercounting of deaths in the study, specifically in the more deprived areas, is cited as a possible reason for a weaker effect. Like many other studies it considered migration between two time points, in this case between 1971 and 1991, compared to tracking quarterly small area level migration employed in our study, albeit for the shorter study period of six years. It is unclear whether the study period considered in these studies is comparable to our study period, which is characterised by increasing house prices, for example, which could influence migration patterns differently, as could different housing policies relating to social housing. Another study in England and Wales found evidence of an effect of migration for those aged under 75 where migration had contributed 50% of the increase in inequalities during the 1990s (Connolly et al., 2007). In older age groups, however, selective migration was responsible for the narrowing of mortality differentials, but for all ages, as used in our study, there was little evidence of an effect (Connolly et al., 2007).

A study in England and Wales found that exaggerations of inequalities in health, not specifically mortality, were found to be driven by moves in mid-life from more to less deprived areas (Norman & Boyle, 2014). In our analysis of mortality we are focussing on older people before their death, and may therefore not see these patterns in the six years before death. Further research using other health outcomes or even longer follow-up period should be conducted.

Broadly, for migration to alter the observed inequalities the group of people who leave or join the most and least deprived areas would have to be different in their mortality risk to the group they left and/or joined. This could potentially lower the mortality risk in the least deprived areas or raise it in the most deprived areas increasing the difference between the two and thus the measure of inequalities in the population. We found evidence of health selective migration for people aged under 75 who moved away from most deprived areas and who had a lower mortality risk than the people they left, suggesting they were healthier. Similarly, those aged 75 and over who moved away from the least deprived areas had higher mortality rates, suggesting they were less healthy. These deprivation change groups could have a widening effect on inequalities. We found the opposite pattern, however, for the older age group (75+) who left the most deprived quintile or joined the least deprived quintile or the younger age group who joined the most deprived quintile, suggesting a narrowing effect on inequalities. Whilst these results provide an indication of the direction of alteration of inequalities for the deprivation change groups, the estimates cannot be directly compared between different analyses. The relative number of people in each deprivation change group would be important, and some groups were relatively small compared to others and those who did not change deprivation. In our analysis of all ages, however, we found no evidence that migration during the six years has altered the gradient, and this suggests that the groups who differentially changed deprivation are either small or have negligible or cancelling effects. As reported elsewhere (Norman & Boyle, 2014) it is likely that selective migration in mid-life influences inequalities before study start; our study of selective migration during a six-year window cannot provide further evidence to corroborate or challenge this finding.

Comparing movers and non-movers, we found that the risk of death was higher following a move (HR 1.55) compared to those who did not move. The relationship between migration and the risk of death was, however, not uniform across all age groups but the risk increased with age (Table 3). Movers are generally considered younger and healthier, but increasing health challenges may become a driver for moving in older people (Boyle & Norman, 2009). We investigated mortality as it is a well-established indicator of population health and forms the basis for widely used measures of inequalities including life expectancy. Using mortality as the outcome and six years of follow-up meant, however, that we had focussed on older people in the cohort and their moves before their death. We found that people aged 75 and over who changed deprivation (leaving or joining the most or least deprived areas) had a higher risk of death than those who remained in the most or the least deprived areas (Table 4). One reason could be the need to live near relatives or access to care such as moves to a care home, although our dataset did not contain the reason for any move. A study in Sheffield found higher mortality rates in areas with high care home bed provision, but overall selective migration did not substantially alter the mortality gradient (Maheswaran et al., 2014).

We also investigated the likelihood of moving for different groups. Similar to previous literature we found that younger people (under 35) and older people (aged 85 and over) were most likely to move, with the younger people making up the largest share of movers in the population (Tables 1 and 2). This is likely to include young people moving for work and study, young families setting up home, and elderly people moving to be nearer family or to access care. People in mid-life were less likely to move, which includes families with children. There was an association between moving and area deprivation as people living in the most deprived areas were more likely to move internally (HR 1.17, Table 2), but only half as likely to move out of Wales as people living in least deprived areas. Moves out of Wales may be related to moves for work or study and more likely to be made by those who are more advantaged. People in urban areas were more likely to move within Wales than in rural areas, whilst people in rural 'town and fringe' areas were less likely to move out of Wales than those in urban or rural 'village and dispersed' areas.

4.1. Limitations

The cohort is based on the entire population with a GP registration on 01/01/2006 and living in Wales, and follow-up of 6 years. Containing over 3 million people this is a very large record-linked dataset and is one of the main strengths of this study. People who moved to Wales after the start date and during the 6-year follow up were not included. People who moved out of Wales during the study period (219,470, 7%) were included until the time they left the cohort. 3 297 people (0.1%) moved back into Wales and were included for all time periods they lived in Wales. This means that, whilst it is a very large dataset, the cohort by the end of the study did not contain the entire population (93%) but due to the size of the cohort this is unlikely to have a substantial effect on any conclusions drawn.

The total GP registered population in our cohort in 2006 (3,136,881) is 151,181 or around 5% larger than the resident population in the 2006 mid-year population estimates (2,985,700) published by ONS. This difference has in the past been found to be concentrated in the 20–39 year olds (Gartner & Lester, 2006) suggesting that younger people, particularly students, may leave the country and fail to deregister with their GP. In our analysis we therefore underestimate moves in younger people, as we overestimate the younger population of non-movers who have left Wales but are still recorded in the dataset.

Migration was based on residence in an LSOA in Wales and so moves within LSOAs were not captured in the data. This means that some people were classed as non-movers when they could have moved a short distance. The deprivation quintile associated with the person is, however, correctly assigned to examine any alteration on the gradient. The LSOA supplied is based on a valid postcode and so there is also a small chance of errors in geocoding or errors in the postcode entered, but we expect this to be small.

We used an area-based deprivation measure, the WIMD 2008, for the entire study period. It does therefore not consider changes in deprivation level in each area over time, for example through regeneration or new housing developments. Not everyone living in an area classed as deprived is themselves deprived, and similarly for areas of lowest deprivation. Area-based measures of inequalities use residence in an area and its associated deprivation level. To investigate this, we used the current deprivation level based on residence with every move.

We expect errors in the linkage to be small for this dataset, as all complete records from the Welsh Demographic Service (WDS) were included if they could be linked over the time period. For further details on data linkage please see the report on CHALICE (Fone et al., 2016). A study from 2009 compared a sample of the age-sex register used within SAIL to the GP practice records and these matched 99.99% (Lyons et al., 2009). We expect any effect of linkage error on our analysis to be small. Where the date of death in the WDS differed from the mortality file from ONS, the date of death from the ONS was used in the analysis. The mortality file is considered more robust as the date of death registration is taken from the death certificate rather than other notification to the GP.

5. Conclusion

Our findings suggest there is little evidence that routine mortality gap measures are biased by migration over the shorter term and during our study period. Further research investigating other health outcomes or a longer follow-up period could capture migration effects in younger people or in mid-life, and thus investigate effects over the life course. Although not captured in our study, it is possible that selective migration in early or mid-life influences inequalities in mortality in later life. Additionally, new patterns of migration relating to unemployment, housing, regeneration, austerity policy such as changes to benefits may affect area-based inequalities differently in the future, and migration should therefore not be discounted in analysis of inequalities over time.

Declarations of interest

None.

Financial declaration of interest

None.

Statement that ethics approval is not required

Our dataset in this study is based on a dataset from the CHALICE study. The CHALICE study received approval from the Information Governance Review Panel (IGRP), which assesses whether all proposals for analysis of the SAIL databank meet the strict information governance arrangements set out in the multiple data access agreements, ensures anonymity and does not require referral to the National Research Ethics Service (NRES). IGRP includes members from the British Medical Association, NRES, Public Health Wales NHS Trust, Informing Healthcare and lay members. We received advice from NRES that NHS Research Ethics Committee review was not required for the study as it did not involve NHS patients or staff but was classified under the category of an anonymised research database.

Acknowledgements

Funding for this work was received from Public Health Wales NHS Trust as part of a report on migration and health. Support for the report was also received from the National Centre for Population Health and Wellbeing Research (NCPHWR). Andrea Gartner is funded through the NCPHWR and David Fone, Shantini Paranjothy and Daniel Farewell are members of the NCPHWR team in Cardiff University, School of Medicine. Neither funder bears any responsibility for the analysis or interpretation of the data presented here. We used data from the CHALICE project, which was originally funded by the National Institute for Health Research Public Health Research (NIHR PHR) Programme (project number 09/3007/02). The views and opinions expressed therein are those of the authors and do not necessarily reflect those of the NIHR PHR Programme or the Department of Health. We would like to thank Jenny Morgan for her work on data cleaning and validation of the original dataset.

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