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Do cardiometabolic, behavioural and socio-economic factors explain the 'healthy migrant effect' in the UK? Linked mortality follow-up of South Asians compared to White Europeans in the Newcastle Heart Project

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Abstract

Background

Immigrants are sometimes found to have better health than locally born populations. We examined the mortality experience of South Asian origin and White, European origin individuals living in Newcastle upon Tyne, UK.

Methods

A linked 17-21 year mortality follow-up of a cross-sectional study of European (n=825) and South Asian (n=709) men and women, aged 25-74 years, recruited between 1993-7. Poisson regression was used to estimate mortality rate ratios (MRR) for all-cause mortality. Sensitivity analysis explored the possible effect of differences between ethnic groups in loss to follow-up. The impact of adjustment for established risk factors on MRRs was studied.

Results

South Asians had lower all-cause age and sex adjusted mortality than Europeans (MRR 0.70; 95% confidence interval 0.58, 0.85). There was higher loss to follow-up in South Asians. Sensitivity analyses demonstrated that this did not account for the observed lower mortality. Adjustment for cardiometabolic, behavioural and socio-economic characteristics attenuated but did not eliminate the mortality differences between South Asians and Europeans, although confidence intervals now cross 1 (MRR 0.79; 95% confidence interval 0.55, 1.13).

Conclusions

South Asians had lower all-cause mortality compared to European origin individuals living in ~~the UK~~ Newcastle upon Tyne that were not accounted for by incomplete mortality data. It is possible that such migrants to the UK have the resources and motivation to move in search of better opportunities, and may be healthier and wealthier than those who remain in their country of origin.

These findings challenge us to better understand and measure the factors contributing to their survival advantage.

Keywords: migrant health, all-cause mortality, South Asians

Summary box

What is already known on this subject?

- Migrants from poorer to richer parts of the world sometimes have better health than the locally born population
- This might be because of a *healthy migrant* effect – people who migrate have good physical and psychological health

What does this study add?

- South Asian migrants to Newcastle-upon-Tyne, UK have lower all-cause mortality than Europeans
- Our findings support the *healthy migrant* hypothesis
- Established risk factors do not wholly account for the difference in mortality rate between South Asians and Europeans

Introduction

Several studies have shown that migrants moving from poorer to richer parts of the world sometimes have better health than locally born populations.(1-6) For example, lower mortality has been observed in Hispanics, especially Mexican born people, compared to non-Hispanics living in the USA(7). A 'healthy migrant' effect has been proposed to explain this. Migrants might be self-selected for the good physical and psychological health needed to emigrate internationally. Data artefacts have also been proposed. For example, the 'salmon bias' hypothesis suggests that mortality rates for immigrants in the host country are artificially lowered by individuals who become sick, and subsequently return to their country of origin, with their death not being recorded in the host country.(8-10) Recent studies, however, suggest salmon bias does not explain the phenomenon (8) and have pointed to lifestyle explanations, particularly smoking.(11)

European mortality data from six countries show a complex picture that is influenced by country of birth, country of destination, and sex.(12) A healthy migrant effect was apparent for South Asian born populations in Scotland and France, but not in England and Wales, and comparatively higher mortality was found in Denmark. In England (data sometimes combined with Wales), unlike Scotland, the evidence of a healthy migrant effect in relation to South Asian populations is unclear. Around the 1991 census, Gill et al reported lower mortality in Pakistani men, and Pakistani and Bangladeshi women but higher mortality in Indian men and women, and Bangladeshi men.(13) Around the 2001 census in England and Wales, Wild et al(14) found no clear healthy migrant effect with similar all-cause mortality in people born in Pakistan and Bangladesh, with a slightly lower standardised mortality rate (SMR) only in the Indian born men (96, 95% CI 94-98). These kinds of study are subject to numerator-denominator and other biases as previously discussed.(13, 15) Studies from the UK Office for National Statistics (ONS) Longitudinal Survey, linking a sample from decennial censuses to individual outcomes, also provide little evidence of a South Asian mortality

advantage, whether considered by country of birth or ethnic group, as we consider further in the discussion.(14, 16, 17)

The aim of this study was to address three questions: 1) Is there evidence of a healthy migrant effect when comparing South Asians (and subgroups of Indians, and Pakistanis+Bangladeshis combined) and White Europeans living in Newcastle upon Tyne, UK? 2) To what extent might differences in mortality be a result of incomplete data on mortality, especially in South Asians? 3) To what extent might differences in established cardiometabolic, lifestyle and socio-economic risk factors account for differences in all-cause mortality rates?

Methods

Study design

The Newcastle Heart Project (NHP) is a cross-sectional study in men and women of European (n=825) and South Asian (n=709) origin, aged 25-74 years and resident in Newcastle-upon-Tyne in 1993-7 with linked mortality follow-up. Details have been published.(18) Briefly, European participants comprised a systematic random sample from 6448 people sampled from the Family Health Services Authority (FHSA) register (a list of all patients registered with a general practitioner in the UK, estimated to include 95% of the population,(19)) who had participated in a prior postal survey (the Newcastle Health and Lifestyle Survey). Of 1744 Europeans sampled, 1308 were contacted and 840 (64.2%) screened. South Asians comprised a systematic random sample from 7482 South Asian sounding names identified from the FHSA register using established name-searching techniques.(20, 21) Of 2160 individuals identified with South Asian sounding names, 1050 were contacted and 709 were screened (67.5%). Europeans were defined as individuals with ancestral origins in European countries and were identified by excluding people from ethnic minority populations. South Asians were defined as individuals with three or more grandparents born on the South Asian subcontinent and self-identified as Indian, Pakistani, or Bangladeshi at interview.

Ethics

Newcastle upon Tyne Joint Ethics Committee approved the study. Written informed consent was obtained from participants.

Baseline measurements

Interviews and clinical data collection sessions occurred between April 1993 and October 1994 for Europeans and between May 1995 and March 1997 for South Asians. South Asians (Indians, Pakistanis and Bangladeshis) confirmed ethnicity at interview. The study included biochemical, haematological, anthropometric and blood pressure measurements, and an electrocardiogram.

Mortality follow-up and coding of causes

Participants in the NHP were flagged at baseline for mortality with ONS, which informed us of any deaths. All participants traced until 31 May 2014 were included here. Participants' status was recorded as alive and traced, deceased, embarked (no longer resident in England and Wales) or cancelled, meaning that the participant's status was not known (i.e. lost to follow-up).

Data and statistical analysis

Person years at risk for each participant were calculated as time from recruitment to the census date or date of death or date of recorded loss to follow-up.

Mortality rate ratios (MRRs) for South Asians, and Indians and Pakistanis+Bangladeshis (combined) separately, with Europeans as a reference for all-cause mortality were estimated using Poisson regression with a robust variance estimator.(22) We have previously reported that South Asians are a heterogeneous group.(18) Ideally Indians, Pakistanis and Bangladeshis should be considered separately in analyses. Due to small numbers in the Bangladeshi group, and similarity in CVD risk factor profile between the Pakistani and Bangladeshi groups, in contrast to marked differences between these two groups and the Indian group, Pakistanis and Bangladeshis were combined for these analyses. MRRs were, adjusted for age and, when appropriate, also for sex. Sensitivity analysis applied three assumptions to those who were lost to follow-up: 1) all had died; 2) mortality rates were the same as in those with known status; 3) mortality rates were double those with known status.

We explored if the putative risk factors (see Box. Risk factors considered) were associated with all-cause mortality in South Asians and White Europeans separately and if they exerted an influence on the MRR, comparing South Asians and White Europeans. To examine the effect of established risk factors on the MRR for all-cause mortality, we selected those variables established in previous studies to be the most important in terms of their impact on health and mortality and that represent

each risk factor domain (anthropometry, lifestyle, glucose, lipids, blood pressure and socio-economic position). These were: (body mass index [BMI], waist-to-hip ratio,(23) diabetes,(24) low density lipoprotein (LDL), hypertension, physical activity, smoking, diet, alcohol consumption(25) and social class(26) on the MRR for all-cause mortality, age and sex were entered into an initial Poisson regression model. In subsequent models variables were added as follows: health behaviours (model 2: physical activity, smoking, diet, alcohol consumption), anthropometric measures (model 3: BMI and waist-to-hip ratio), biochemical measures and blood pressure (model 4: diabetes, LDL cholesterol, hypertension) and finally, social class (model 5). For continuous variables relationships were assumed to be linear.

Box. Risk factors considered

Factors included in studying relationship between all-cause mortality and ethnic differences in all-cause mortality

Age (years) and sex

Anthropometry: BMI (weight[kg]/height[m]^2), waist circumference (cm), waist to hip (circumference) ratio (WHR)

Biochemistry: fasting blood glucose (mmol/l), 2-hour post 75g glucose challenge blood glucose (mmol/l), fasting insulin (mu/l), 2-hour post 75g glucose challenge insulin (mu/l), HOMA estimated insulin resistance (HOMA-IR); diabetes diagnosed at screening with an oral glucose tolerance test (WHO criteria), dysglycaemia (defined as fasting glucose $\geq$6.1 mmol/l and/or 2-hour post challenge glucose $\geq$7.8 mmol/l)

Lipids: triglycerides (mmol/l), total cholesterol (mmol/l), high density lipoprotein (HDL; mmol/l), LDL (mmol/l), dyslipidaemia (triglycerides greater than or equal to 1.7mmol/l and/or HDL less than or equal to 1.0(M)/1.3(F) mmol/l)

Blood Pressure: systolic blood pressure (SBP; mean of two measurements, mmHg), diastolic blood pressure (DBP; mean of two measurements, mmHg), hypertension (BP $\geq$140/90 mmHg)

Self-reported health and health behaviours: doctor diagnosis of diabetes, 'healthier' diet (defined as reporting consumption of at least 2 portions of fruit or vegetables most days), physically active (defined as reporting at least 30 minutes of daily activity of at least moderate intensity), alcohol consumption (units per week reported and categorised as less than or greater than 7 units per week), smoking status (self-reported as never, former or current)

Self-reported socio-economic circumstances: social class (categorised as manual or non-manual occupation of the "head of household"), level of education (categorised as attending Further/Higher Education or lower educational attainment), household income (adjusted for household composition: reported household income/[1+0.7 for each additional adult + 0.5 for each child in the household]), Townsend Deprivation Score (TDS): an ecological, measure of material deprivation at the census enumeration district level.(27)

The analysis was repeated to estimate mortality rate ratios for South Asian subgroups. The small number of events, especially in Bangladeshis, led us to combine Pakistani and Bangladeshi groups. MRRs for all-cause mortality were estimated for the Indian subgroup and Pakistani+Bangladeshi

(combined) sub-group compared to the European population and for the Pakistani+Bangladeshi (combined) sub-group compared to the Indian population.

All data were adjusted for age and sex (or both simultaneously) and 95% confidence intervals for MRRs and p values were calculated. Analysis was conducted using Stata 14.1 (StataCorp. 2015. College Station, TX: StataCorp LP).

Results

Baseline characteristics

Baseline characteristics for NHP participants have been published and described in detail.(18) Most Indians (86%) and Pakistanis (93%) and all Bangladeshis in the NHP were born on the Indian subcontinent. The median age at migration was 24 years (inter quartile range 10.2 years). The Pakistani+Bangladeshi population was socio-economically disadvantaged compared to the European and Indian population on several indicators, including income and Townsend score. Fewer Indians than Pakistanis+Bangladeshis and European men were employed in a manual occupation. Pakistani+Bangladeshi women (but not men) had lower levels of education than both Indian and European women. The groups were similar in age at recruitment to the study, although Pakistani+Bangladeshi women were younger than the European and Indian women (medians were 46.7 years, 52.4 years and 53.0 years respectively).

Higher waist-to-hip ratios were seen in the South Asian groups compared to the European groups. The South Asian groups generally had a worse metabolic profile than European men and women (higher prevalence of diabetes and dyslipidaemia), but reported several healthier lifestyle behaviours (better diet and lower levels of alcohol consumption), although lower physical activity. There was a lower prevalence of hypertension in Pakistani+Bangladeshis compared to the Europeans and Indians.

Follow-up for mortality and sensitivity analyses

Median follow-up time was 23.1 years (range min 2.5 to max 23.1 years) for Europeans and 19.4 years (0.9 to 19.4) for South Asians. Status information was obtained for all 684 South Asians and

817 Europeans followed to 31 May 2014 (Figure 1). Of these 34 (5%) South Asians (7 Indian, 19 Pakistani, 8 Bangladeshi) and 4 (0.5%) Europeans could not be traced.

(Figure 1 here)

During follow-up 278 deaths occurred in Europeans (34% of participants) and 128 (18.7%) in South Asians of whom 47 [18.1%] were Indians, 61 [20.1%] Pakistanis, and 20 [16.7%] Bangladeshis. The Pakistani and Bangladeshi groups were, henceforth, combined.

Table 1 shows that South Asians had lower age adjusted mortality rates and mortality rate ratios from all-causes than Europeans (MRR 0.70; 95% CI 0.58, 0.85). Supplementary table 1 shows that Pakistanis+Bangledeshis had a lower MRR than Europeans, but higher MRR than Indians.

(Table 1 here)

Table 2 shows all-cause mortality for European, Indian and Pakistani+Bangladeshi groups with, firstly, Europeans as reference and secondly with Indians as reference. Both the Indian and Pakistani+Bangladeshi groups had lower risk of all-cause mortality than the Europeans, but the Pakistani+Bangladeshi group had an increased risk compared to the Indian group, although the confidence interval included 1 (1.29; 95% CI 0.93 to 1.80).

(Table 2 here)

Table 3 shows that if all individuals lost to follow-up had died the MRR for South Asians compared to Europeans would be 0.86 (95% CI 0.71 to 1.57) for all-cause mortality. If the mortality rate was double that of those with known status the MRR would be 0.73 (95% CI 0.60, 0.90). If the mortality rate was the same as in those with known status the MRR would be 0.71 (95% CI 0.58, 0.88).

(Table 3 here)

MRRs in relation to univariable and multivariable analysis of risk factors and in relation to differences in all-cause mortality in South Asians compared to Europeans

Univariable associations were in the expected direction in both Europeans and South Asians, although 95% CIs often included 1 (supplementary table S2). In Europeans, obesity, current or former smoking, lower social class and higher Townsend score (indicating worse socio-economic deprivation) were most clearly associated with increased risk of mortality. Completing secondary education was associated with lower risk of mortality.

In South Asians having diabetes, being a current smoker and lower social class were most strongly associated with increased risk of mortality.

Supplementary table S3 shows equivalent associations for the Indian and Pakistanis+Bangladeshi groups separately. Current smoking was associated with increased risk of mortality in the Indian group while increasing BMI and waist circumference appeared to be associated with a reduced risk of mortality in Pakistanis+Bangladeshis. Lower social class and diabetes were associated with higher mortality risk in Pakistani+Bangladeshis.

Supplementary tables S4 and S5 show, in multivariable analysis, that current smoking was the factor most consistently associated with increased mortality in Europeans and South Asians.

Effect of adjusting for risk factors on MRRs for all-cause mortality in Europeans and south Asians

Table 4 shows that adjustment for anthropometric measures (Model 2) reduced the age and sex adjusted risk of mortality for South Asians compared to Europeans, consistent with the higher BMI and especially WHR found in the South Asians increasing their mortality risk. When lifestyle factors were added to the model (Model 3) the MRR for South Asians increased slightly and the confidence

intervals for the estimate included 1 (MRR 0.74; 95% CI 0.55, 1.01). The addition of biochemical markers and hypertension (Model 4) yielded a very similar MRR to the age and sex adjusted only model. In the fully adjusted model (Model 5), in which social class was added, the MRR for South Asians compared to Europeans was 0.79 (95% CI 0.55, 1.13). We examined the impact of restricting the analysis to deaths from CVD and cancer, conditions most strongly related to the risk factors considered. The results were similar to those obtained when all-cause mortality was the outcome, but with somewhat lower MRRs for the models including lifestyle, biological and socio-economic factors (MRR=0.66, 95% CI 0.45 to 0.97; 0.64, 0.64, 0.43 to 0.97; and 0.65, 0,42 to 1.02 for models 3, 4 and 5 in Table 4 respectively). In addition, to take account of the potential impact of including individuals of South Asian origin who were born in the UK, rather than migrants, in our analyses, we repeated the analyses excluding those Indians and Pakistanis not born on the Indian subcontinent. Our findings were not altered. For model 5, including all the risk factors considered: MRR= 0.80 [95% CI 0.55, 1.16], compared to 0.79 [0.55, 1.13]).

Supplementary table S6 shows that all-cause mortality in the Pakistani+Bangladeshi group was similar to that in Indians after adjustment for all the risk factors considered.

To examine the impact of duration of residence in the UK on our results we repeated the analyses including duration of residence in the UK for South Asian migrants in the models presented in Table 4. This resulted in somewhat smaller MRRs (for example, model 5: MRR =0.70 [95% CI 0.39, 1.27] compared to 0.79 [0.55, 1.13]), indicating greater disparity in mortality between the South Asian and European groups, but did not alter the findings, nor our interpretation of them.

We adjusted our analyses for age and sex. We also conducted sex-specific analyses. The patterns were similar when men and women were considered separately. For example, the age adjusted MRR (95% CI) for South Asian compared to European men was 0.67 (0.52, 0.86) and for women 0.75 (0.56, 1.01)

(Table 4 here)

Compared to Indians (supplementary Table S5), Pakistanis+Bangladeshis had a higher age and sex adjusted MRR of 1.24 (95% CI 0.89 to 1.74). Adjustment for most variables had little effect on the estimate of mortality risk, although adjustment for lifestyle factors (including smoking) and social class attenuated the relationship. Compared to Europeans (Table 4) Indians had a lower age and sex adjusted MRR of 0.63 (95% CI 0.47, 0.84). After adjustment for lifestyle factors, biological variables and social class this relationship was no longer apparent. Compared to Europeans (Table 4) Pakistanis+Bangladeshis had a lower age and sex adjusted MRR of 0.87 (95% CI 0.78, 0.97). Adjustment for anthropometric, lifestyle and biological variables did not alter the MRR. After adjustment for social class confidence intervals widened (0.71 to 1.05).

Discussion

In contrast to results from other studies in England and Wales(13, 14, 16, 17) but in line with results from Scotland,(6) South Asians, including both Indians and Pakistanis+Bangladeshis separately, had lower all-cause mortality than Europeans. Even assuming that the mortality rate in those lost to follow-up was twice that in those with known status we still found lower all-cause mortality in South Asians than in Europeans. Established risk factors that we were able to explore within this study did not wholly account for the lower all-cause mortality rate in South Asians, which could, therefore, be attributable to the healthy migrant effect. The difference between Indians and Pakistanis+Bangladeshis was in line with our predictions based upon an examination of cardiovascular risk factor patterns.(18, 28)

Cross-sectional analyses have reported lower all-cause standardised mortality ratios in South Asian groups (Indian born, Pakistani born and other South Asia born) than in the Scotland born population in Scotland(6). In New Zealand and USA the same has been found.(29, 30) In England and Wales the results have been contradictory.(13, 14) Two studies from the ONS Longitudinal Study have not found a healthy migrant effect in South Asians (identified by country of birth and also by ethnicity)(16, 17) but a third one has, and reported that it is not a data artefact.(31, 32) In this context, our new work on a well characterised sample, with linked mortality follow-up adds to existing knowledge.

The selection of healthy people at the point of migration and both loss to follow-up and remigration at the onset of chronic diseases (salmon bias) (5, 9) have been suggested as explanations for the lower mortality observed in migrants. The evidence for these explanations is sparse. Recent studies in the US have examined the importance of classical risk factors, especially smoking, on differences in mortality rates between ethnic or country of birth groups.(4, 11, 33) We have previously reported that differences exist in risk factors between Europeans, Indians, Pakistanis and Bangladeshi origin

individuals living in the UK.(18, 34, 35) We have linked these data to mortality to shed light on the potential healthy migrant effect in South Asians in England.

Our study aligns with the evidence that migrants experience lower mortality than the locally born population (the healthy migrant hypothesis) and we could speculate that the high proportion of South Asian men (although not women) who had post-secondary education in our sample (41% compared to 21% in the locally born population) supports the hypothesis that those with the greatest resources are more likely to migrate. However, our study did not find that established risk factors, including lower socio-economic status, are the determinant factors for differences in mortality between migrants and the locally born population. However, in Indians, although not in Pakistanis+Bangladeshis, lifestyle factors, including smoking, attenuated the difference in mortality rate compared to Europeans. As indicated above, the data on the healthy migrant effect in South Asians in England and Wales is contradictory,(13, 14, 31, 32) though more clear cut in Scotland.(6) There are unresolved questions around whether or not the mortality advantage in immigrant groups is lasting, and whether it will cross generations. Most analyses are based on country of birth, although the importance of studying ethnic minority groups (comprising immigrants and their offspring) is increasingly recognised. In relation to chronic diseases the data suggest that, over time, and probably as a result of acculturation and the adoption of lifestyles that promote chronic diseases, the healthy migrant effect dissipates,(3, 16, 36-38) although this was not found in Australia.(39)

Our analysis suggests that the lower mortality rate in South Asians compared to Europeans is not wholly attributable to differences in socio-demographic, economic and lifestyle, clinical or biochemical risk factors, contrasting with recent studies in the US.(4, 11, 40, 41) In our analysis we were able to check whether risk factor-outcome relationships were in alignment with the literature and similar in South Asians and Europeans. Mostly, this was the case. One surprising result was the

lack of association (perhaps even an inverse association) in South Asians between indicators of adiposity and obesity (WHR and BMI) and mortality, which contrasted with that in Europeans. While surprising, this result aligns completely with three major cohorts on the Indian subcontinent.(42-44) This finding is important and deserves more research given the emphasis on reducing the BMI cut-off to signify overweight and obesity in South Asians.(45)

We considered whether or not bias from returning to country of origin (salmon bias) or unexpected and unrecorded deaths abroad played a major role in explaining lower mortality in South Asians compared to Europeans. Even when the extreme assumption was made that all those of South Asian origin who were lost to follow up had died, their all-cause mortality experience was similar to that of Europeans. Given recent findings that this kind of bias is unlikely to be important,(8) and given the quality and availability of health care free at the point of delivery in the NHS in the UK, we think it unlikely that the majority of people with chronic diseases would emigrate to their countries of origin.

An alternative to the healthy migrant and salmon bias theories to explain lower mortality in first generation immigrant populations in wealthy countries has been suggested.(46) Razum and Twardella propose that immigrants from lower-income countries experience a health transition that is rapid in terms of gaining access to improved medical treatment but slow with regard to the impact of CVD risk factors exerting an influence on mortality.(46) They suggest this unusual health transition means that immigrants experience a short term mortality advantage. It will be possible to examine the role of this theory in explaining low mortality among migrants in the future, as subsequent generations of immigrants age.

Strengths and limitations

The strengths of our study include a well characterised sample of South Asians and Europeans, with detailed information at baseline, including a wide range of potential explanatory risk factors; long-term follow-up with individual linkage of outcomes to the baseline sample; setting in the UK where

health care is provided free at the point of delivery, and death certification is by a qualified medical practitioner; and the relatively small loss to follow-up combined with the capacity to undertake sensitivity analysis to evaluate the potential biases of this.

Cross-sectional analyses of mortality, where death certificates provide the numerator and data on country of birth (usually) or ethnicity (very rarely), and the population register or census provides the denominator, are subject to numerator and denominator errors.(6, 14, 47) Yet, these are the most common types of analysis. A strength of this study is that we used mortality data linked to individuals from the Newcastle Heart Project. This provided data on both country of birth and ethnicity, which was self-defined and based on ancestry, giving an accurate rate of mortality by ethnic group. The majority of South Asian participants in the NHP were born in South Asia and migrated to the UK.

In common with most similar studies(48) we relied on a single baseline measurement of risk factors. The use of a single measurement may have resulted in misclassification at baseline, due to both biological variation and measurement error. Such, non-differential, misclassification would tend to minimise any true associations. In addition, we were unable to take changes that occurred in these risk factors during follow-up into account in our analyses. Failure to take changes in risk factors into account is likely to have resulted in some dilution of the risk calculated to be associated with the factors considered.(49) It is possible that, if the true association between the risk factors and mortality was stronger than we estimated, the mortality difference between South Asians and Europeans observed would be attenuated. There is evidence that improvements in risk factors during follow-up might be greater in Europeans than South Asians,(50) which suggests that is we had follow-up measures of risk factors the gap between the Europeans and South Asians is likely to have narrowed. We relied on self-reported measures of diet and physical activity. We used daily consumption of daily fruit and vegetables as an indicator of diet quality, but this is a rather imprecise measure and does not take account of, for example, other macro-nutrients in the diet.

Substantial heterogeneity exists between the South Asian sub-groups (Indian, Pakistani and Bangladeshi), in risk factor profile(18) and now, seemingly, mortality experience. Presently, the numbers of deaths are too small to identify precisely relationships that might exist between risk factors and mortality within the South Asian sub-groups, and especially the Bangladeshi group separately.

An examination of mortality by specific cause of death (for example cardiovascular disease) was not possible at present as the number of events was too small (87 cardiovascular disease deaths in Europeans and 61 in South Asians).

We have, as with virtually all studies of this kind, no information on those lost to follow up, so are unable to draw conclusions on whether or not they have returned to their country of origin and if they are still alive.

To address questions about whether or not the healthy migrant effect reflects a selection bias, whereby healthy populations are more likely to emigrate, we would need to compare migrants with equivalent non-migrants still resident in the countries of origin and ideally would need to have information on migrants' health prior to migration. These kind of analyses are rare(51) and not possible in our data set.

Future work should study the mortality experience of younger cohorts of South Asians, both immigrants and those born in the UK. Based on the worse risk factor profile we have identified in the South Asians in the NHP, which might be attributable to acculturation (i.e. immigrants adopting the lifestyles of the resident population), we might hypothesise that second and third generation UK South Asians, born in the UK, will not benefit from the health advantage of their parents and grandparents and may have higher mortality than the European population. However, this cannot be assumed as, mostly, convergence has been found to be slow with the exception of diabetes and heart disease. In addition future studies seeking to explore the role of selection bias in the future

health experience of migrants should consider collecting data on health and social status on individuals planning to migrate prior to migration and simultaneously on individuals who plan to remain in their country of origin, where possible.

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All authors have read and approved the final manuscript.

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Competing interest: None declared

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Contributorship Statement

LH contributed to the planning, conduct and interpretation of data analyses, and was the lead writer. RB, MW and NU contributed to the study hypotheses and design, supervision, screening, planning and interpretation of data. RM contributed to the planning and interpretation of data analyses. AT contributed to data management and planning of analyses. All authors read and agreed the final manuscript.

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Table 1. All-cause mortality in the Newcastle Heart Project: age standardised rates per 1000 person years [a] (95% CI)

	Men		Women		Both	
	European	South Asian	European	South Asian	European	South Asian
Person years of follow-up	8018	5550	8222	6407	16240	11957
Number of deaths	168	72	110	56	278	128
Mortality rate [a] (95% CI)	17.9 (15.2, 20.6)	11.7 (9.0, 14.4.0)	12.8 (10.4, 15.2)	9.5 (7.0, 12.1)	15.3 (13.5, 17.1)	10.4 (8.6, 12.2)
MRR (95% CI) [b]	1.00	0.67 (0.52, 0.86)	1.00	0.75 (0.56, 1.01)	1.00	0.70 (0.58, 0.85)

Mortality is based on known status; where status was unknown the individual was assumed to be alive

[a] Directly standardised to the England and Wales population 2001

[b] Adjusted for age

Table 2. Comparison of all-cause mortality – Europeans compared to South Asian sub-groups, and Indians compared to Pakistanis+Bangladeshis

	European	Indian	Pakistani+Bangladeshi
		MRR (95% CI)	**MRR (95% CI)**
Person years of follow-up	16240	5950	6008
All-cause mortality	1.00	0.63 (0.47, 0.84)	0.75 (0.60, 0.94)
All-cause mortality		1.00	1.29 (0.93, 1.80)

Table 3. Sensitivity analyses – South Asian compared to European mortality, assuming three different mortality rates among South Asian participants who were lost to follow-up

	All-cause
	MRR (95% CI)
Scenario 1 (all lost to follow-up died)	0.86 (0.71, 1.57)
Scenario 2 (rate in lost to follow up equal to known)	0.71 (0.58, 0.88)
Scenario 3 (rate in lost to follow up double known)	0.73 (0.60, 0.90)

Table 4. Poisson regression for all-cause mortality during follow-up, by ethnicity (South Asians, Indians and Pakistanis+Bangladeshis compared to Europeans [reference])

	South Asian			Indians			Pakistanis+Bangladeshis		
	MRR	95% CI	p	MRR	95% CI	p	MRR	95% CI	p
Model 1:									
Age and sex	0.70	0.58, 0.85	<0.001	0.63	0.47, 0.84	<0.001	0.87	0.78, 0.97	0.014
Model 2:									
Model 1 + BMI and waist-to-hip ratio	0.59	0.47, 0.75	<0.001	0.51	0.37, 0.71	<0.001	0.78	0.68, 0.90	<0.001
Model 3:									
Model 2 + physical activity, smoking, diet, alcohol consumption	0.74	0.55, 1.01	0.056	0.74	0.49, 1.12	0.150	0.84	0.71, 0.99	0.041
Model 4:									
Model 3 + diabetes, LDL cholesterol, hypertension	0.73	0.53, 1.00	0.051	0.75	0.49, 1.16	0.194	0.82	0.69, 0.98	0.026
Model 5:									
Model 4 + social class	0.79	0.55, 1.13	0.196	0.81	0.48, 1.37	0.434	0.86	0.71, 1.05	0.147

* Diabetes and hypertension = known + newly diagnosed at screening

Figure legends

Figure 1. Follow-up of NHP cohort (1991-2014)