Estimating Diabetes Prevalence by Small Area in England

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Abstract. Diabetes risk is strongly linked both to deprivation and ethnicity and so prevalence will vary considerably between areas. This paper uses prevalence rate data by age, sex and ethnicity from the Health Survey for England to estimate diabetes prevalence for 354 English local authorities and eight thousand smaller areas (electoral wards). A prevalence adjustment for social factors is based on diabetes prevalence according to area deprivation quintiles. The resulting prevalence estimates are used to assess variations between areas in adverse hospitalisation indicators for diabetics and to assess the relationship between diabetes related mortality and prevalence.

Key Words. Prevalence. Mortality. Performance Indicators. Diabetes. Social gradient. Small Area. Ethnic Relative Risks.

1 Introduction: Relevance of Estimating Diabetes Prevalence

Diabetes is a risk factor for cardiac disease and stroke, and has complications such as blindness, kidney failure, and nerve damage leading to amputation. Diabetes prevalence has been rising in developed countries across all age and ethnic groups. For England, the 2003 Health Survey for England (HSE) showed 4.3% of adult males (16 and over) to have the disease, as do 3.4% of adult females – this compares to 2% for both sexes in

1991 (Figure 1). The 1999 HSE found major variation in diabetes prevalence by ethnic group (Primatesta and Brookes, 2001); see Figure 2. Further rises in prevalence are forecast (Amos et al, 1997). Most of the expected increase is in Type 2 diabetes, attributable in part to an ageing population (diabetes risk rises with age), growth in the ethnic elderly (with higher diabetes rates), but also to rising levels of obesity and other risk factors for diabetes (Evans et al, 2000; Meadows, 1995). There is also evidence of increased type 1 diabetes in children (Rangasami et al, 1997).

The future burden of diabetes care is therefore set to increase due to increased prevalence across all age and ethnic groups. However, in some areas in England, especially certain metropolitan areas, national trends are compounded by the impact of deprivation - especially important for the more common type 2 diabetes (e.g. Agardh et al, 2004) - and by large ethnic minority populations with high diabetes risk. Estimating current prevalence and extrapolating prevalence by small area is important both in providing and targeting diabetes care, and in assessing the quality of diabetes health care.

The question of appropriate treatment in appropriate settings involves questions such as appropriate therapy in primary care (Kelly et al, 1994; Clarke and Lee, 1995), avoidance of emergency hospitalisations related to diabetes, and lessening the rate of adverse outcomes. For example, Figure 3 shows wide variations between English strategic health authorities on two hospital outcomes (based on data for two financial years, 2000-1 and 2001-2): namely, a two fold variation in the persons rate for diabetic ketoacidosis (DKA) & coma, and nearly three fold variation in lower limb amputation rates. Such variation in health performance may be due in part to genuine variations in morbidity, but may also reflect variations in care effectiveness or imbalances between resourcing, provision and need; see Hippisley-Cox et al (2004) and Kelly et al (1994) on inverse care in diabetes.

The analysis here provides small area estimates of both types of diabetes based on recent evidence of age, sex, and ethnic group prevalence differences, with an additional adjustment for the impact of social deprivation. It demonstrates how prevalence estimates may be used in assessing variations in health performance indicators and explaining geographic variations in diabetes-related mortality. The application to performance indicators (e.g. rates of diabetic amputation) is based on comparing the level of adverse outcomes to an estimated prevalent population as well as (or possibly instead of) to the 'expected' cases based on demographic standardisation taking account of age-sex variations in the adverse outcome itself. An excess of adverse outcomes in relation to prevalence is suggestive of deficiencies in health care (beyond the effect of what can be attributed to morbidity); it may also indicate inadequate funding in relation to need.

2. Assumptions on Age and Ethnic Risk Used in Obtaining Prevalence Estimates

Data from the 1999 and 2003 Health Survey for England are used here to provide benchmark rates of diabetes by age, sex, ethnic group, and specific for diabetes types 1 and 2. The 2003 Health Survey for England provides prevalence data by age, sex, and social group. However, the 1999 Survey was the last designed to provide reliable information on prevalence by ethnicity, especially on ethnic subgroups with varying prevalence; this was achieved via a weighted follow up survey that, inter alia, achieved sufficient coverage of South Asian sub-groups to provide estimated sub-group relative risks.

Variations in diabetes prevalence by social position are also important: Table 1 shows the social gradient in diabetes (2003 HSE) by the Office of National Statistics socio-economic classification (NS-Sec) and by equivalised household income (household income adjusted for the number of people in a household). The prevalence of diabetes rises in adult males from 2.3% in the highest income quintile to 6.1% in the lowest; and in women from 1.7% to 4.0% respectively. This strong gradient is noted in the HSE 2003 report (ONS, 2004) as are regional contrasts (see Table 1), with highest prevalence in London, and lowest in the South West (men) and North East (women). To convert individual survey evidence to small area prevalence requires equivalent variables in both the Census (or some other area based information source) and the individual survey. Of the two socio-economic classifications in Table 1, the NS-Sec classification can be replicated using area data from the 2001 Census, but income information is not provided by the UK Census.

As a first step in making the area prevalence estimates, age-sex-ethnic group prevalence rates obtained from the 2003 and 1999 HSE are applied to small area level from the 2001 Census (age sex-ethnic group population totals). Specifically, gender-specific relative risks for the major ethnic groups from the 1999 HSE are applied uniformly across age-sex group prevalence rates from the 2003 HSE to produce ethnic/age/sex specific rates. The assumption of proportionality in the impact of age and ethnicity on relative risks underlying this procedure was confirmed by analysis of data from the 1999 HSE (see Appendix Table 1). The age-sex-ethnic rates derived from combining information over the 2003 and 1999 HSEs are applied to 2001 ward populations by age, sex and ethnicity (ST101 Tables) to give initial estimates of ward level prevalent populations. These are then adjusted for the impact of social factors on prevalence as described below.

The ethnic groups on which the 1999 HSE provides information are whites, black Caribbeans, Indians, Pakistanis, Bangladeshis, and Chinese. In line with the 1999 HSE prevalence data, the prevalence of diagnosed type 2 diabetes in black Caribbean men is assumed to be 2.5 times greater than for white men, while for women the relative risk is 4.2. As in Goyder et al (2002) it is assumed that other black ethnic groups have the same relative risks as black Carribeans. Chaturvedi et al (1993) also found the prevalence of type 2 diabetes for black males to be about twofold that of white males and a prevalence for black females fourfold that of white females. Type 1 diabetes is assumed to have the same prevalence across all ethnic groups. Type 1 diabetes rates for under 16s are based on Scottish data from Rangasami et al (1997), averaging 24 per 100,000. Type 2 diabetes among children in England is still rare as compared to the USA (Kaufman, 2002) but there is some evidence of its recent emergence, partly due to child obesity. Recent work by Ehtisham et al (2004) has suggested a prevalence of 2.1 per million for ages under 16.

3 Adjusting for Social Structure and Deprivation

To adjust for social structure one option is to compare the NS-Sec ward or local authority level composition to that for England, and obtain an adjustment factor that takes account of the variation in relative risks over the NS-Sec occupation categories, as provided by the HSE for 2003 (see Table 1). Thus an area with many routine (manual) workers would have its age-sex-ethnic rates adjusted upwards and an area with many professional/managerial workers would receive a downward adjustment. If the relative risks for J occupation groups are $r_1, r_2, .. r_J$ then the adjustment for an area with totals $n_1, .. n_J$ in each group would be

$$\sum_j r_j n_j / \sum_j n_j$$

However, some drawbacks with the NS-Sec classification have been encountered in terms of representing social contrasts in behaviour and health (Meier & Moy, 2004). Also such an adjustment procedure (taking account of occupation only) does not incorporate the full effect of social position and socio-economic deprivation, which includes factors such as education, employment status, and income.

Deprivation is especially important in explaining individual and area variation in the more common type 2 diabetes. As Riste et al (2001) note, poverty has been under-recognised as a contributory factor to varying diabetes prevalence, and standard mortality from reported diabetes (which is under-recorded) is strongly correlated with area deprivation; see also Robinson-Lloyd & Stevens (1998). Individual and area deprivation also impacts on diabetes complication rates (Bachmann et al, 2003).

An alternative procedure for obtaining a deprivation adjustment factor for prevalence estimates therefore involved assessing the impact of deprivation on gender specific diabetes prevalence. The HSE for 2003 includes the official index of multiple deprivation for 2004 (IMD2004) for the small area of residence for each survey respondent - specifically the IMD score for Census 2001 super-output area (SOA) of residence, there being circa 32500 SOAs in England. A deprivation effect on prevalence is derived via separate logit regressions of diabetes prevalence probabilities (see Appendix 2) for males and females that adjust for the effect of age and ethnicity. It may be noted that (as compared to the 1999 HSE) ethnicity is broadly recorded in the 2003 HSE and here further aggregated to white, black, Asian and other. The resulting gradient in prevalence over the IMD quintiles, expressed as a ratio to average prevalence, is (0.76, 0.84, 0.91, 1.13, 1.37) for males and (0.80, 0.84, 0.93, 1.07, 1.36) for females. An excess prevalence in the top quintile is apparent for both sexes, though the female deprivation gradient is slightly shallower.

These ratios are applied within the quintile bands defined by the SOA scores: the lowest quintile set of areas (least deprived) has IMD scores between 0.55 and 9.015, the next quintile has scores between 9.016 and 14.148, and so on. The 8000 electoral wards are allocated to the relevant band and their male/female prevalence on the basis of age structure and ethnicity alone is further adjusted by one of the five ratios above. Then prevalence is aggregated to local authorities and strategic health authorities.

One way of depicting the resulting prevalence estimates is in terms of household income estimates for the 354 English local authorities in 1999

(ONS, 2001). So a gradient in estimated prevalence over local authority areas grouped by income (e.g. income quintiles or deciles) can be obtained. Table 2 shows the estimated prevalence (cases and percents) of both diabetes types combined by area income decile. The estimated percent prevalence varies from 2.6% to 3.6% with a virtually monotonic gradient over the income deciles. Such a gradient at area level is consistent with the individual level evidence in Table 1.

4. The Pattern of Area Diabetes Type 1 and 2 Estimates

As Table 2 shows, the total England diabetes prevalent population (all ages) is estimated as 1.529 million, with the all persons all ages rate being 3.1% (males 3.4%, females 2.8%). The over 16 prevalent population estimate is 1.511 million, with the adult rate being 3.85% (4.3% males, 3.5% females). The two type estimates are 188,000 type 1 and 1.341 million type 2. At strategic health authority (StHA) level, total diabetes prevalence varies from 2.4% (Thames Valley) to 4% (North East London) – see Table 3.

At local authority level the prevalence rates vary from 5% in Tower Hamlets to 2% in Bracknell Forest. The former is located in the North East London StHA and is an area with 49% non-white ethnicity (compared to an England figure of 9%), and has high deprivation also (an IMD of 45.2 compared to the England average of 21.7). The latter is an affluent commuter area in the Thames Valley SHA with an IMD of 9 and 5% non-white ethnicity. The estimated ward level prevalence rates range from 7.4% (Latimer ward in Leicester with majority South Asian population and high deprivation) to

0.7% in Hipswell ward in the affluent rural Richmondshire district of North Yorkshire.

Estimates produced by the procedure here relate to doctor diagnosed diabetes, and can be compared with another recent prevalence analysis for England (including both diagnosed & undiagnosed diabetes) by the Yorkshire & Humber Public Health Observatory, Brent Primary Care Trust, and University of Sheffield School of Health and Related Research; this is known as the PBS model (Merrick, 2004). The model applies age/sex/ethnic group-specific estimates of diabetes prevalence rates, derived from epidemiological population studies, to 2001 Census resident populations. There is no correction for socio-economic effects in the PBS model. Also unlike the estimates derived by the procedure in this paper, female prevalence under the PBS model is higher than male prevalence (which is not consistent with the HSE data in Table 1). Discrepancies at SHA level are also apparent (see Table 3). The PBS estimated prevalence rates are relatively low for Manchester and North Central London, and high for the South West peninsula, an area with relatively low ethnic minority populations.

5. Diabetes Mortality Gradients According to Prevalence

One assessment of the predictive validity of the prevalence estimates obtained in the present study considers male and female diabetes mortality over 1999-2001 for the 354 local authorities in relation to prevalence categories. A smaller area analysis (for the circa 8000 electoral wards) is prevented by boundary inconsistencies between the 2001 Census wards and the wards used to report deaths till 2002. Let Y_{i1} denote male deaths and E_{i1} denote expected deaths (using England 2000 rates), where i=1,..,354; Y_{i2} and E_{i2} are the same quantities for women.

Then a Poisson regression is used with

$$Y_{i1} \sim Po(E_{i1}m_{i1}); \qquad \log(m_{i1})=\beta[Q_{Mi}]$$

where Q_{Mi} is the male prevalence quintile to which area i belongs. A similar regression is made for female diabetes mortality:

$$Y_{i2} \sim Po(E_{i2}m_{i2}); \qquad \log(m_{i2})=\beta[Q_{Fi}]$$

where Q_{Fi} is the female prevalence quintile to which area i belongs. The SMR according to quintile is then $100\exp(\beta[Q_i])$.

A Poisson regression is satisfactory as there is no overdispersion (deviance for males is 326 and females of 345, with N=354). The mortality gradient as prevalence increases is more regular for females (see Figures 4A and 4B). However, the top prevalence quintile for males has a higher mean SMR of 121, which compares to 87 in the lowest prevalence quintile; for females the SMR contrast between extreme prevalence quintiles is less pronounced, namely 111 vs. 88.

6. Assessing Diabetic Hospitalisation Outcomes against Prevalence.

A second validation exercise (and application) of prevalence estimates is in the analysis of health performance indicators. Performance initiatives relating to health delivery and patient outcomes have been motivated and justified in terms of concepts such as effectiveness, patient safety, health improvement, efficiency, equity and access (McLoughlin et al, 2001). In the

England National Health Service (NHS), a Performance Assessment Framework based on a set of around 60 high level performance indicators was introduced in the late 1990s with each indicator justified under one or more of six performance domains: health improvement, fair access, effective delivery, efficiency, patient experience and health outcome of care (Smith, 2002). Diabetes care indicators relate especially to provision of effective primary and community care; the goal is then to reduce hospitalisations for (a) diabetic ketoacidosis (sometimes abbreviated as DKA) and coma and (b) lower limb amputations in diabetic patients. The basis for this at patient level is through a planned programme of care and appropriate early intervention.

In the official NHS approach, these outcomes are assessed by age standardised hospitalisation or operation rates without reference to the influence of social or ethnic structure on prevalence. Such a procedure may overstate both the performance deficiencies of high prevalence areas and the apparently effective performance of low prevalence areas. To assess such effects we here compare rankings of the 28 StHAs based on (a) age standardised rates of DKA and amputations, and (b) ratios of DKA/coma episodes and amputation operations to estimated prevalent populations.

Another criterion for the validity of official diabetes performance indicators, as measures of performance per se, is that they should be uncorrelated with prevalence rates (in more technical terms, the 95% interval for the correlation should straddle zero). If performance indicators in fact are positively correlated with prevalence the implication is that they are not simply measuring performance but also reflect prevalence.

The analysis is based on diabetes indicators in the 2002 Compendium of Clinical and Health Indicators, with pooling of data over the years 2000/1 and 2001/2. Table 4 compares the official age standardised rates (ASR, in columns 6 & 7) with rates which compare event totals to prevalent population estimates (rates per prevalent population or RPP, columns 8 & 9).

There is in fact a reasonable consistency between the top ASR and RPP rankings, especially for amputation rates. The rank correlation between the ASR and RPP series for amputation is 0.78 and for DKA/coma is 0.62. So for amputation, inferences from rates which take account of age structure alone are not dramatically changed when the full prevalence pattern is taken account of. Some changes in rank do occur: for instance the top ranking StHA (28th of 28) on amputation ASRs is County Durham & Tees Valley but this area has rank 25 on the amputation RPP. For DKA and coma, the rank of Birmingham & the Black Country (with high prevalence) falls from 24th among ASRs to 11th among RPPs while that of low prevalence Hampshire/Isle of Wight rises from 14th to 24th.

Viewed in terms of the other criterion (the correlation between ASRs and prevalence rates) the DKA/coma ASR indicators do seem to some extent to be positively correlated with prevalence rates and so less clearly a true performance measure than the amputation ASRs. There is a correlation of 0.41 (95% interval 0.35 to 0.47) between the DKA/coma ASRs and the population prevalence rates in column 3, whereas the corresponding correlation for the amputation ASRs is –0.06 (95% interval –0.135 to 0.015).

7. Discussion and Conclusions

This paper has set out a procedure for prevalence estimation that can be taken to an area level for which populations are available (or estimated) by age, sex and ethnicity, and for which measures of area deprivation are calculated. Therefore it is potentially updateable outside Census years using population estimates or projections that include ethnicity (this is true, for example, of projections for London made by the Greater London Authority). Such updating is also made possible by the fact that area deprivation measures in the UK are now increasingly derived by using non-Census indicators (e.g. current unemployment and benefit uptake) and so are not reliant on the decennial Census.

A similar procedure can be applied to other diseases when survey information provides sufficient detail on ethnic group and on small area deprivation. It is also potentially extendable to prevalence forecasts by area that would include extrapolated national rates of age-sex-ethnic group prevalence as well as area projections by age, sex and ethnic group.

There are implicit assumptions of proportionality in the prevalence estimation procedure used here. However, it is often the case that health surveys include insufficiently large samples to assess statistically significant prevalence interactions between age and ethnicity or between age and deprivation category. Main effects can be established but establishing interactions might require use of informative priors (these can be included in a Bayesian analysis but not in classical approaches). While such interactions may be established as significant for a subset of population sub-groups (e.g. for Pakistani men aged 55-59 in the analysis of the 1999 HSE described in

Appendix 1) it may be that proportionality still remains justifiable over the full set of sub-groups, as judged by overall fit criteria (such as the DIC used in Appendix 1). To allow for interactions in such circumstances, while possible, would increase the complexity of the procedure.

It would also be preferable to base the estimated prevalence gradient over area deprivation levels on a finer gradation of deprivation, such as deciles of the IMD score for an analysis of English areas, since the most deprived areas (e.g. in the top 5% of IMD scores) may have their prevalence understated by a procedure relying on deprivation quintiles.

Despite such caveats it has been shown that the prevalence estimates can be used to explain variation in diabetes mortality and also have a role in analysing performance indicators. The latter do not usually consider the impact of prevalence and may give a distorted impression of performance if in fact high rates of (say) ketoacidosis and coma are partly due to prevalence variations. The analysis above in fact showed a stronger correlation between DKA/coma rates and estimated prevalence rates than between amputation and prevalence. This suggests that variation in amputation rates is largely a matter of performance and quality of care variation.

Appendix 1: Assessing proportionality of age and ethnicity impacts on diabetes prevalence.

To assess the impact of age and ethnicity on prevalence, counts of diagnosed diabetes cases from the 1999 HSE were obtained by sex, age (18 five year bands 0-4,5-9,..80-84,85+) and ethnic group (seven groups: white, black, Indian, Pakistani, Bangladeshi, Chinese, Other). The counts, denoted y_{ijk}

(i=1,2;j=1,18;k=1,7) are modelled as Poisson variables with means $\mu_{ijk}E_{ijk}$, where μ_{ijk} models the impact of sex, age and ethnicity, and E_{ijk} is the expected count in subgroup (i,j,k) based on applying the overall diabetes prevalence rate of 2.3% to the sampled population totals P_{ijk}.

A fully Bayesian modelling strategy was employed with the WINBUGS package; this involves specifying prior densities on the parameters and updating these densities using the observed data via Markov Chain Monte Carlo (MCMC) techniques. Model comparison is based on the deviance information criterion of Spiegelhalter et al (2002), with lower DIC representing a better fitting model after taking account of model complexity: a complex model might give a slightly better fit but at the expense of a large increase in parameters and model complexity (summarised in a complexity measure).

For the model terms μ_{ijk}, we assume two options: a model with proportional effects

$$\log(\mu_{ijk}) = \alpha + \beta_i+\gamma_j+\delta_k$$

and one with age-ethnic group interactions

$$\log(\mu_{ijk}) = \alpha + \beta_i+\gamma_j+\delta_k+\varepsilon_{jk}.$$

In both models the age effect is modelled using a random walk prior that assumes diabetes rates for successive age groups will tend to be similar; this is a smoothing prior (e.g. Fahrmeir and Lang, 2001) in contrast to one that retains the possibly jagged age schedule resulting from sampling fluctuations. Specifically, it is assumed that

$$\gamma_j \sim N(\gamma_{j-1},1/\tau_\gamma)$$

for j=2,..18, where N(m,V) denotes a Normal density with mean m and variance V, where the initial value γ_1 is assigned a diffuse N(0,1000) prior, and the precision τ_γ is assigned a Ga(1,1) prior. The gender and ethnic parameters β_i and δ_k are assigned fixed effects priors, with corner constraints: $\beta_1=\delta_1=0$, with β_2 ~N(0,1000) and δ_k~N(0,1000) (k=2,7). The interaction parameters are assumed random but unstructured. Thus ε_{jk} ~N(0,1/τ_ε) where τ_ε is assigned a Ga(1,1) prior.

We find that the model without interactions has a lower DIC than the model including interactions; the latter has a lower average deviance (namely 558 as compared to 580 for the no-interaction model), but the complexity measure rises from 20 to 50, so the DIC increases from 600 to 608. To assess the 'significance' of the interactions, we consider the probability that $\varepsilon_{jk}>0$ for a particular age-ethnic group (Knorr-Held and Rainer, 2001). We find that the highest posterior probability for a positive effect is 0.96 for Pakistanis aged 55-59, but no other such probabilities exceed 0.95 (the next highest is 0.93 for Bangladeshis aged 55-59). There is one probability below 0.05, in line with an age-ethnic combination at relatively low risk, namely whites aged 50-54 with Pr($\varepsilon_{11,1}$>0)=0.02.

Appendix 2 Assessing the Prevalence Gradient over Deprivation Categories.

The 2003 HSE included a five level category according to the quintile of the index of multiple deprivation of the respondent's SOA (super output area, a 2001 Census subdivision), with quintile 5 for the highest deprivation SOAs.

The HSE of 2003 did not include a weighted follow up survey to assess disease risk by ethnicity and so ethnicity is recorded broadly. Here a four way ethnic categorisation is used: white, black, Asian and other. Ages are grouped into nineteen five year bands: 0-4, 5-9, 10-14,…,85-89, 90 & over.

Then for each sex separately, logistic regressions are carried out including impacts of age, ethnicity and deprivation quintile. In this way the effects of deprivation are corrected for any impacts of age and ethnicity on prevalence. As in the Appendix 1 analysis, a fully Bayes approach is used, with a random walk prior on the age effects to smooth irregularities in the observed schedules of diabetes prevalence by age. Thus for 8439 males, let $y_i=1$ if the subject has doctor diagnosed type 1 or 2 diabetes, and 0 otherwise. Then $y_i \sim \mathrm{Bern}(\pi_i)$ (where Bern denotes Bernoulli density) and for ethnic group E_i, age group A_i and deprivation quintile D_i, let

$$\mathrm{logit}(\pi_i)= \beta[E_i]+\gamma[A_i]+\delta[D_i]$$

Viewed in terms of the ranges of the categories, j=1,..,4 (ethnic groups), k=1,..19 (age groups) and m=1,..5 (deprivation quintiles), the model can be written

$$\mathrm{logit}(\pi)= \beta_j+\gamma_k+\delta_m.$$

As in Appendix 1, the random walk prior on age effects has the form

$$\gamma_k \sim N(\gamma_{k-1},1/\tau_\gamma) \qquad k=2,..,19,$$

with $\gamma_1 \sim N(0,1000)$ and the effects centred to zero at each MCMC iteration. The deprivation effects are assumed to follow an incremental gradient, in line with well documented positive deprivation effects on diabetes prevalence. Thus

$$\delta_m \sim N(0,1000)\, I(\delta_{m-1},\delta_{m+1}) \qquad m=2,4$$

$$\delta_1 \sim N(0,1000)\ I(,\delta_2)$$

$$\delta_5 \sim N(0,1000)\ I(\delta_4,)$$

where I(a,b) means the interval from a to b, so that sampling is constrained to produce a monotonic gradient. For ethnic effects a Normal prior (with a corner constraint for identifiability) is assumed: $\beta_1=0$, $\beta_j \sim N(0,1000)$, j=2,4.

As outlined in the main text of the paper, IMD quintile specific ratios to average prevalence, denoted ρ_k, are used to scale ethnic/age prevalence rates. These are obtained (at each MCMC iteration) by calculating prevalence probabilities $\pi_k=\exp(\gamma_k)/[1+\exp(\gamma_k)]$ by quintile, then comparing π_k to the average $\bar{\pi}$, namely

$$\rho_k = \pi_k / \bar{\pi}\ .$$

The posterior means and 95% intervals for the male ratios are (starting with the least deprived quintile): 0.76 (0.65,0.86), 0.83 (0.73,0.94), 0.91 (0.80,1.04), 1.13 (0.97,1.30) and 1.37 (1.19,1.62). For the 10073 females the corresponding figures are 0.80 (0.67,0.90), 0.84 (0.70,0.94), 0.93 (0.81,1.04), 1.07 (0.93, 1.26), and 1.36 (1.14, 1.64).

References

Agardh, E, Ahlbom, A, Andersson, T, Efendic, S, Grill, V, Hallqvist, J, Goran-Ostenson, C (2004) Explanations of socioeconomic differences in excess risk of type 2 diabetes in Swedish men and women. Diabetes Care, 27, 716–721.

Amos A, McCarty D, Zimmet P (1997) The rising global burden of diabetes and its complications: estimates and projections to the years 2010. Diabetic Medicine, 14: S7-S85.

Bachmann, M, Eachus, J, Hopper, C, Davey Smith, G, Propper, C, Pearson, N, Williams, S, Tallon, D, Frankel, S (2003) Socio-economic inequalities in diabetes complications, control, attitudes and health service use: a cross-sectional study. Diabetic Medicine, 20, 921-929

Chaturvedi N, McKeigue P, Marmot M. (1993) Resting and ambulatory blood pressure: differences in Afro-Caribbean and Europeans. Hypertension, 22, 90-96.

Clark C, Lee D (1995) Prevention and Treatment of the complications of diabetes mellitus. New England Journal of Medicine, 332, 1210 - 1217

Ehtisham, S, Hattersley, A, Dunger, D, Barrett, T (2004) First UK survey of paediatric type 2 diabetes and MODY. Archives of Disease in Childhood, 89, 526–529.

Evans J, Newton R, Ruta D, MacDonald T, Morris A (2000) Socioeconomic status, obesity and prevalence of type 1 and type 2 diabetes mellitus. Diabetic Medicine, 17, 478–480

Fahrmeir, L, Lang, S (2001) Bayesian inference for generalized additive mixed models based on Markov random field priors. Applied Statistics 50, 201-220

Goyder, E, Sherry, R, Warren, E (2002) Implementing the Diabetes National Service Framework: A Diabetes Prevalence Model. University of Durham/Trent Public Health Laboratory.

Hippisley-Cox, J, O'Hanlon, S, Coupland, C (2004) Association of deprivation, ethnicity, and sex with quality indicators for diabetes:

population based survey of 53 000 patients in primary care. British Medical Journal, 329, 1267-1269

Kaufman, F (2002) Type 2 diabetes in children and young adults: a "new epidemic". Clinical Diabetes 20:217-218.

Kelly W, Mahmood R, Turner S, Elliott, K (1994) Geographical mapping of diabetes patients from deprived inner city areas shows less insulin therapy and more hyperglycaemia. Diabetic Medicine, 11, 344 –348.

Knorr-Held, L, Rainer, E (2001) Projections of lung cancer mortality in West Germany: a case study in Bayesian prediction. Biostatistics, 2, 109-129

Mcloughlin, V, Leatherman, S, Fletcher, M, Wyn Owen, J (2001) Improving performance using indicators. Recent experiences in the United States, the United Kingdom, and Australia. International Journal for Quality in Health Care, 13, 455-462.

Meadows P (1995)Variation of diabetes mellitus prevalence in general practice and its relationship to deprivation. Diabetic Medicine, 12, 696–700

Meier, E, Moy, C (2004) Social grading and the Census. International Journal of Market Research, 46, 141-170.

Merrick, D (2004) The PBS Diabetes Population Prevalence Model. Research Report, Yorkshire and Humber Public Health Observatory, University of York, Heslington, YORK YO10 5DD, England

Office for National Statistics (2001) ONS Model-Based Estimates of Income User Guide: Model-Based Estimates of Income for Wards (1998/99). Office for National Statistics

Office for National Statistics (2004) Health Survey for England, 2003, Volume 2: Risk factors for cardiovascular disease. The Stationery Office: London

Primatesta P, Brookes M. (2001) Chapter 3: Cardiovascular disease: prevalence and risk factors in Erens B, Primatesta P, Prior G (eds). Health Survey for England 1999: The Health of Minority Ethnic Groups. The Stationery Office, London

Rangasami, J, Greenwood,D, McSporran, B, Smail, P, Patterson, C, Waugh, N (1997) Rising incidence of type 1 diabetes in Scottish children, 1984-93. Archives of Disease in Childhood, 77, 210-213

Riste L, Farida Khan F, Cruickshank J (2001) High diabetes prevalence in all ethnic groups including Europeans in a British inner city: poverty, history, inactivity or 21st century Europe? Diabetes Care, 24, 1377-1383

Robinson-Lloyd C, Stevens L (1998) Social deprivation and mortality in adults with diabetes mellitus. Diabetic Medicine, 15, 205–212.

Smith, P (2002) Performance management in British health care: will it deliver? Health Affairs, 21, 103-115

Spiegelhalter, D, Best, N, Carlin, B, van der Linde, A (2002) Bayesian measures of model complexity and fit. Journal of the Royal Statistical Society, Series B, 64, 583-639

Table 1 Doctor-diagnosed diabetes, % prevalence, 2003 HSE, Social Group & Region Aged 16 and over with diagnosed diabetes

A) by NS-SEC of household reference person

	Managerial & Professional	Interm-ediate	Small employers and own-account	Lower supervisory & technical	Semi-routine & routine
Men					
Observed	3.9	2.4	5	4.7	5
Standardised	3.6	2.6	4.1	3.5	4.1
Women					
Observed	2.3	2	4.1	4.8	4.6
Standardised	2.6	1.6	4.2	4.3	4

B) by equivalised annual household income quintile

Highest	Highest	2nd	3rd	4th	lowest
Men					
Observed	2.3	3.2	4.2	6	6.1
Standardised	2	3.4	3.6	4.6	5
Women					
Observed	1.7	2.4	2.7	4.5	4
Standardised	1.6	1.8	2.8	5.7	4.7

C) By region

	North East	North West	Yorkshire & Humberside	East Midlands	West Midlands	East England	London	South East	South West
Observed	3.9	3.8	4	4.3	5.4	5.6	5.1	2.4	3.4
Standardised	3.1	3.3	3.5	3.7	4.9	4.8	5.4	2.9	2.8
Women									
Observed	2.8	2.8	2.9	3.7	4	3.8	3.8	3.5	3.2
Standardised	2.5	2.7	2.8	3.5	3.8	3.7	4.4	3.2	2.7

Table 2 Prevalence Estimates by Local Authority Income Decile

Area Income Decile	*Estimated Prevalence % (types 1&2)*	*Estimated Cases*
1 (Lowest Incomes)	*3.62*	*207580*
2	*3.62*	*232084*
3	*3.41*	*198960*
4	*3.04*	*115305*
5	*3.01*	*121258*
6	*2.99*	*136018*
7	*2.89*	*128179*
8	*2.90*	*139075*
9	*2.64*	*132542*
10 (Highest Incomes)	*2.60*	*117818*
England	*3.11*	*1528818*

Table 3 Estimated diabetes prevalence, Type 1 or 2, England and Strategic Health Authorities

	Prevalent Cases			% Diagnosed Prevalence				% Diagnosed & Undiagnosed (PBS Model)			
	P	M	F	P	M	F	SHA rank (persons), (rank higher with prevalence)	P	M	F	SHA rank (persons)
England	1528818	814391	714427	3.1	3.4	2.8		4.4	3.6	5.2	
Avon Gloucestershire & Wiltshire	58816	31455	27362	2.7	3.0	2.5	4	4.3	3.4	5.1	9
Bedfordshire & Hertfordshire	41551	22476	19075	2.6	2.9	2.3	2	4.2	3.5	4.8	3
Birmingham & Black Country	90733	48295	42438	4.0	4.4	3.7	28	4.7	4.0	5.4	25
Cheshire & Merseyside	75459	40065	35394	3.2	3.6	2.9	16	4.3	3.5	5.1	8
County Durham & Tees Valley	37897	20399	17498	3.3	3.7	3.0	20	4.3	3.5	5.0	7
Cumbria & Lancashire	61398	33041	28357	3.2	3.6	2.9	17	4.5	3.7	5.3	23
Dorset & Somerset	36421	19287	17134	3.1	3.4	2.8	14	5.0	3.9	6.0	28
Essex	44752	23831	20921	2.8	3.0	2.5	6	4.4	3.5	5.2	15
Greater Manchester	85098	45564	39534	3.4	3.7	3.1	21	4.2	3.5	4.9	5
Hampshire & Isle Of Wight	47796	25490	22306	2.7	2.9	2.5	3	4.3	3.4	5.1	10
Kent & Medway	44059	23545	20514	2.8	3.1	2.5	8	4.4	3.5	5.2	14
Leicestershire, Northants & Rutland	43943	23699	20244	2.9	3.2	2.6	10	4.4	3.7	5.1	17
Norfolk Suffolk & Cambridgeshire	62782	33894	28889	2.9	3.2	2.6	9	4.5	3.7	5.3	22
North & East Yorkshire & N. Lincs	47940	25698	22241	3.0	3.3	2.7	12	4.5	3.6	5.3	20
North Central London	40236	20568	19667	3.4	3.6	3.2	23	4.2	3.5	4.8	4
North East London	59117	31006	28111	4.0	4.3	3.7	27	4.4	3.8	5.0	18
North West London	59708	31486	28222	3.4	3.7	3.2	26	4.8	4.3	5.2	26
Northumberland Tyne & Wear	47196	25330	21866	3.4	3.8	3.1	22	4.4	3.5	5.2	16
Shropshire & Staffordshire	44461	24125	20335	3.0	3.3	2.7	13	4.3	3.5	5.1	11
South East London	48768	24559	24210	3.3	3.4	3.2	18	4.1	3.3	4.9	2
South West London	35126	18077	17049	2.7	2.9	2.6	5	4.2	3.5	4.9	6
South West Peninsula	51656	27596	24060	3.3	3.6	3.0	19	4.9	3.8	5.9	27
South Yorkshire	43290	23261	20029	3.4	3.8	3.1	24	4.3	3.5	5.1	12
Surrey & Sussex	70842	36990	33852	2.8	3.0	2.6	7	4.7	3.7	5.6	24
Thames Valley	51583	27827	23755	2.4	2.6	2.2	1	4.0	3.3	4.6	1
Trent	81859	44397	37462	3.2	3.5	2.8	15	4.4	3.6	5.2	19
West Midlands South	44881	24320	20561	2.9	3.2	2.7	11	4.5	3.7	5.3	21
West Yorkshire	71451	38109	33342	3.4	3.8	3.1	25	4.3	3.6	5.0	13

Table 4 Comparison of Adverse Outcomes to Prevalence

	Prevalent Cases (Persons, both types)	*% Prevalence (both types, persons)*	*Total Lower Limb Amputations 2000-1 & 2001-2 (Two years)*	*Total Ketoacidosis & Coma 2000-1 & 2001-2 (Two years)*	Age Standardised rates *Amputation ASR (per 100 thousand total popn)*	*DKA & Coma ASR (per 100 thousand total popn)*	Rates to Prevalent Popn (RPP) *Amputation Rate (annual rate per 10000 prevalent population)*	*DKA & Coma (annual rate per 10000 prevalent population)*	*Rank Amputation ASR*	*Rank DKA & Coma ASR*	*Rank Amputation RPP*	*Rank DKA & Coma RPP*
England	**1528818**	**3.1**	**4142**	**27799**	**3.4**	**27.5**	**13.5**	**90.9**				
StHA												
Avon Gloucestershire & Wiltshire	**58816**	**2.7**	**199**	**1162**	**3.5**	**26.1**	**16.9**	**98.8**	**16**	**13**	**22**	**21**
Bedfordshire & Hertfordshire	**41551**	**2.6**	**117**	**783**	**3.2**	**24.4**	**14.1**	**94.2**	**12**	**8**	**17**	**18**
Birmingham & Black Country	**90733**	**4.0**	**143**	**1535**	**2.8**	**32.4**	**7.9**	**84.6**	**8**	**24**	**4**	**11**
Cheshire & Merseyside	**75459**	**3.2**	**181**	**1743**	**3.0**	**36.6**	**12.0**	**115.5**	**10**	**27**	**14**	**26**
County Durham & Tees Valley	**37897**	**3.3**	**159**	**683**	**5.8**	**30.1**	**21.0**	**90.1**	**28**	**22**	**25**	**15**
Cumbria & Lancashire	**61398**	**3.2**	**168**	**969**	**3.3**	**25.6**	**13.7**	**78.9**	**13**	**12**	**15**	**8**
Dorset & Somerset	**36421**	**3.1**	**100**	**494**	**2.7**	**20.8**	**13.7**	**67.8**	**6**	**3**	**16**	**1**
Essex	**44752**	**2.8**	**217**	**863**	**4.9**	**27.1**	**24.2**	**96.4**	**27**	**15**	**28**	**19**
Greater Manchester	**85098**	**3.4**	**202**	**1456**	**3.6**	**28.5**	**11.9**	**85.5**	**18**	**19**	**12**	**12**
Hampshire & Isle Of Wight	**47796**	**2.7**	**205**	**959**	**4.8**	**26.2**	**21.4**	**100.3**	**26**	**14**	**26**	**24**
Kent & Medway	**44059**	**2.8**	**169**	**802**	**4.2**	**24.7**	**19.2**	**91.0**	**23**	**9**	**24**	**16**
Leicestershire, Northants & Rutland	**43943**	**2.9**	**144**	**880**	**4.0**	**27.1**	**16.4**	**100.1**	**22**	**15**	**20**	**22**
Norfolk Suffolk & Cambridgeshire	**62782**	**2.9**	**226**	**1478**	**3.9**	**32.4**	**18.0**	**117.7**	**21**	**25**	**23**	**27**
North & East Yorkshire & N. Lincs	**47940**	**3.0**	**155**	**667**	**3.5**	**20.3**	**16.2**	**69.6**	**17**	**2**	**19**	**3**
North Central London	**40236**	**3.4**	**74**	**715**	**3.3**	**30.2**	**9.2**	**88.9**	**14**	**23**	**6**	**14**
North East London	**59117**	**4.0**	**128**	**859**	**4.5**	**28.4**	**10.8**	**72.7**	**24**	**18**	**7**	**5**
North West London	**59708**	**3.4**	**70**	**826**	**2.0**	**24.0**	**5.9**	**69.2**	**1**	**6**	**1**	**2**
Northumberland Tyne & Wear	**47196**	**3.4**	**109**	**828**	**3.1**	**29.6**	**11.5**	**87.7**	**11**	**21**	**10**	**13**
Shropshire & Staffordshire	**44461**	**3.0**	**140**	**724**	**3.8**	**23.5**	**15.7**	**81.4**	**20**	**5**	**18**	**9**
South East London	**48768**	**3.3**	**107**	**1015**	**3.6**	**33.7**	**11.0**	**104.1**	**18**	**26**	**8**	**25**
South West London	**35126**	**2.7**	**51**	**643**	**2.1**	**25.5**	**7.3**	**91.5**	**2**	**11**	**2**	**17**
South West Peninsula	**51656**	**3.3**	**226**	**998**	**4.7**	**29.5**	**21.9**	**96.6**	**25**	**20**	**27**	**20**
South Yorkshire	**43290**	**3.4**	**66**	**726**	**2.3**	**28.2**	**7.6**	**83.9**	**3**	**17**	**3**	**10**
Surrey & Sussex	**70842**	**2.8**	**236**	**1003**	**3.3**	**19.2**	**16.7**	**70.8**	**15**	**1**	**21**	**4**
Thames Valley	**51583**	**2.4**	**114**	**1034**	**2.6**	**24.3**	**11.1**	**100.2**	**5**	**7**	**9**	**23**
Trent	**81859**	**3.2**	**191**	**2094**	**2.8**	**37.9**	**11.7**	**127.9**	**9**	**28**	**11**	**28**
West Midlands South	**44881**	**2.9**	**107**	**699**	**2.8**	**22.6**	**11.9**	**77.9**	**7**	**4**	**13**	**7**
West Yorkshire	**71451**	**3.4**	**116**	**1073**	**2.3**	**25.3**	**8.1**	**75.1**	**4**	**10**	**5**	**6**

Figure 1 Prevalence of diagnosed diabetes in adults, 1991-2003, England

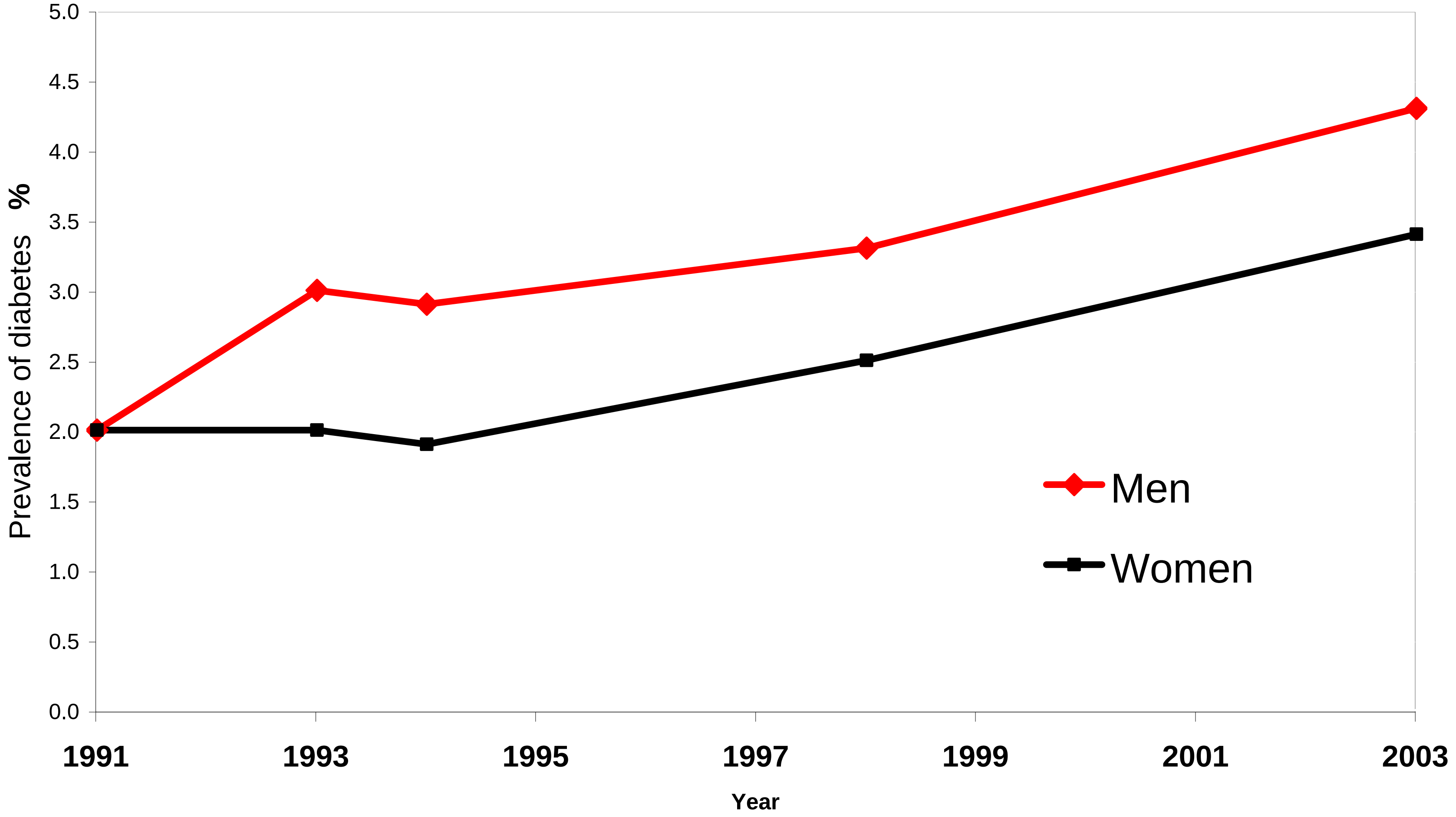

Figure 2 Diagnosed Diabetes Prevalence, Relative Risks to White Population by Ethnic Group and Gender (1999 Health Survey for England)

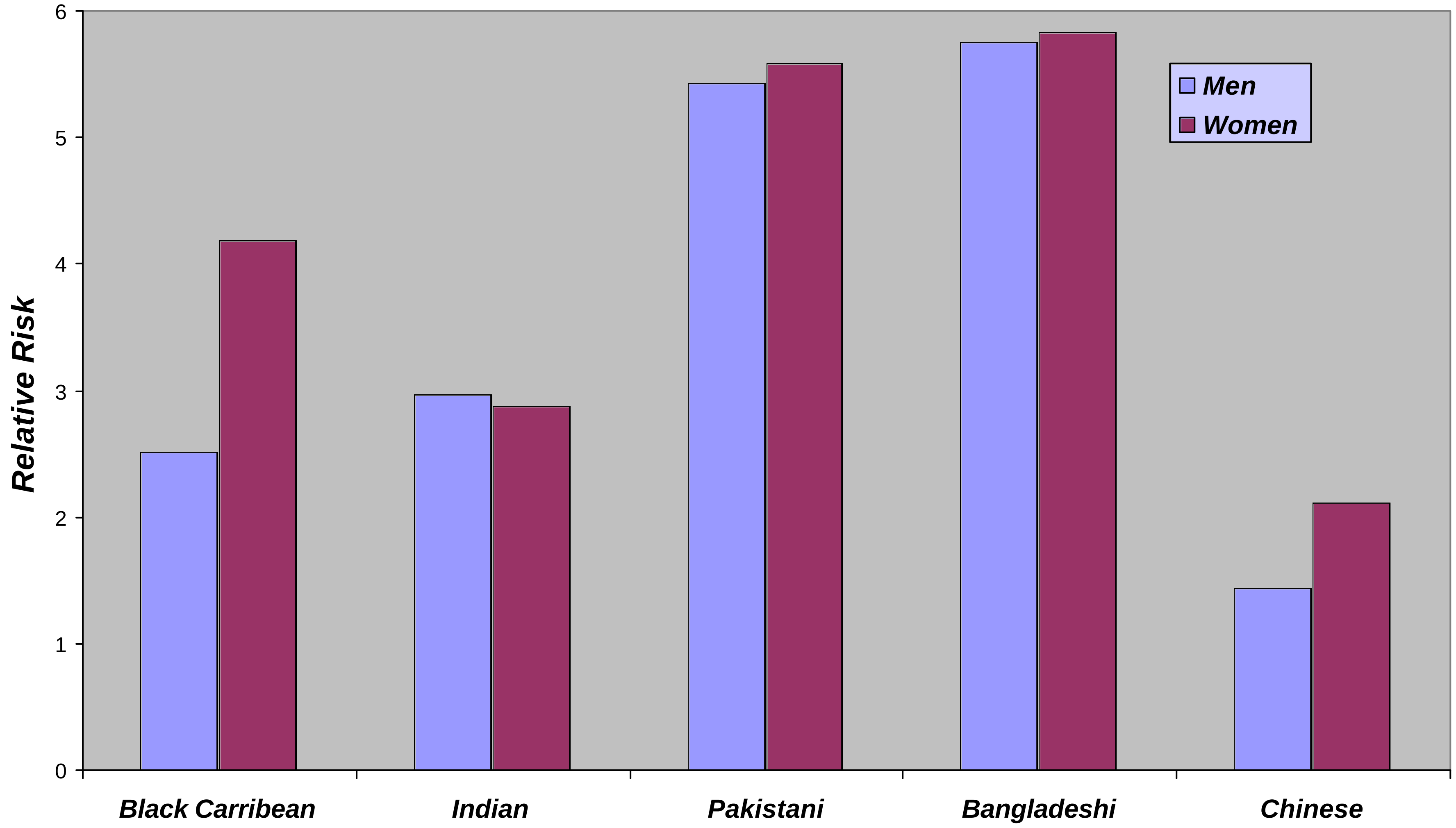

Figure 3 Variations in Adverse Hospitalisations

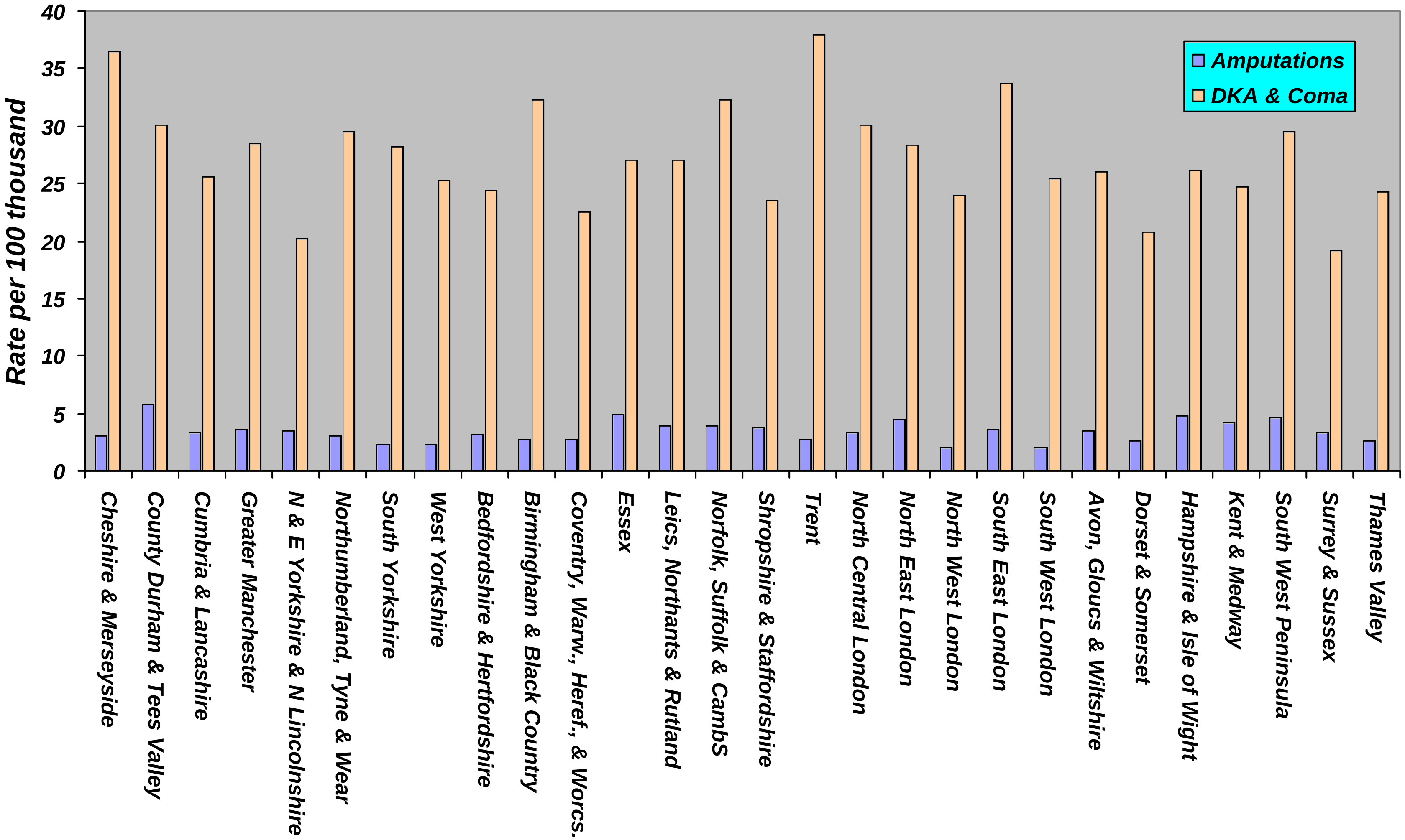

Figure 4A Male Diabetes Mortality

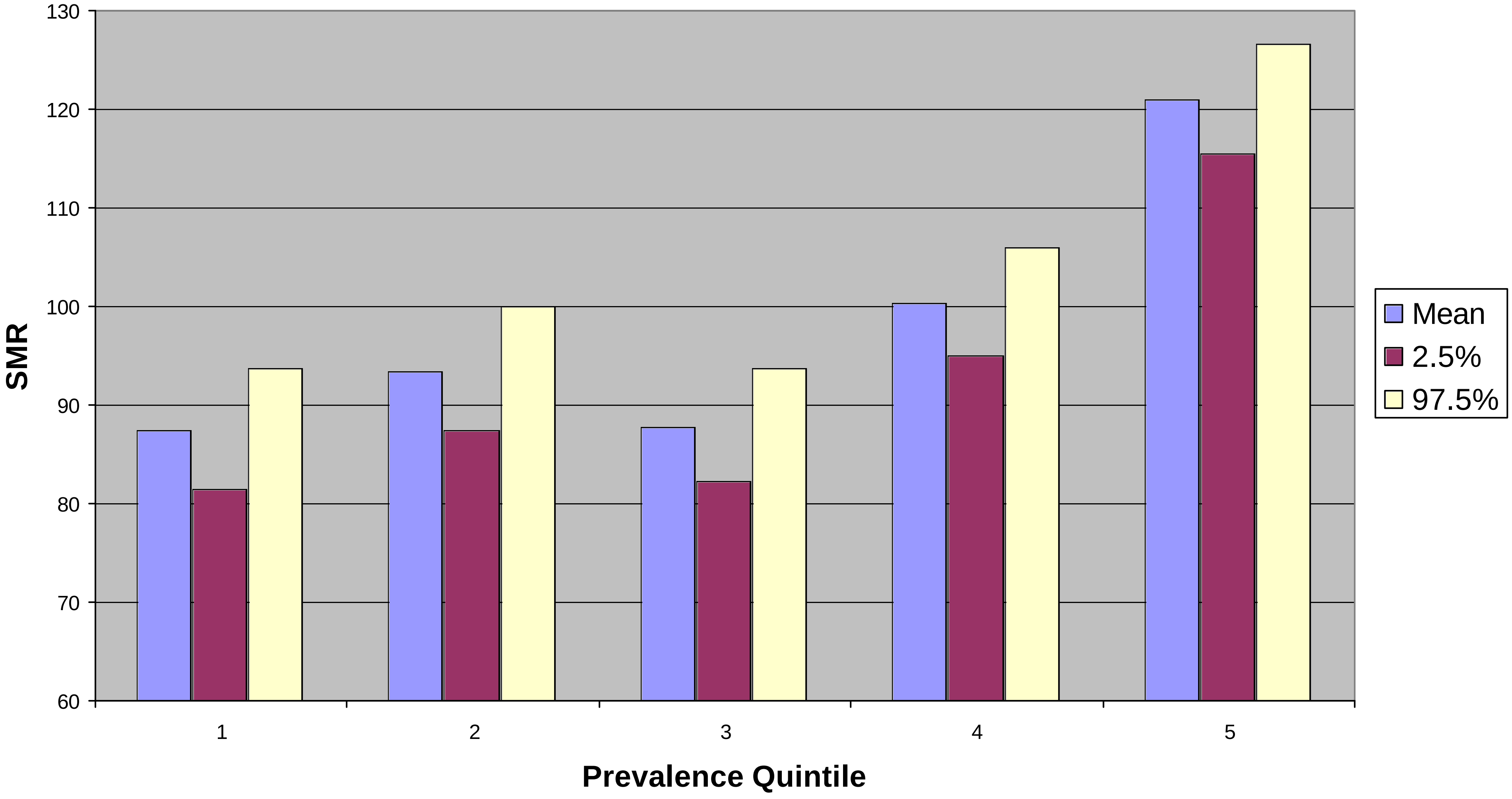

Figure 4B Female Diabetes Mortality