Supplementary Materials

A. Choice of model for the effects of age and deprivation

We used generalized additive logit models with penalized cubic regression splines[1] to examine the shape of the relationship between age or deprivation and risk of admissions. We considered models in which the logarithm of the odds of emergency admission was expressed as a linear combination of separate smooth functions of age and deprivation (ie restricted to smooth functions of single variables). The non-parametric spline functions were plotted against the logarithm of the odds of emergency admission to help identify the most parsimonious polynomial function of age or deprivation that captured the key features of the data. We explored the impact of varying the basis dimension k for the smooth terms. Where the degree of smoothness selected by the model was close to the limit of the dimensionality imposed by the value used for k, the model was refitted with an increased value of k to see if a more complex model was selected. To reduce risk of overfitting, the scaling parameter “gamma’ in the gam function was increased from its default value to 1.4[2].

Supplementary Figures 1a and 1b show the smoothed functions of IMD and age for the selected cubic regression spline model. Both age and IMD had non-linear effects on risk of emergency admissions (edf=3.07 and 8.85 respectively). Similar results were obtained when the model fitting was repeated using thin plate regression splines.

The graphs suggest that the effect of IMD can be approximated by a cubic function and this was the specification used in our main analyses. However, when investigating univariate logistic regression models for the effect of IMD (i.e. excluding age), the cubic model did not provide a better fit than a quadratic model (likelihood ratio test p=0.18). The more parsimonious quadratic model was therefore used to summarise the unadjusted relationship between IMD score and risk of emergency admissions (Supplementary Table 2).

The spline plot suggests that the effect of age is more complex but to avoid overfitting we initially selected a quadratic function. The addition of cubic terms did not significantly improve the model fit (likelihood ratio test p=0.4). We note that the quadratic model does not account for apparent local minima at ages 13 and 40, and a drop in risk above age 90.

Further exploration of the shape of the relationship with age was conducted by fitting a logistic regression model in which age was categorized into 5-year bands (with a single category for patients aged over 90) and deprivation categorized into quintiles**.** The features of the spline model identified above are less evident in this model, and a quadratic function provides a reasonable approximation to the overall shape of the age effect (Supplementary Figure 2). However, consistent with the spline model, we note that the quadratic relationship appears to break down above age 90 at which point there is an apparent plateau in the risk of emergency admissions, potentially resulting from a healthy survivor effect. The model with categorised age also suggests that there may be a dip in risk of admissions during the middle of childhood (around age 10). Given the potential benefits of having a simple parametric model for the effect of age, we adopted the quadratic model for the main analyses presented in this paper. We note that particular caution should be exercised in using this model to draw inferences about risk of admissions in patients over 90 years old.

B. Final models

Supplementary Table 1: Logistic regression model for probability of emergency admission as a function of age

	Coefficient	Standard error	95% confidence interval	p-value
Intercept	-3.38	0.0078	-3.39, -3.36	<0.001
Age – 43.63	0.019	0.0002	0.018, 0.019	<0.001
$(\text{Age} - 43.63)^2$	0.00073	0.000008	0.00071, 0.00074	<0.001

Supplementary Table 2: Logistic regression model for probability of emergency admission as a function of social deprivation

	Coefficient	Standard error	95% confidence interval	p-value
Intercept	-2.76	0.006	-2.77, -2.75	<0.001
IMD score – 17.26	0.0067	0.0007	0.0053, 0.0081	<0.001
$(\text{IMD score} - 17.26)^2$	0.0001	0.00004	0.00002, 0.00017	0.010

Supplementary Table 3: Logistic regression model for probability of emergency admission as a function of age and social deprivation (interaction model with age as a continuous variable and IMD score categorized into quintiles)

	Coefficient	Standard error	95% confidence interval	p-value
Intercept	-3.60	0.03	-3.65, -3.55	<0.001
Age – 43.63	-0.020	0.0007	-0.019, -0.021	<0.001
$(\text{Age} - 43.63)^2$	0.0008	0.00003	0.00075, 0.00085	<0.001
IMD quintile				
Q1	0.67	0.04	0.59, 0.74	<0.001
Q2	0.38	0.03	0.32, 0.45	<0.001
Q3	0.21	0.03	0.15, 0.27	<0.001
Q4	0.09	0.03	0.03, 0.15	0.002
Q5	0.00			
IMD quintile * (Age – 43.63)				
Q1	-0.00058	0.0010	-0.003, 0.001	0.563
Q2	-0.00074	0.0008	-0.002, 0.001	0.346
Q3	-0.00087	0.0007	-0.0023, 0.0006	0.239
Q4	-0.00099	0.0008	-0.0025, 0.0005	0.195
Q5	0.00000			
IMD quintile * $(\text{Age} - 43.63)^2$				
Q1	-0.00020	0.00004	-0.00028, -0.00013	<0.001
Q2	-0.00012	0.00003	-0.00018, -0.00006	<0.001
Q3	-0.00008	0.00003	-0.00013, -0.00003	0.004
Q4	-0.00003	0.00003	-0.00008, 0.00003	0.373
Q5	0.00000			

C. Analysis by gender

The combined model for emergency admissions, with deprivation categorized into quintiles and age specified as a quadratic polynomial function, was fitted separately for males and females. The J-shaped risk curve for age was apparent for both genders, and social deprivation had a consistent effect for the two genders (Supplementary Figure 3).

The patterns of effect sizes for age and deprivation in the sub-populations of patients aged under 65 and 65 or over were similar for males and females (Supplementary Table 4). Within the sub-population of patients aged under 65, age and social deprivation had similar magnitudes of effect on the risk of admissions (with all estimates < 2%). For patients aged 65 or over, age had a much stronger effect than deprivation (with effect sizes more than ten-fold greater for age than IMD in both males and females).

Supplementary Table 4: Gender-specific effect sizes for age and deprivation in the sub-populations of patients aged under 65 and over 65. Effect sizes were estimated as the differences in probability of emergency admissions between the top and bottom quintiles of deprivation and age in each sub-population.

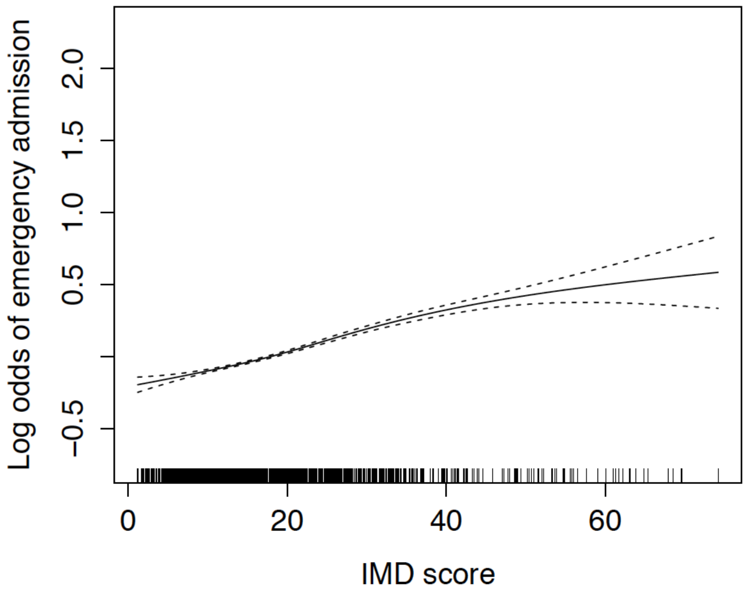
	Age		IMD	
	Under 65	65 or over	Under 65	65 or over
Males	0.69%	19.08%	1.27%	1.48%
Females	1.12%	17.82%	1.67%	1.66%

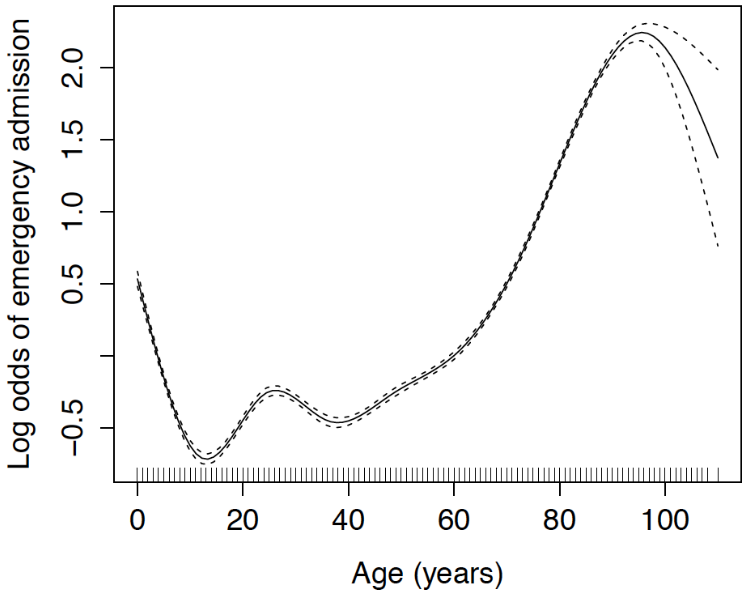
References

1. Wood SN. Low-rank scale-invariant tensor product smooths for generalized additive mixed models. Biometrics 2006; 62:1025-36 .
2. Wood SN (2006). Generalized Additive Models: An Introduction with R. Chapman and Hall/CRC.

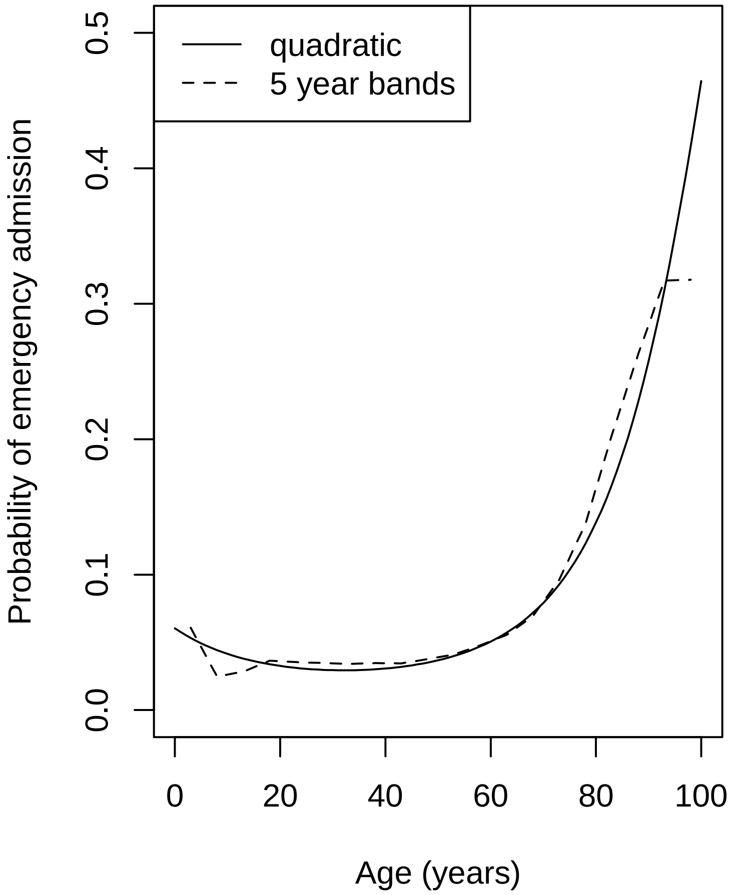
Figures

Supplementary Figure 1: Graphical representation of the functional form for age and IMD modeled using cubic regression splines in a generalized additive logit model for risk of emergency admission. The plots show the smoothed, fitted log odds and 95% confidence intervals, with rug plots to represent the number of patients on the x-axis: (a) smoothed function of IMD; (b) smoothed function of age.


Log odds of emergency admission
2.0
1.5
1.0
0.5
−0.5
0
20
40
60
IMD score

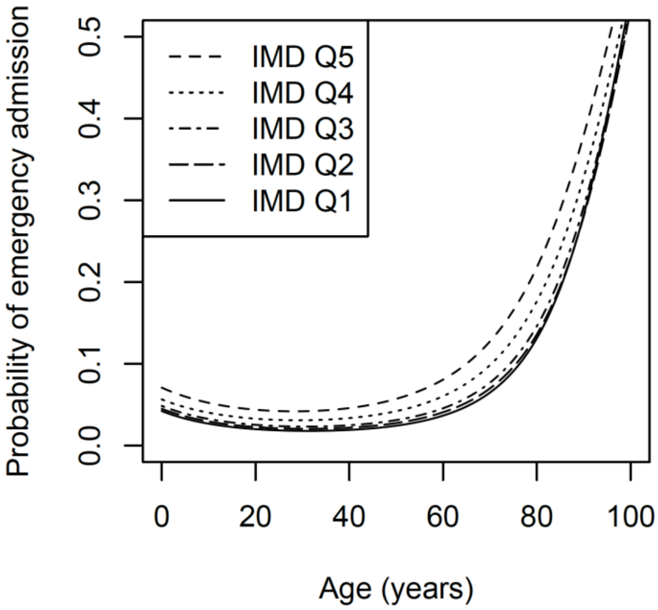

Log odds of emergency admission
2.0
1.5
1.0
0.5
−0.5
0
20
40
60
80
100
Age (years)

Supplementary Figure 2: Graphical representation of the effect of age in a logistic regression model for risk of emergency admission in which age was categorized into 5-year bands (with a single category for patients aged over 90). The risk function from a model with a quadratic function of age has been added to the plot for comparison.

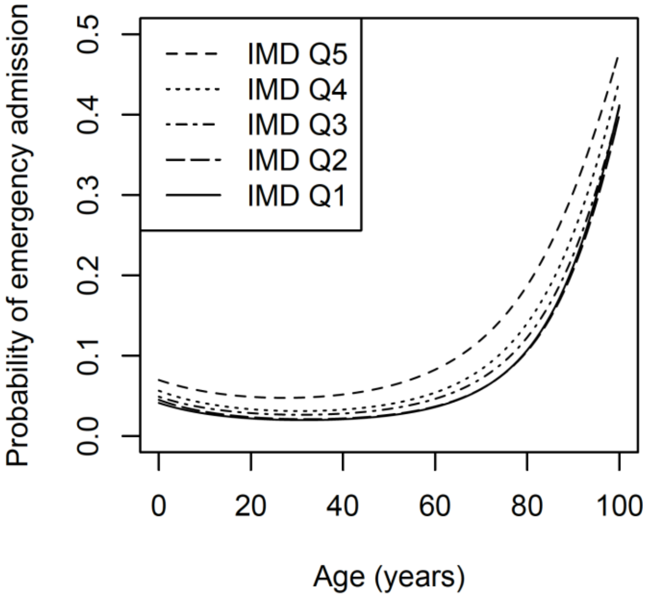


Supplementary Figure 3: Relationship between age and probability of emergency admission to hospital for each quintile of deprivation, based on separate models for males and females.

(a) Males



(b) Females


IMD Q5
IMD Q4
IMD Q3
IMD Q2
IMD Q1
Probability of emergency admission
0.0
0.1
0.2
0.3
0.4
0.5
0
20
40
60
80
100
Age (years)