Socioeconomic Patterning in the Incidence and Survival of Children and Young People Diagnosed with Malignant Melanoma in Northern England

Richard J.Q. McNally[1], Nermine O. Basta[1], Steven Errington[1], Peter W. James[1], Paul D. Norman[2] and Alan W. Craft[3]

Previous studies have found marked increases in melanoma incidence. The increase among young people in northern England was especially apparent among females. However, overall 5-year survival has greatly improved. The present study aimed to determine whether socioeconomic factors may be involved in both etiology and survival. All 224 cases of malignant melanoma diagnosed in patients aged 10–24 years during 1968–2003 were extracted from a specialist population-based regional registry. Negative binomial regression was used to examine the relationship between incidence and area-based measures of socioeconomic deprivation and small-area population density. Cox regression was used to analyze the relationship between survival and deprivation and population density. There was significantly decreased risk associated with living in areas of higher unemployment (relative risk per 1% increase in unemployment = 0.93; 95% confidence interval (CI) 0.90–0.96, $P<0.001$). Survival was better in less deprived areas (hazard ratio (HR) per tertile of household overcrowding = 1.52; 95% CI 1.05–2.20; $P=0.026$), but this effect was reduced in the period 1986–2003 (HR = 0.61; 95% CI 0.40–0.92; $P=0.018$). This study found that increased risk of melanoma was linked with some aspects of greater affluence. In contrast, worse survival was associated with living in a more deprived area.

Journal of Investigative Dermatology (2014) **134,** 2703–2708; doi:10.1038/jid.2014.246; published online 10 July 2014

INTRODUCTION

During the 1970s, malignant melanoma was very rare in children, teenagers, and young adults, with around 2% of all melanomas occurring in those aged less than 20 years and only 0.2% occurring in children aged 0–10 years (Bader *et al.*, 1985). Since then and up to the early 21st century there has been a marked increase in the incidence of melanoma in children and young people residing in developed countries (Downing *et al.*, 2006; Purdue *et al.*, 2008). A previous analysis from northern England has shown that a marked rise in incidence was confined to females (Magnanti *et al.*, 2008). It is well known that both genetic susceptibility and exposure to UVR are key factors in etiology (Cockburn *et al.*, 2001; Wachsmuth *et al.*, 2001; Shahbazi *et al.*, 2002; El Ghissassi *et al.*, 2009). The finding of a seasonal association between time of birth and risk of subsequently developing melanoma suggests that early life exposures may be implicated (Basta *et al.*, 2011). Some studies from the United States of America have found that higher incidence of melanoma is associated with greater socioeconomic affluence (Clegg *et al.*, 2009; Hausauer *et al.*, 2011; Singh *et al.*, 2011). In the United Kingdom, the putative association between risk of melanoma and socioeconomic deprivation has only been studied at the Government Office Region level. The observed patterns were not clear at this large level of aggregation (Wallingford *et al.*, 2013). The possible roles that socioeconomic factors may have in the survival of patients diagnosed with malignant melanoma have not been investigated in the United Kingdom. In general, survival from most adult cancers has been found to be lower in areas of greater deprivation (Coleman *et al.*, 2004).

In light of the previous findings, this study aimed to test whether spatial variation in incidence and survival of cases of melanoma relate to area-level population density and area-level socioeconomic deprivation and provide context for the interpretation of lifestyle factors (e.g., for incidence, exposure to UVR). The following *a priori* hypotheses were examined: a main factor determining spatial variation of incidence of melanoma is modulated by differences in (i) less and more densely populated areas of residence and (ii) less and more socioeconomically deprived areas of residence; and a main factor determining spatial variation in survival from melanoma is modulated by differences in (iii) less and more densely populated areas of residence and (iv) less and more socio-economically deprived areas of residence. We have analyzed

[1]*Institute of Health and Society, Newcastle University, Newcastle upon Tyne, UK;* [2]*School of Geography, University of Leeds, Leeds, UK and* [3]*Northern Institute of Cancer Research, Newcastle University, Newcastle upon Tyne, UK*

Correspondence: Dr Richard JQ McNally, Institute of Health and Society, Newcastle University, Sir James Spence Institute, Royal Victoria Infirmary, Queen Victoria Road, Newcastle upon Tyne NE1 4LP, UK. E-mail: Richard.McNally@ncl.ac.uk

Abbreviations: CI, confidence interval; CL, confidence limit; HR, hazard ratio; NRYPMDR, Northern Region Young Persons' Malignant Disease Registry

Received 27 February 2014; revised 24 April 2014; accepted 8 May 2014; accepted article preview online 13 June 2014; published online 10 July 2014

data from the population-based Northern Region Young Persons' Malignant Disease Registry (NRYPMDR). The study describes socioeconomic patterning in the incidence of and survival from malignant melanoma in children and young people (aged 10–24 years), diagnosed while resident in Northern England.

RESULTS

Incidence

The study analyzed 224 cases of malignant melanoma diagnosed in those aged 10–24 years. There were 82 (37%) cases aged 10–19 years (30 males, 52 females), of whom 14 (17%) were aged 10–14 years, and 142 (63%) cases aged 20–24 years (36 males, 106 females). The overall age-standardized rate was 9.32 per million persons per year (95% confidence interval (CI) 8.10–10.54) for all cases aged 10–24 years. Case numbers, crude rates, and age-standardized rates by age group, gender, and period are presented in Table 1. Poisson regression analysis found that there was a significant increase in incidence of 4.8% per year (95% CI 3.4–6.2%) over the duration of the study (Figure 1). Furthermore, joinpoint regression revealed no evidence of discontinuities in the trend.

Age and gender both significantly improved the model fit for melanoma incidence ($P<0.001$ for both variables), with higher rates in females and higher rates for older ages. Period also significantly improved the model fit ($P<0.001$), with incidence increasing over time. The effect of gender was the same for all age groups, as an age by gender interaction was not significant ($P=0.338$) (Table 2, models 1–5). The composite Townsend score (Townsend *et al.*, 1988), as well as all individual components, significantly improved the model fit (Townsend: $P<0.001$; household overcrowding: $P<0.001$; non-home ownership: $P<0.001$; unemployment: $P<0.001$; non-car ownership: $P<0.001$) (Table 2, models 6–10). Population density and interactions between unemployment by age, unemployment by gender, and unemployment by period did not further improve the model (Table 2, models 11–14). The best-fitting model contained gender, age, period, and household unemployment together with spatial effects representing increased incidence for North Tyneside and for Redcar and Cleveland (Table 2, model 16). Table 3 presents relative risks for the final model (model 16), which showed that there was a statistically significant decreased risk associated with higher levels of unemployment (relative risk for 1% increase in the level of unemployment = 0.93; 95% CI 0.90–0.96; $P<0.001$). Figure 2 shows incidence rates, together with 95% CIs, by tertile of unemployment.

Table 1. Rates of malignant melanoma in Northern England by age, gender, and period during 1968–2003

	N	Population (000's)	Crude rate/ million	ASR (95% CI)
Age				
Ages 10–19	82	15,711.1	5.22	5.26 (4.12–6.40)
Ages 20–24	142	7,689.9	18.47	18.47 (15.27–21.28)
Gender				
Males	66	11,845.5	5.51	5.51 (4.18–6.84)
Females	158	11,555.6	13.18	13.18 (11.12–15.24)
Period				
1968–1976	29	6,350.9	4.57	4.67 (3.02–6.60)
1977–1985	39	6,482.3	6.02	5.89 (4.04–7.73)
1986–1994	65	5,529.5	11.76	10.75 (8.12–13.38)
1995–2003	91	5,038.3	18.06	17.90 (14.22–21.57)
Total	224	23,401.0	9.32	9.32 (8.10–10.54)

Abbreviations: ASR, age-standardized rate; CI, confidence interval; *N*, number of cases.

Survival

Age and gender did not improve the model fit for melanoma survival ($P=0.576$ and 0.075, respectively; Table 4, models 1 and 2). The composite Townsend score, as well as two individual components, significantly improved the model fit (Townsend: $P=0.026$; unemployment: $P=0.032$; household overcrowding: $P=0.006$; Table 4, models 4, 5, and 8). Population density, non-home ownership and non-car ownership did not further improve the model (Table 4, models 3, 6, and 7). The best-fitting model contained household overcrowding with linear variation in tertiles and an interaction with period (Table 4, model 20). Living in an area with greater levels of household overcrowding was associated with worse survival (hazard ratio (HR) per tertile of household overcrowding = 1.52; 95% CI 1.05–2.20; $P=0.026$), but this effect was reduced for the time period 1986–2003 (HR = 0.61; 95% CI 0.40–0.92; $P=0.018$; Figure 3).

DISCUSSION

This study presents small-area analysis of socioeconomic patterning in the incidence of and survival from malignant melanoma. It has been feasible because of the availability of highly accurate and complete cancer registration data from the NRYPMDR (a specialist regional population-based registry), together with matching census population and socioeconomic data. There were two significant findings: (a) decreased risk of melanoma was associated with residing in areas of greater unemployment; and (b) worse survival from

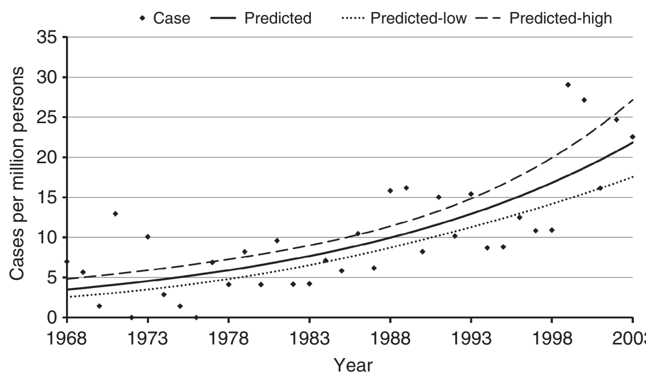

Figure 1. Trends over time for crude incidence (per million population) of malignant melanoma in the age group 10–24 years. Predicted-low, lower 95% confidence limit (CL); predicted-high, upper 95% CL.

Table 2. Hierarchical series of models for malignant melanoma incidence with goodness-of-fit diagnostics

Model	Variables	Residual d.f.	Deviance	AIC	Contrast	Difference in d.f.	Difference in Deviance	*P*-value
0	Null	7,667	1,425.3	0.26398				
1	Gender	7,666	1,391.5	0.25983	0 vs. 1	1	33.8	<0.001
2	Age	7,666	1,360.1	0.25573	0 vs. 2	1	65.2	<0.001
3	Gender, age	7,665	1,332.0	0.25232	1 vs. 3	1	59.5	<0.001
4	Gender, age, gender × age	7,664	1,331.0	0.25246	3 vs. 4	1	0.9	0.338
5	Gender, age, period	7,663	1,269.8	0.24474	3 vs. 5	2	62.2	<0.001
6	Gender, age, period, Townsend	7,662	1,250.1	0.24242	5 vs. 6	1	19.7	<0.001
7	Gender, age, period, non-home ownership	7,662	1,256.8	0.24331	5 vs. 7	1	13.0	<0.001
8	Gender, age, period, unemployment	7,662	1,249.2	0.24231	5 vs. 8	1	20.6	<0.001
9	Gender, age, period, overcrowding	7,662	1,253.0	0.24281	5 vs. 9	1	16.8	<0.001
10	Gender, age, period, without cars	7,662	1,256.7	0.24329	5 vs. 10	1	13.1	<0.001
11	Gender, age, period, population density	7,662	1,267.9	0.24475	5 vs. 11	1	1.9	0.170
12	Gender, age, period, unemployment, unemployment × age	7,661	1,248.6	0.24250	8 vs. 12	1	0.6	0.455
13	Gender, age, period, unemployment, unemployment × gender	7,661	1,245.6	0.24210	8 vs. 13	1	3.6	0.058
14	Gender, age, period, unemployment, unemployment × period	7,660	1,246.8	0.24252	8 vs. 14	2	2.4	0.299
15	Gender, age, period, unemployment, North Tyneside	7,661	1,241.5	0.24157	8 vs. 15	1	7.7	0.006
16	Gender, age, period, unemployment, North Tyneside, Redcar/Cleveland[a]	7,660	1,237.1	0.24125	8 vs. 16	2	12.1	0.002

Abbreviations: AIC, Akaike information criterion; d.f., degrees of freedom.
[a]Best-fitting model.

Table 3. Effect of gender, age, and unemployment on the incidence of malignant melanoma

Variable	Coefficient (95% CI)	RR (95% CI)	*P*-value
Female	0.76 (0.46, 1.05)	2.13 (1.58, 2.87)	<0.001
Age 20–24	1.13 (0.85, 1.42)	3.11 (2.34, 4.12)	<0.001
Period 1986–1995	0.36 (0.01, 0.71)	1.44 (1.01, 2.04)	0.045
Period 1996–2003	0.77 (0.37, 1.17)	2.16 (1.44, 3.23)	<0.001
Unemployment	−0.07 (−0.10, −0.04)	0.93 (0.90, 0.96)	<0.001
N. Tyneside LA	0.71 (0.27, 1.16)	2.04 (1.30, 3.18)	0.002
Redcar/Cleveland UA	0.61 (0.08, 1.15)	1.85 (1.08, 3.16)	0.024

Abbreviations: CI, confidence interval; LA, local authority; RR, relative risk; UA, unitary authority.

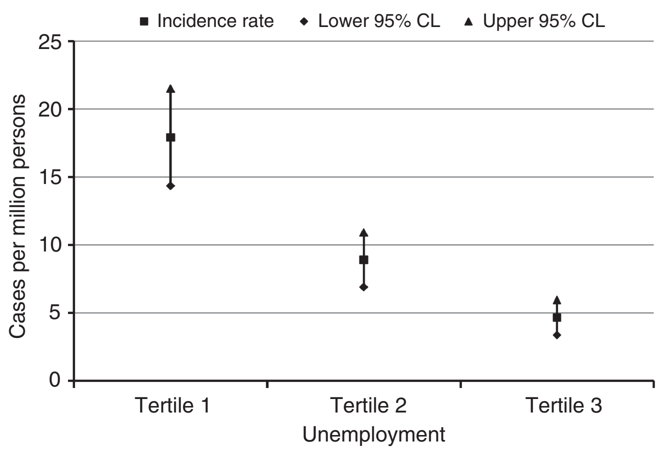

Figure 2. Incidence of melanoma by tertile of unemployment. CL, confidence limit.

melanoma was associated with residing in areas of greater household overcrowding.

Our prior hypotheses were as follows: a main factor determining spatial variation of incidence of melanoma is modulated by differences between lifestyle factors occurring in (i) less and more densely populated areas of residence and (ii) less and more socioeconomically deprived areas of residence; and a main factor determining spatial variation in survival from melanoma is modulated by differences in lifestyle occurring in (iii) less and more densely populated areas of residence and (iv) less and more socioeconomically deprived areas of residence.

The results suggest that spatial variation of incidence is modulated by differences in patterns of early life exposure to UVR (e.g., sunlight) occurring in areas with less and more unemployment (reflecting a component of area-level socioeconomic deprivation). Thus, there was support for prior hypothesis (ii) but not for prior hypothesis (i), because incidence was not related to area-level population density. Better living conditions (which may be a proxy for greater affluence) conferred greater risk. The results also suggest that spatial variation of survival is modulated by differences in patterns of social behavior (e.g., accessing medical care or adherence to treatment) occurring in areas with less and more household overcrowding (one component of socioeconomic deprivation). Hence, there was support for prior hypothesis (iv) but not for prior hypothesis (iii), because survival was not related to area-level population density. As there was no evidence of interaction between period and unemployment, the effect on incidence was constant throughout the study period. However, for survival there was an

Table 4. Hierarchical series of Cox regression models for malignant melanoma survival with goodness-of-fit diagnostics

Model	Variables	-2ln(*L*)	Model Compared	d.f.	χ^2	*P*-value	AIC
0	Null	515.76					
1	Gender	512.60	1 vs. 0	1	3.161	0.075	514.600
2	Age	515.45	2 vs. 0	1	0.313	0.576	517.448
3	Population density	515.60	3 vs. 0	1	0.157	0.692	517.605
	Deprivation for households						
4	Townsend	510.78	4 vs. 0	1	4.980	0.026	512.781
5	Unemployment	511.16	5 vs. 0	1	4.605	0.032	513.156
6	Non-home ownership	512.48	6 vs. 0	1	3.282	0.070	514.479
7	Non-car ownership	515.11	7 vs. 0	1	0.649	0.420	517.112
8	Overcrowding	508.21	8 vs. 0	1	7.552	0.006	510.209
9	Townsend quintile as continuous	509.83	9 vs. 0	1	5.927	0.015	511.835
10	Unemployment quintile as continuous	510.75	10 vs. 0	1	5.009	0.025	512.752
11	Non-home ownership quintile as continuous	513.39	11 vs. 0	1	2.369	0.124	515.392
12	Non-car ownership quintile as continuous	514.23	12 vs. 0	1	1.530	0.216	516.231
13	Overcrowding quintile as continuous	503.53	13 vs. 0	1	12.231	<0.001	505.530
14	Townsend tertile as continuous	507.76	14 vs. 0	1	8.000	0.005	509.761
15	Unemployment tertile as continuous	511.67	15 vs. 0	1	4.090	0.043	513.671
16	Non-home ownership tertile as continuous	512.64	16 vs. 0	1	3.124	0.077	514.637
17	Non-car ownership tertile as continuous	514.51	17 vs. 0	1	1.252	0.263	516.509
18	Overcrowding tertile as continuous	502.22	18 vs. 0	1	13.539	<0.001	504.222
19	Overcrowding tertile as nonlinear	502.21	19 vs. 0	2	13.548	0.001	506.213
20	Overcrowding tertile as continuous × period[a]	495.33	20 vs. 18	1	6.887	0.009	499.335

Abbreviations: AIC, Akaike information criterion; d.f., degrees of freedom; L, likelihood function.
[a]Best-fitting model.

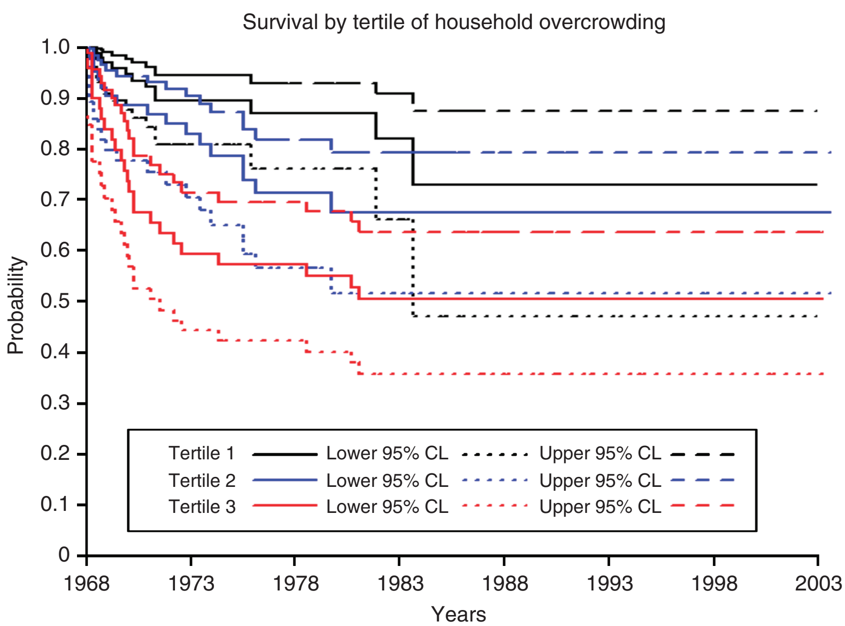

Figure 3. Survival of melanoma cases by tertile of household overcrowding. Tertile 1, least overcrowded; tertile 3, most overcrowded. CL, confidence limit.

interaction between period and household overcrowding, which indicated that the effect diminished in the later years of the study.

There are some methodological caveats. First of all, Townsend deprivation scores (Townsend *et al.*, 1988) and census ward population density may not truly reflect the characteristics of individual cases and therefore should only be viewed as ecological proxies. As area-level measurements have been allocated to individuals, caution should be exercised when making inferential extrapolation from grouped data to individuals. It is possible that there could be other unmeasured confounders that display similar spatial variability (Richardson and Monfort, 2000). Second, 2001 census boundaries were used to analyze case, population, and socio-demographic data. The putative effect of migration was not considered. It is possible that this could have affected the analyses. However, migration appears to have had little or no effect as the marked findings were clearly demonstrated. Third, it is possible that delays in diagnosis may be related to the demographic factors that have been analyzed. Hence, it is conceivable that cases have been differentially lost in relation to the demographic variables. Finally, data on stage at diagnosis were not available.

Our findings relating to incidence contrast with the recent study by Wallingford *et al.* (2013). They analyzed national data, but only allowed for deprivation measured at the much larger level of Government Office Region. They found that increased risk of malignant melanoma for young females (aged 10–29 years) was higher in more deprived regions. They concluded that this may be due to increased prevalence of sun-bed use and foreign holidays among the more deprived communities. However, our study included all cases of melanoma aged 10–24 years from northern England, an area noted for high levels of deprivation (Townsend *et al.*, 1988), and found that higher incidence was linked with residence in areas of greater affluence. Thus, the findings of Wallingford and colleagues may be an example of an ecological fallacy, due to the size of the areal unit analyzed (Richardson and Monfort, 2000), as in 2001 England's Government Office Regions ranged in size from 2.5 million (North–East) to 8 million persons (South–East). We acknowledge that an overall limitation of our analysis was the sparse number of cases over a prolonged time interval.

In the United Kingdom, prompt diagnosis of cancer to improve survival chances has been highlighted by the National Cancer Research Institute, the National Cancer Intelligence Network, and the National Awareness and Early Diagnosis Initiative. Furthermore, it has been recognized that less attention has been paid to teenagers and young adults. This group has a tendency for presenting late and not fully utilizing the health-care system (Eden, 2006). Our findings show that worse survival is associated with social deprivation, and this could be because of 'patient' or 'professional' related delays in the diagnostic pathway.

In conclusion, this study has shown that increased risk of malignant melanoma is linked with greater affluence, as measured by area-based level of unemployment. This suggests that exposure to UV is linked to some aspects of lifestyle, such as frequency of holidays to countries with greater amounts of sunshine. In contrast, worse survival was associated with living in a more deprived area. This could suggest that patients in more deprived areas are less likely to seek early diagnosis or are less likely to adhere to treatment regimens.

MATERIALS AND METHODS

Study subjects

The study included case data on all patients, aged between 10 and 24 years inclusive, who were diagnosed during the period 1968–2003 and registered by the specialist NRYPMDR, a population-based registry of all childhood and young adult malignancies since 1968 in the northern region of England (Compton, 1972; Cotterill *et al.*, 2000; Craft *et al.*, 1993). The data are exempt from individual patient consent originally under Section 60 of the UK Health and Social Care Act 2001, which has now been superseded by Section 251 of the National Health Service Act 2006, and have a high level of accuracy and completeness (over 98% case ascertainment). The study included six cases of *in-situ* melanoma. The study excluded cases aged 0–9 years as they are likely to have a different etiology related to genetic predisposition (Fishman *et al.*, 2002; Livestro *et al.*, 2007).

Population data

The data were analyzed at the small-area census ward level. For ages 10–24 years, the population of wards ranged from 80 to 4741 (median = 725). During the study period, there were censuses in 1971, 1981, 1991, and 2001. There were widespread boundary changes in each inter-censal period, which especially affected small areas. To allow for these perturbations, population estimates were derived using the small-area boundaries that pertained at the time of the 2001 census (Norman *et al.*, 2008).

Demographic data

The demographic characteristics of census wards were derived from the 1971, 1981, 1991, and 2001 censuses. These included population density (persons per hectare) and level of deprivation, which was calculated on the basis of the Townsend score for area-based deprivation (Townsend *et al.*, 1988). This is a combination of four census measures: unemployment, households with no car, non-home ownership, and household overcrowding. A time series of Townsend deprivation scores was constructed by apportioning these four constituent measures from the 1971, 1981, 1991, and 2001 censuses (applied to 1968–1975, 1976–1985, 1986–1995, and 1996–2003 data, respectively) to the 2001 census geography (Norman, 2010). Increasingly negative Townsend scores represent lower area deprivation. Increasingly positive scores represent higher deprivation. Population density was apportioned in a similar way to the 2001 census geography.

Statistical analysis

Midyear population estimates for the study region were obtained from the Office for National Statistics and used to calculate age-specific incidence rates per million persons per year. The standard world population was applied to obtain age-standardized rates (Smith, 1992). Poisson regression was used to assess temporal trends. A linear trend assumption was tested by the inclusion of a quadratic term in the model. Joinpoint regression was used to test for discontinuities in the trend (Kim *et al.*, 2000).

There was evidence of extra-Poisson variation: 97.2% of age group and gender-specific ward cells had zero counts. Hence, negative binomial regression was used to model incidence at the census ward level in STATA (StataCorp, 2007), with the number of observed cases in each census ward as the dependent variable and the logarithm of the underlying population as the offset. The census-derived ward characteristics were the ecological (independent) variables that were allocated to the 2001 census geography (Norman, 2010). Cox regression modeling was used to analyze survival (Collett, 2003).

A series of multivariable models were fitted for analysis of both incidence and survival. The following independent variables were included: age (categorized into two groups as 10–19 and 20–24 years), gender, period (1968–1985, 1986–1995, 1996–2003), population density, and the Townsend score (as a composite). The four components of the Townsend score were included in separate models that did not include the composite score: percentage of overcrowded houses, percentage of households without a car, percentage of residents unemployed, and percentage of homes that are not owner occupied. The interactions between age, gender, period, and the Townsend score (and its components) were also considered for inclusion in the models. Each variable was removed sequentially and compared using a likelihood ratio test. Hence, the effect of each variable was determined by calculating differences in residual differences and making comparison with a χ^2-test distribution with degrees of freedom (d.f.) equal to the difference in residual degrees of freedom. Model fit was assessed using both the residual deviance and the Akaike information criterion. Linearity assumptions were tested by inclusion of quintiles of significant continuous variables as ordinal variables in the models.

For the analysis of incidence, significant effects are reported as relative risks and associated 95% CIs. For the analysis of survival, significant effects are reported as hazard ratios and associated 95% CIs. All *P*-values were two-sided and statistical significance was taken as $P<0.05$ for all the analyses.

CONFLICT OF INTEREST

The authors state no conflict of interest.

ACKNOWLEDGMENTS

We thank all colleagues from NRYPMDR. We thank the North of England Children's Cancer Research Fund for financial support (NOB, PWJ).

REFERENCES

Bader JL, Li FP, Olmstead PM *et al.* (1985) Childhood malignant melanoma. Incidence and etiology. *Am J Pediatr Hematol Oncol* 7:341–5

Basta NO, James PW, Craft AW *et al.* (2011) Seasonal variation in the month of birth in teenagers and young adults with melanoma suggests the involvement of early-life UV exposure. *Pigment Cell Melanoma Res* 24:250–3

Clegg LX, Reichman ME, Miller BA *et al.* (2009) Impact of socioeconomic status on cancer incidence and stage at diagnosis: selected findings from the surveillance, epidemiology and end results: National Longitudinal Mortality Study. *Cancer Causes Control* 20:417–35

Cockburn M, Black W, McKelvey W *et al.* (2001) Determinants of melanoma in a case-control study of twins (United States). *Cancer Causes Control* 12:615–25

Coleman MP, Rachet B, Woods LM *et al.* (2004) Trends and socioeconomic inequalities in cancer survival in England and Wales up to 2001. *Br J Cancer* 90:1367–73

Collett D (2003) *Modelling Survival Data in Medical Research,* 2nd edn. Chapman and Hall/CRC: Boca Raton

Compton E (1972) *Local Government Boundary Commission Reports,* Her Majesty's Stationery Office: London

Cotterill SJ, Parker L, Malcolm AJ *et al.* (2000) Incidence and survival for cancer in children and young adults in the North of England, 1968-1995: a report from the Northern Region Young Persons' Malignant Disease Registry. *Br J Cancer* 83:397–403

Craft AW, Parker L, Openshaw S *et al.* (1993) Cancer in young people in the north of England, 1968–85: analysis by census wards. *J Epidemiol Community Health* 47:109–15

Downing A, Newton-Bishop JA, Forman D (2006) Recent trends in cutaneous malignant melanoma in the Yorkshire region of England; incidence, mortality and survival in relation to stage of disease, 1993-2003. *Br J Cancer* 95:91–5

Eden T (2006) Keynote comment: challenges of teenage and young-adult oncology. *Lancet Oncol* 7:612–3

El Ghissassi F, Baan R, Straif K *et al.* (2009) A review of human carcinogens-part D: radiation. *Lancet Oncol* 10:751–2

Fishman C, Mihm MC Jr, Sober AJ (2002) Diagnosis and management of nevi and cutaneous melanoma in infants and children. *Clin Dermatol* 20:44–50

Hausauer AK, Swetter SM, Cockburn MG *et al.* (2011) Increases in melanoma among adolescent girls and young women in California: trends by socioeconomic status and UV radiation exposure. *Arch Dermatol* 147:783–9

Kim HJ, Fay MP, Feuer EJ *et al.* (2000) Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med* 19:335–51

Livestro DP, Kaine EM, Michaelson JS *et al.* (2007) Melanoma in the young: differences and similarities with adult melanoma: a case-matched controlled analysis. *Cancer* 110:614–24

Magnanti BL, Dorak MT, Parker L *et al.* (2008) Sex-specific incidence and temporal trends in solid tumours in young people from Northern England, 1968–2005. *BMC Cancer* 8:89

Norman P, Simpson L, Sabater A (2008) 'Estimating with Confidence' and hindsight: new UK small-area population estimates for 1991. *Popul Space Place* 14:449–72

Norman P (2010) Identifying change over time in small area socio-economic deprivation. *Appl Spatial Anal Pol* 3:107–38

Purdue MP, Freeman LE, Anderson WF *et al.* (2008) Recent trends in incidence of cutaneous melanoma among US Caucasian young adults. *J Invest Dermatol* 128:2905–8

Richardson C, Monfort C (2000) Ecological correlation studies. *In:* Elliott P, Wakefield J, Best N *et al.* (eds) *Spatial Epidemiology: Methods and Applications*. Oxford University Press: Oxford, 205–20

Shahbazi M, Pravica V, Nasreen N *et al.* (2002) Association between functional polymorphism in EGF gene and malignant melanoma. *Lancet* 359:397–401

Singh SD, Ajani UA, Johnson CJ *et al.* (2011) Association of cutaneous melanoma incidence with area-based socioeconomic indicators-United States, 2004-2006. *J Am Acad Dermatol* 65(5 Suppl 1): S58–68

Smith PG (1992) Comparison between registries: age-standardised rates. In: Parkin DM, Muir CS, Whelan SL *et al.* (eds). *Cancer Incidence in Five Continents* Volume VI. International Agency for Research on Cancer Scientific Publications: Lyon, France, 865–70

StataCorp (2007) *Stata Statistical Software Release 10*. StataCorp LP: College Station, TX

Townsend P, Phillimore P, Beattie A (1988) *Health and Deprivation: Inequality and the North*. Croom Helm: London

Wachsmuth RC, Gaut RM, Barrett JH *et al.* (2001) Heritability and gene-environment interactions for melanocytic nevus density examined in a U.K. adolescent twin study. *J Invest Dermatol* 117:348–52

Wallingford SC, Alston RD, Birch JM *et al.* (2013) Regional melanoma incidence in England, 1996-2006: reversal of north-south latitude trends among the young female population. *Br J Dermatol* 169:880–8