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Slip! Slap! Slop! Cutaneous malignant melanoma incidence and social status in New Zealand, 1995–2000

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Abstract

Numerous studies have noted a strong social gradient in many types of ill health. In particular, people in more deprived areas tend to be less healthy than those in more affluent communities, even once the demographic and socio-economic differences of the people in those areas have been taken into account. The social gradient is evident for many types of health outcomes, including diseases such as cancer. However, this positive relationship is not evident for rates of melanoma incidence and mortality, with rates of the disease tending to *decrease* with measures of disadvantage. In this study, we assess the relationship between the incidence of melanoma and deprivation in New Zealand, a country with particularly high rates of the disease. In the light of greater public awareness of the risk factors associated with melanoma, through public awareness campaigns such as 'Slip! Slap! Slop' and 'No Suntan is Safe', we analyse small-area data on standardised rates of melanoma for the period 1995–2000. We found that melanoma rates increase with social status, even once other confounding factors are controlled for, but that the relationship is very small. Furthermore, the relationship between melanoma incidence and deprivation is context-dependent. Possible explanations for the relationship between melanoma and deprivation are discussed, including more frequent exposure to intermittent sunshine among less disadvantaged groups and the underreporting of melanoma incidence in the New Zealand cancer registry among individuals in lower social groups.

Keywords: Melanoma; Socio-economic status; Deprivation; New Zealand

Introduction

Global rates of cutaneous malignant melanoma (melanoma) have been increasing considerably in incidence for several decades. Rates of melanoma mortality have also been increasing but at a slower rate than incidence (Mackie, 1998), although in recent years both age standardised incidence and mortality rates have begun to decline (LaVecchia et al., 1999) in some, but not all, regions of the world (DeVries et al., 2003a). Despite such trends, melanoma rates remain particularly high especially among fair skinned populations of northern Europe, North America and Australasia. By contrast, lower rates tend to be found among people indigenous to Africa, Asia and Latin America and darker skinned whites in Southern Europe (Bevona and Sober, 2002).

The geographical distribution of melanoma often reflects the influence of sun exposure given that incidence rates in many countries increase at latitudes closer to the equator (Sinha and Benedict, 1996). However, latitudinal gradients are not always evident

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within countries or regions because of the influence of confounding variables, such as skin colour or socio-economic status. Furthermore, because of population mobility, latitudinal gradients in melanoma have often become less significant (Lee, 1997). However, this is less true of socio-economic gradients, which have tended to persist (DeVries et al., 2003b; Hemminski et al., 2003).

This paper examines the incidence of melanoma and its relationship to socio-economic status in New Zealand, a country with particularly high rates of the disease. Despite increased media attention to the risks of melanoma due to the efforts of organisations such as the Cancer Society through media weather reports and other public health campaigns (Bulliard and Reeder, 2001), rates of melanoma, after Australia, remain the second highest in the world (Bevona and Sober, 2002) and indeed for women the New Zealand rates are the world's highest.

However, despite this unenviable reputation it is not clear to what extent the positive gradient of risk between socio-economic status and melanoma continues to persist in New Zealand or whether, in response to greater public awareness, recent years have seen a dilution of this gradient. This paper contributes to this debate by specifically focusing on changes in the socio-economic incidence of melanoma in New Zealand and how such gradients are shaped by place. The paper is organised as follows. First we provide a theoretical overview of why a positive social gradient in melanoma has been identified in most studies, one which contrasts with the incidence of most other cancers (Burnley, 1997). Second, we provide a critique of the literature which has examined social gradients in melanoma and present three hypotheses which guide our research. Third, we provide a brief context for our New Zealand study and discuss the extent to which social risk factors identified in the literature should be present in New Zealand. The fourth section of the paper then briefly outlines the data and research methods used in the study. This is followed by a discussion of the findings and implications of the research, in particular how place-based analyses of melanoma can aid in identifying the importance of local factors and the need for more selective targeting of population groups at risk.

Interpreting the social gradient of melanoma risk

A large number of studies in different parts of the world have concluded that the incidence of, and mortality from, melanoma rises with increasing socio-economic status. Positive social gradients have been reported from a wide variety of contexts including those in Europe (Elwood et al., 1990; Bouchardy et al., 2002; Faggiano et al., 1995; DeVries et al., 2003a), especially the Scandinavian countries (Rimpela and Pukkala, 1987; Aase and Bentham, 1994; Linet et al., 1995; Andersen, 1992; Hemminski et al., 2003). Similar findings have been reported from the USA (Kirkpatrick et al., 1990; Goodman et al., 1995; Pion et al., 1995; Harrison et al., 1998), Canada (Gallagher et al., 1987; Fritschi and Siemiatycki, 1996), Australia (Smith et al., 1996: Burnley, 1997) and New Zealand (Pearce and Bethwaite, 1997).

Despite a plethora of recent research findings indicating a positive social class gradient with melanoma, Lee and Strickland's (1980) view that "there is currently no satisfactory explanation of this social gradient in the incidence of malignant melanoma" is probably still apt. Burnley's (1997) observation that the positive social gradient of melanoma was "an unexpected association", suggests that the causes of such positive gradients warrant further research. That the gradient is "unexpected" reflects the fact that, not only is the social distribution of melanoma the opposite of most cancers (Faggiano et al., 1995), but also that increased awareness of the disease should, if anything, be resulting in a dilution of the positive social gradient, especially given higher levels of education among the more at risk groups.

Despite some early attention to the role of alcohol (Williams, 1976) and dietary factors (Veierod et al., 1997), three major explanations have been given for the positive social gradient of melanoma. First, that it is due to differences in occupational exposure of indoor versus outdoor work, thus highlighting the significance of intermittent and intense sun exposure as a risk factor. Second, higher rates of melanoma incidence among more affluent groups may also reflect patterns of recreational activity which, it is argued, are more likely to be characteristic of more affluent groups. Third, social differences in melanoma incidence and mortality are more likely to be evident in countries where cost barriers are present which limit the use of primary and hence preventive care services. Each of these arguments is reviewed in turn.

Indoor versus outdoor work

Generally it has been assumed that outdoor work is more predominant among lower socio-economic status (SES) groups, resulting in chronic exposure patterns, while more affluent groups are more likely to be characterised by intermittent (primarily recreational) exposure. Evidence in support of such assumptions is provided by studies which show that SES gradients in the frequency of melanoma are most marked in body sites not usually exposed to the sun (Kirkpatrick et al., 1990) and thus most affected by intermittent exposure (Katsambas and Nicolaidou, 1996; Bulliard et al., 1997).

However, evidence in support of the effects of occupational exposure to sunlight as an explanation of

SES variations in melanoma incidence and mortality remains elusive. Some studies have indicated that chronic exposure, indicated by days of outdoor activity by occupation was associated with significantly reduced risk (Walter et al., 1999). Such findings have been particularly evident in comparisons between farming and non-farming occupations (e.g. Fincham et al., 1992; Hanrahan et al., 1996; Vacchino, 1999). By contrast, other studies (Cooke et al., 1984; Pion et al., 1995) have found no evidence of a difference in risk between indoor and outdoor workers of similar social class. Given that SES variations in both incidence and mortality occurred within both indoor and outdoor occupations then degree of occupational exposure cannot be used as an explanation of such variations. Indeed the intermediate group of occupations (mixed indoor/outdoor), which might have been expected to have had the highest level of intermittent exposure, had the lowest risk (Cooke et al., 1984). However, in contrast to the latter, Goodman et al. (1995) concluded that, while relative to indoor occupations, melanoma risk was highest among the mixed indoor/outdoor category, increasing levels of education or training required for the occupation was associated more strongly with melanoma risk than characteristics of the work environment. Furthermore, research which has involved detailed patient recall data of occupational sun exposure, has shown that once controls were made for host factors, such as skin or hair colour, additional controls for occupational sunlight exposure substantially reduced but did not eliminate the SES gradient in risk of melanoma (Gallagher et al., 1987).

Recreational exposure

In the light of the above findings, it has been suggested that higher income groups are more at risk from intermittent exposure to ultra violet radiation due to their greater involvement in recreational and vacation activities (Walter et al., 1999). Faggiano et al. (1995), for example, argued that the positive relationship between education and high rates of melanoma among North Italian men could be explained by the habit of the more affluent to spend their weekends and holidays in sunny resorts. Similarly, in the Netherlands, DeVries et al. (2003b) showed that melanoma rates were highest in the western and northern parts of the country and attributed this to the greater involvement of higher income groups in recreational activities in these areas, along with the increased tendency since the 1990s for Dutch people to take holidays in sub-tropical locations.

Other authors, such as Bentham and Aase (1996), in a time series study of the incidence of melanoma in Norway between 1955–89, have shown that while the positive relationship between income and the incidence of melanoma weakened over time, the opposite occurred for an indicator of the proportion of Norwegians holidaying abroad. This finding lead them to suggest that while overseas holidays were initially the preserve of the rich, this was less true over time especially since areas with the greatest increase in melanoma were those with the lowest incomes in the 1950s and 1960s, places whose residents were subsequently more likely to undertake foreign holidays. By contrast, a Swedish case control study, involving melanoma versus other cancer patients, found that the former were more educated and travelled more often to sub-tropical locations (Westerdahl et al., 1992). However, the effect of leisure activities on melanoma is difficult to assess. There is often a long lag effect of sunburn and sun exposure experienced during childhood holidays before melanoma is diagnosed (Gallagher et al., 1987; Kaskel et al., 2001).

Health system factors

While differences in occupational and recreational exposure may account for part of the positive SES gradient in melanoma, variations in the use of health services may also contribute to this trend. Higher rates of melanoma among the affluent might also suggest that such groups are more likely to have their melanoma detected and acted upon (Leon and Wilkinson, 1989). The increased detection of thin melanomas is perhaps indicative of such a trend (Burton and Armstrong, 1995). Evidence in support of the above is provided by Eiser et al. (2000) and Melia et al. (2000) who found that the uptake of targeted screening in one general practice in the UK was lower for people from deprived areas. Similarly, Geller et al. (1996) showed that, despite their lower overall risk of melanoma, residents of lower income communities were more likely to die than higher income residents if they contacted the disease, suggesting a later stage of cancer presentation and treatment.

Gender differences are also important given that the above trends are more likely to be characteristic of men (Melia et al., 2000; Eiser et al., 2000). Furthermore, while there is evidence that social differences in melanoma mortality have diminished over time, such trends have been more characteristic of women than men (Streetly and Markowe, 1995), again suggesting that men present later and respond less to traditional health education approaches (DeVries et al., 2003b).

Critique of past research on social gradients in melanoma

Despite a large number of studies of SES variations in melanoma, a number of critiques can be made. First, while much attention has been devoted to examining geographical variations in melanoma, especially how the effect of latitude on melanoma has varied by age (e.g. Lee and Scotto, 1993; Sinha and Benedict, 1996), gender (Bulliard, 2000; Jones et al., 1992) and migration status (Mack and Floderus, 1991; Khlat et al., 1992; Swerdlow et al., 1995), with one exception (Faggiano et al., 1995), no studies have examined the extent to which social gradients in melanoma vary geographically. It could be hypothesised that social gradients may be less in areas of greater environmental risk and where the emergence of a service economy coupled with higher rates of indoor work means that a greater number of lower income individuals are at risk from intermittent exposure. As Bentham and Aase (1996) suggest, outdoor recreation and vacations in sunny climates are not necessarily the preserve of the rich, especially if local environments provide such opportunities for most social groups. Conversely, in areas with less sunshine, where opportunities for outdoor recreation and vacations are more restricted, if higher income persons are more likely to undertake holidays in warmer places, then social gradients are likely to be greater. Such a hypothesis may well explain Faggiano's et al. (1995) finding of regional variations in the nature of melanoma inequalities, with a positive social relationship observed for northern Italian men and the reverse in the South. Furthermore, little work has considered whether the social gradient varies with urbanicity despite the noted urban-rural variations in melanoma rates (Espinosa Arranz et al., 1999).

Second, while attention has been directed towards increased melanoma risk with age and especially the levelling off in its incidence among younger people (LaVecchia et al., 1999; Bevona and Sober, 2002; Newnham and Moller, 2002), very few studies have examined the extent to which social gradients in melanoma have changed over time. Bentham and Aase (1996) noted that the positive association between income and melanoma observed in Norway in the 1970s had weakened by the 1980s by which time it was negative and not significant. Similar findings were reported by Pearce and Bethwaite (1997) in New Zealand. The positive social gradient, evident in the 1970s (1974–78), disappeared by the 1980s (1984–87), leading the authors to hypothesise that ''changing recreational exposures and patterns of diagnostic practice and ascertainment may explain the dilution of the social class gradient'' (Pearce and Bethwaite, 1997, p. 201). However, this study did not control for the potentially important confounding factors such as ethnicity and exposure to solar radiation. Furthermore, both of the above studies rely on historical data and fail to answer the question of whether *current* melanoma incidence and mortality has now become a more general health problem and not one largely confined to more educated and higher income groups. Also, given observations that men have a higher rate and deeper melanomas than women (Lee et al., 1992; Martin and Robinson, 2004), the interaction between changes in melanoma incidence and mortality and gender warrants further examination.

Third, while positive social gradients have been found for a wide range of social status variables, including occupation (Bouchardy et al., 2002; Hemminski et al., 2003), income (Kirkpatrick et al., 1990), education (Westerdahl et al., 1992), poverty level (Harrison et al., 1998) and overcrowding (Burnley, 1997), analysis of what is the key social predictor of melanoma has seldom been undertaken. For instance, Harrison et al. (1998), after controlling for confounders, found, that education was a more important predictor of the incidence of melanoma than income. However, why this should be the case remains unclear, especially since persons with higher levels of education are more likely to have early diagnoses (Melia et al., 2000) and to be less likely to die from their melanoma (Geller et al., 1996). Thus more research needs to be undertaken to disentangle the independent effects of different measures of SES, especially given an increased public awareness of the risks of melanoma particularly among persons with higher levels of education.

Thus in summary, in the light of the above comments especially the attempts to increase public awareness to melanoma, this research has two aims. First, we consider whether melanoma remains the cancer of the affluent in New Zealand. We examine whether the positive social gradient in melanoma that was observed during the 1970s and 1980s persisted during the period 1995 to 2000. Second, we consider whether specific characteristics of place influence the rates of melanoma in New Zealand. If the social gradient in melanoma incidence remained during the 1990s, we consider whether the gradient is less likely to occur in physical environments with warmer climates where the population has greater accessibility to outdoor recreation. We examine whether the incidence of melanoma is higher in urban compared to rural areas of the country and whether any urban-rural variation is significant once age and sex as well as other demographic and environmental characteristics are controlled for and, importantly, whether the social gradient varies between urban and rural areas. Before turning our attention to these two hypotheses, we provide a brief contextual background to the incidence of melanoma in New Zealand and comment on the extent to which social risk factors identified elsewhere are likely to be present.

Melanoma in New Zealand

Rates of melanoma in New Zealand are the second highest in the world (Bevona and Sober, 2002), most

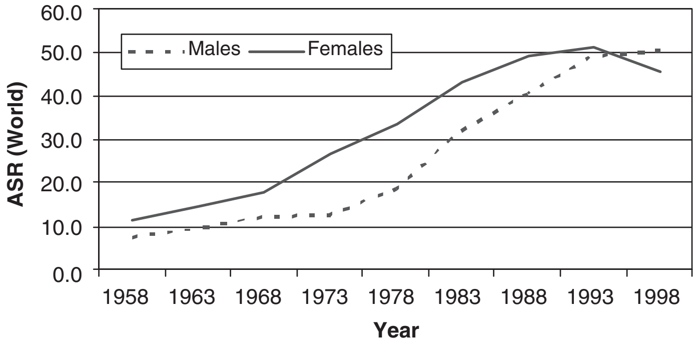

Fig. 1. ASRs of melanoma incidence in New Zealand 1958–1998 for males and females.

likely reflecting high levels of ultraviolet radiation (UV) (New Zealand Public Health Commission, 1994). Indeed, it has been estimated that levels of solar UV radiation are about 13% higher than countries at a similar latitude in the Northern Hemisphere (McKenzie and Elwood, 1990). Furthermore, UV levels in New Zealand have increased over the past two decades, due to decreases in atmospheric ozone (McKenzie and Elwood, 1990). As a consequence the age standardised rate increased from 7.5 to 50.1 per 100,000 for males and 11.1 to 45.4 per 100,000 for females, respectively, between 1958 and 1998 (Fig. 1).

In the light of the risk factors discussed earlier which underlie social variations in melanoma incidence, it is not clear what role they may play in New Zealand. Patterns of occupational exposure in New Zealand are probably similar to other developed countries given the reduction of jobs in primary industries and the development of a service economy. As in other countries an increased proportion of the population now works in indoor occupations who are consequently at a greater risk of melanoma from intermittent exposure.

With respect to the suggestion that variations in outdoor recreational activity may explain social variations in melanoma rates, this does not seem to be evident in New Zealand, where although there is evidence of a social gradient in recreational participation, physical activity does not vary significantly with income or deprivation (Ministry of Health, 1999). Furthermore, in their review of the studies of outdoor recreation in New Zealand, Booth and Peebles (1995) demonstrate that while certain activities including skiing and hunting are dominated by higher income groups, other activities such as mountain biking are less related to social status (New Zealand Council for Recreation and Sport, 1985). Thus, there is only limited evidence to suggest that participation in outdoor recreation is higher for more affluent groups and therefore a significant relationship between melanoma and social status is likely to be less apparent.

Thirdly, by contrast, the effect of health system factors is likely to have accentuated social differences in the incidence of melanoma. Primary health care in New Zealand is characterised by significant co-payments which have proved a barrier to low income groups seeking care (Barnett, 2001). As a result, lower income persons are less likely to have had their melanoma diagnosed. Public health campaigns have raised public awareness about the risks of exposure to UV radiation (Douglass et al., 1997; Richards et al., 2001) and this is possibly the reason why melanoma rates have recently stabilised (Ministry of Health, 2002). Efforts such as the 'Slip! Slap! Slop!' campaign in the 1980s and subsequent ventures including the 'Cover Up', 'Sense in the Sun' and 'No Suntan is Safe' slogans (Cooke, 1996) have aided the prevention, earlier diagnosis and treatment of melanoma (MacKie, 1998). Although there is some evidence that these campaigns were successful in reducing UV exposure and subsequently melanoma incidence rates (Whitehead et al., 1989; Richards et al., 2001), it is not clear whether the reduction in incidence was consistent across all social groups.

With these considerations in mind, the remainder of the paper examines the three hypotheses above using data for the period 1995–2000. This timeframe is of particular interest as it follows a period of extended public health campaigns that aimed to raise public awareness of the disease. Furthermore, it is the first time that the reporting of melanoma was a statutory requirement following the introduction of the Cancer Registry Act 1993. Analyses are undertaken for the periods 1995–1997 and 1998–2000 separately in order to monitor the relationship between melanoma and social status over time.

Data and methods

The numbers of cases of melanoma were provided for males and females across New Zealand at Census Area Unit (CAU) level for the period 1995–2000 by the

New Zealand Health Information Service (NZHIS). Prior to 1995, cancer notification was not obligatory and hence melanoma incidence data before this date cannot be considered reliable (Ministry of Health, 2002). There were 9910 cases during this period of which 5025 were male and 4885 female. The incidence of melanoma steadily increased until the age of 54 and then stabilised for males and females. Until the age of 54, the incidence of melanoma was higher for females than males but over the age of 54, the incidence was higher for males (Fig. 2). Importantly, the domicile code in which the patient lived was included in the dataset. The domiciles match to the 1996 CAUs, which allowed census data to be attached to each record. CAUs are the second smallest unit of dissemination of census data in New Zealand, each representing approximately 2300 people. However, for 448 of the cases diagnosed at the start of the study period, only the 1991 CAU identifier was available. For these cases the record was associated with the corresponding 1996 CAU.

In order to assess the relationship between social status and the incidence of melanoma, age-standardised rates of melanoma were calculated for deprivation deciles using the 1996 New Zealand Deprivation Score (NZDep 96) as a measure of social deprivation (Salmond et al., 1998). The deprivation index was used because it captures a number of the multiple facets of deprivation rather than just individual components such as car ownership or educational attainment. Deprivation indices have been widely utilised in health research to examine the social dimensions of health and ill health (Carstairs and Morris, 1991) and have been found to be highly significant in explaining variations in many types of ill health such as lung cancer (Pearce and Boyle, 2005a, b) and health-related outcomes such as smoking behaviour (Pearce et al., 2003; Barnett et al., 2005). The standardised incidence ratios (SIRs) for melanoma incidence (1995–2000) were calculated for each deprivation quintile using the New Zealand population as the standard.

In order to examine whether the relationship between social status and melanoma incidence was consistent after controlling for potential confounding factors, the relationship was also examined using Poisson regression. The number of cases of melanoma and the population count were calculated for 16 age-sex groups (males and females aged 0–15, 16–24, 25–34, 35–44, 45–54, 55–64, 65–74 and 75 and over). Two categorical variables were included to define which age and sex group each record represented. Rates of melanoma are substantially higher among the Pakeha population (persons of European descent) than for Maori (Ministry of Health, 2002) and therefore, the age- and sex-specific census data were also extracted on the percentage of the resident population whose ethnic origin was classified as 'European'.

A number of studies have found that an individual's risk of melanoma increases with the level of total sun exposure at his or her place of residence (Holman et al., 1986; Green et al., 1986). Therefore, in order to control for variations in sun exposure, estimates of the mean total yearly solar radiation were calculated for each CAU using solar insulation data that had been interpolated for one kilometre grid squares across New Zealand (Leathwick et al., 2002). The zonal mean of the total yearly solar radiation was calculated for each CAU to provide a proxy for potential UV exposure. Some studies have noted the importance of temperature in explaining variations in melanoma incidence (Christophers, 1998). Therefore in addition, the mean temperature was calculated for CAUs using temperature data from the same source and methods as was used to calculate the measures of solar radiation. Finally, the log of population density for each CAU was calculated to examine whether there was an urban excess of cases as has been identified in other studies of cancer (Pearce and Boyle, 2005a, b).

Poisson regression analysis was carried out for the whole time period (1995–2000) and the two periods separately (1995–1997 and 1998–2000) to see which explanatory variables would help to explain the variation in melanoma incidence and to examine whether

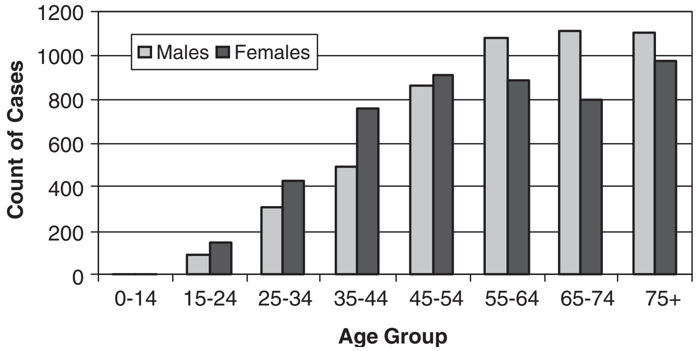

Fig. 2. Age distribution of melanoma cases 1995–2000 for males and females in New Zealand.

social status is a significant predictor of the disease once other risk factors had been controlled for. The age- and sex-specific population count was treated as a constant offset (Knudsen, 1992), effectively making this a model of rates. The goodness of fit was tested by comparing the deviance (a measure of unexplained variation) to a χ^2 distribution with the corresponding degrees of freedom. Candidate explanatory variables were added to the models using a forward stepwise selection procedure. The following set of explanatory variables were used: age, sex, deprivation (NZDep 96), population density, the percentage European, mean annual solar radiation and mean temperature. A total of 1661 CAUs in New Zealand were included in the analysis and because each CAU was represented 16 times (males and females in eight age groups), there were 26,576 records in the entire data set. We begin by assessing a model for all cases of melanoma (1995–2000) with only the deprivation score and then examine the effects of adding age, sex, and the percentage European before testing the environmental variables (exposure to solar radiation, mean temperature and population density) and the interactions between any contextual variables that are significant and deprivation. In order to examine whether the relationship between deprivation and melanoma changed during our study period, we then consider the two time periods separately (1995–1997 and 1998–2000).

Results

Although New Zealand has rates of melanoma that are among the highest in the world, the rates are not uniform across the country. Fig. 3 shows the indirectly standardised incidence ratios (SIR) in Territorial Local Authorities (TLAs) across New Zealand for the period 1995–2000. The SIR is the ratio between the observed number of cases and the expected number of cases of melanoma using age-specific rates for the whole of New Zealand (Moon et al., 2000). This is a useful summary measure for comparing disease rates between different population groups because it adjusts the data so that the confounding effect of age is removed. The map demonstrates that rates of melanoma tend to be highest in the northern part of New Zealand and very low rates in the far south of the country.

Melanoma and deprivation

The relationship between melanoma incidence and deprivation is examined by firstly calculating the SIR value for melanoma for deprivation quintiles across New Zealand. Second, the same relationship is examined in regression models but this time controlling for potential risk factors such as ethnicity, exposure to climatic factors and population density.

Fig. 4 provides the SIR of melanoma cases in NZDep 96 quintiles. Although the SIR values are lowest in quintile five (high levels of deprivation), the pattern between quintiles one to four is non-linear. For example, the SIR is higher in quintile two than it is in quintile one and the SIR in quintile four is greater than 100 (observed cases exceed expected cases) whereas in quintile three the SIR is less than 100 (expected cases exceed observed cases). Furthermore, there is a significant amount of overlap between the confidence intervals for deciles one to four. These results suggest that melanoma is no longer the preserve of the prosperous as high rates of the disease are found among relatively disadvantaged groups. However, this simple analysis does not control for other potential risk factors, particularly ethnicity, exposure to climatic factors and population density.

Melanoma incidence 1995–2000

The results for the entire study period (1995–2000) are shown in Table 1. Model 1 is simply the null model which includes a constant and no other explanatory variables. The deviance from subsequent models can be compared to this to test for goodness of fit. Model 2 shows that the NZDep 96 variable was significantly associated with melanoma incidence in New Zealand (t-value $= -13.56$). The relationship between deprivation and melanoma incidence was negative which suggests that the disease is more common among less disadvantaged groups. However, the effect of deprivation is extremely small (parameter estimate $= -0.019$). Deprivation remained significant, although less so (t-value $= -7.28$), once age, sex, ethnicity and population density were controlled for and the pseudo-r^2 increased from 0.0000 in the null model to 0.2675 (model 3). However, the effect of deprivation on melanoma incidence was smaller than in the univariate model (parameter estimate $= -0.001$). The parameter estimates were intuitively reasonable as melanoma incidence increased significantly with age, the proportion of population who identified themselves as European and population density whilst incidence was lower among females.

A comparison of the mean solar radiation and mean temperature variables demonstrated that, when added separately, both variables were significant in explaining melanoma incidence but that once temperature is included, solar radiation is no longer significant (models 4 and 5). The parameter estimate for solar radiation was positive which suggests that melanoma incidence is higher in warmer climates.

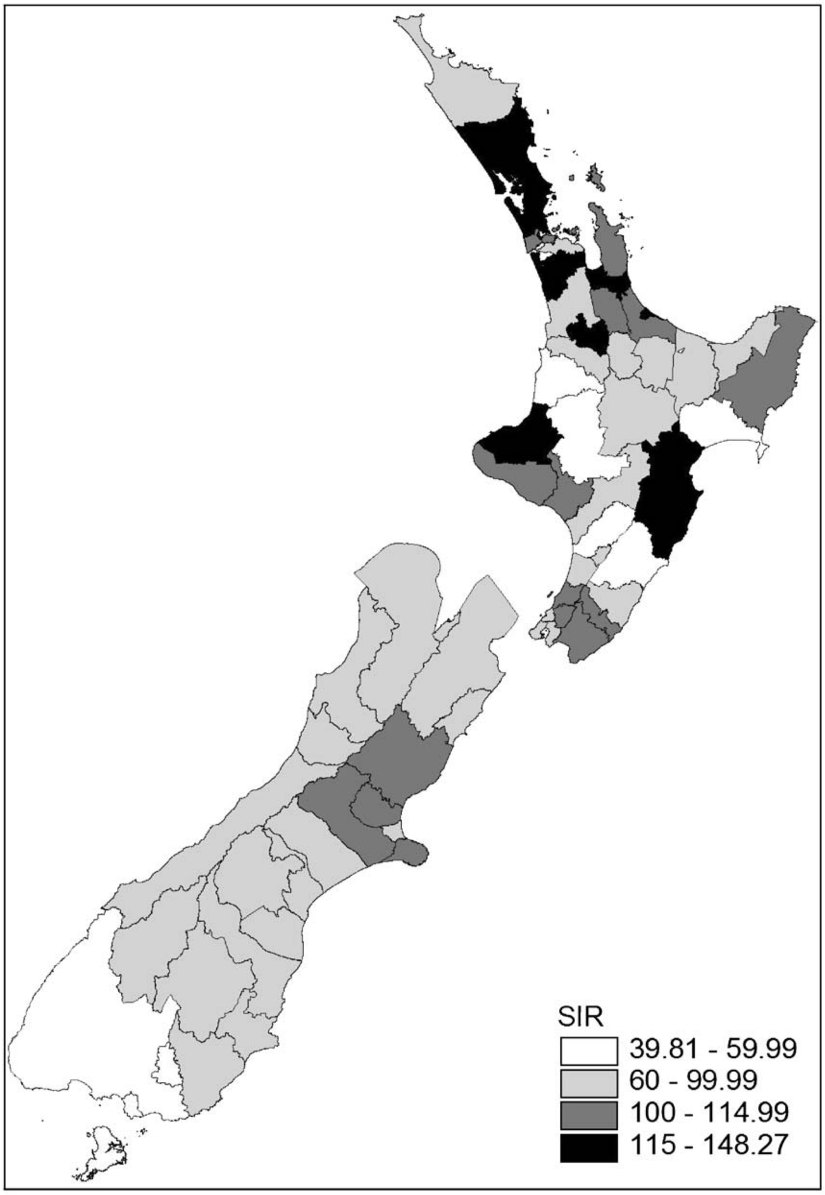

Fig. 3. SIR of melanoma in Territorial Local Authorities across New Zealand (1995–2000).

Melanoma incidence 1995–1998

When the melanoma cases that were diagnosed between 1995 and 1997 were modelled separately, the deprivation variable had a negative parameter estimate and was significant in the univariate model. The addition of the other potential explanatory variables also produced similar results to the model of all melanoma cases. The age, sex, percentage European, population density and mean temperature variables were again significant, with similar parameter estimates to those for all cases and the deprivation variable remained significant (t-value $= -4.36$). The results are not shown because they were very similar to those for the entire study period.

Melanoma incidence 1998–2000

Similar results were found for the period 1998–2000 as deprivation, age, sex, percentage European and mean temperature were all significant (not shown). However,

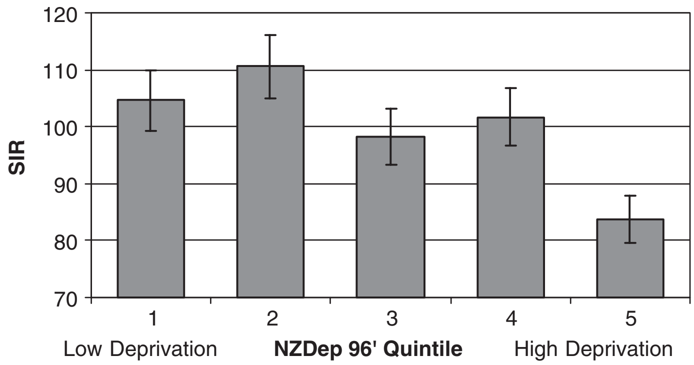

Fig. 4. SIR for melanoma (1995–2000) in deprivation quintiles (NZDep96) (bars denote 95% confidence intervals).

for this time period the population density variable was not significant in explaining melanoma incidence. Deprivation remained significant once the other factors had been controlled for although the t-value was slightly larger (t-value $= -6.29$).

The parameter estimates for the deprivation variable (NZDep 96) were similar in both time periods, both in the univariate and multivariate models. This suggests that there was a small but consistent relationship between melanoma incidence and deprivation during the entire study period (1995–2000).

Contextual effects on deprivation

In order to examine whether there are contextual effects that influence the relationship between deprivation and melanoma, the interactions between the deprivation variable and the two significant contextual variables (mean temperature and population density) were examined. For the model of all cases, the interaction between deprivation (divided into quartiles to provide a categorical measure of deprivation that can be easily interpreted) and mean temperature was not significant (model 6, Table 1). The interaction between the deprivation quartiles and the log of population density variable was negative and significant in the highest deprivation group, which suggests that population density has less of an effect upon melanoma in higher deprivation quintiles (model 7). The interaction terms between deprivation and mean temperature as well as deprivation and the log of population density were replicated when the time periods (1995–1998 and 1998–2000) were considered separately.

Discussion

This study has examined the relationship between melanoma incidence and deprivation in small areas across New Zealand. A number of conclusions can be made with respect to the two objectives of the study.

First, the major finding of the study is that the deprivation gradient in melanoma observed in the 1970s and 1980s continues to persist. The SIR values in deprivation quintiles reveals that, although the rates of melanoma are lowest in the areas of high deprivation, there is not a linear relationship between melanoma and deprivation. However, the results of the regression analyses for the entire study period (1995–2000) as well as when the two time periods are considered separately (1995–1997 and 1998–2000) demonstrate that there is a significant negative relationship between melanoma incidence and deprivation that is consistent for both time periods. Furthermore, this relationship remains once age, sex and exposure to the climatic variables have been controlled for, which makes melanoma distinctive from most other types of cancer that tend to increase with lower social status (Burnley, 1997). However, it is important to note that an inspection of the parameter estimates in the regression models of this study demonstrate that the effect of deprivation on melanoma incidence in New Zealand is extremely small. The reduction in the social gradient may reflect the disproportionate success of the various public awareness campaigns, such as 'Slip! Slap! Slop!' among higher income groups leading to a narrowing of social differences in the incidence of the disease.

In terms of the existence of the small but significant negative relationship observed between melanoma and deprivation, two explanations are possible. First, previous studies have noted that the more affluent social groups have a greater involvement in outdoor leisure activities (Elwood et al., 1985), including holidays abroad (Bentham and Aase, 1996), which may increase the intermittent exposure to solar radiation. However, the outdoor recreation hypothesis seems less likely in New Zealand because the social gradient in outdoor leisure activities is less apparent (Ministry of Health,

Table 1
Results from Poisson regression analysis with the age- and sex-specific count of melanoma incidence as the dependent variable (1995–2000)

Pseudo R^2	Model 1			Model 2			Model 3		
	0.0000			0.0041			0.2675		
	Estimate	Std. Error	*t*-value	Estimate	Std. Error	*t*-value	Estimate	Std. Error	*t*-value
Intercept	−5.905	0.010	−586.35	−4.035	0.138	−29.33	−10.530	0.337	−31.20
NZDep 1996				−0.019	0.001	−13.56	−0.001	0.000	−7.28
Age (15–24)							3.517	0.309	11.40
Age (25–34)							4.533	0.304	14.92
Age (35–44)							5.104	0.303	16.85
Age (45–54)							5.674	0.302	18.76
Age (55–64)							6.051	0.302	20.00
Age (65–74)							6.471	0.302	21.40
Age (75+)							6.696	0.302	22.14
Sex (Female)							−0.129	0.021	−6.20
% European							0.003	0.000	10.43
Log pop density							0.098	0.012	8.07

Pseudo R^2	Model 4			Model 5			Model 6			Model 7		
	0.2714			0.2722			0.2719			0.2721		
	Estimate	Std. Error	*t*-value	Estimate	Std. Error	*t*-value	Estimate	Std. Error	*t*-value	Estimate	Std. Error	*t*-value
Intercept	−13.179	0.392	−33.65	−11.679	0.345	−33.82	−12.801	0.345	−37.10	−12.833	0.320	−40.14
NZDep 1996	−0.001	0.000	−7.47	−0.001	0.000	−7.77						
Age (15–24)	3.523	0.309	11.42	3.521	0.309	11.41	3.520	0.309	11.41	3.520	0.309	11.41
Age (25–34)	4.533	0.304	14.92	4.534	0.304	14.92	4.534	0.304	14.92	4.534	0.304	14.92
Age (35–44)	5.104	0.303	16.85	5.104	0.303	16.85	5.107	0.303	16.86	5.106	0.303	16.86
Age (45–54)	5.672	0.302	18.75	5.670	0.302	18.75	5.675	0.302	18.76	5.674	0.302	18.76
Age (55–64)	6.052	0.302	20.01	6.051	0.302	20.01	6.052	0.302	20.01	6.050	0.302	20.00
Age (65–74)	6.482	0.302	21.44	6.483	0.302	21.44	6.484	0.302	21.45	6.481	0.302	21.44
Age (75+)	6.702	0.302	22.16	6.701	0.302	22.16	6.700	0.302	22.15	6.697	0.302	22.15
Sex (Female)	−0.124	0.021	−6.04	−0.124	0.021	−6.02	−0.123	0.021	−5.99	−0.123	0.021	−6.00
% European	0.003	0.000	13.26	0.003	0.000	13.75	0.003	0.000	14.78	0.003	0.000	14.89
Log pop density	0.080	0.012	6.59	0.042	0.013	3.33	0.038	0.013	2.92	0.089	0.025	3.60
Mean solar rad	0.185	0.014	13.28									
Mean temperature				0.101	0.007	14.83	0.106	0.013	8.34	0.097	0.007	14.15
NZDep96 2							−0.170	0.234	−0.73	0.120	0.091	1.31
NZDep96 3							0.263	0.237	1.11	0.079	0.106	0.75
NZDep96 4							−0.005	0.284	−0.02	0.249	0.120	2.07
NZDep96 2.Temp							0.011	0.017	0.65			
NZDep96 3.Temp							−0.021	0.018	−1.18			
NZDep96 4.Temp							−0.013	0.021	−0.60			
NZDep96 2.LPDen										−0.050	0.031	−1.61
NZDep96 3.LPDen										−0.035	0.035	−0.98
NZDep96 4.LPDen										−0.146	0.040	−3.63

2002). It is likely that a smaller number of people travel abroad for their holidays compared to Europe and exposure to UV radiation during foreign holidays is less likely to be pertinent for people living in a country, such as New Zealand, where levels of UV radiation are relatively high. These factors may help to explain why the effect of social status is so small in New Zealand compared to elsewhere.

Second, an alternative explanation for the small effect of deprivation upon melanoma may be explained by decreased levels of underreporting of the disease in cancer registries (Brochez et al., 1999; Melia et al., 1995;

Richards et al., 1995). Until the Cancer Registry Act 1993 came into effect, melanoma cases were significantly underreported in New Zealand (Bulliard and Cox, 1996; Ministry of Health, 2002), leading, not surprisingly, to significant social, but also partially artefactual differences in the melanoma incidence. Underreporting occurred because of inaccurate coding and the reliance on hospital inpatient records to identify cases of a disease that is frequently treated on an outpatient basis (Paterson et al., 2001), but also because it was an outcome of significant financial barriers in access to primary care on the part of low income groups (Barnett and Barnett, 2004). However, since the introduction of the Cancer Registry Act in 1994 and the reduction of GP fees, at least for lower income families, underreporting of melanoma is less likely to occur than previously and this may well explain the diminished link between deprivation and the incidence of the disease.

While such a link, although small, still exists, the second major finding suggests that there are also contextual factors that influence the relationship between deprivation and melanoma. When examined independently, the measures of solar radiation and mean temperature are significant in explaining melanoma once age, sex, deprivation and ethnicity have been controlled for. This is consistent with previous studies that have noted latitudinal differences in melanoma (Bulliard et al., 1994). However, this study has found that mean temperature rather than mean solar radiation is more significant in explaining variations in melanoma incidence and indeed solar radiation is not significant once mean temperature has been controlled for. The importance of temperature in explaining melanoma incidence has been noted elsewhere and although it has been suggested that this observation may have a biophysical pathway (Christophers, 1998), it is more likely to be explained by behavioural factors. In warmer climates people may spend a greater proportion of their recreational time outdoors and therefore have greater intermittent exposure to UV radiation. Therefore, the behavioural influence of temperature may have a greater environmental role to play than the geographical variations in UV radiation.

The interaction between temperature and deprivation was not significant, which suggests that the effect of temperature upon melanoma incidence is consistent across all social groups in New Zealand. This relationship is perhaps unsurprising in New Zealand given the unclear relationship between outdoor recreation activity and social status.

The results of this study have also noted that the population density variable is significant in explaining melanoma for the full study period (1995–2000). This relationship suggests that there is an urban excess in melanoma incidence that is not explained by the deprivation, demographic and environmental explanatory variables. This is consistent with other studies of cancer that have noted an urban excess (Schouten et al., 1996; Pearce and Boyle, 2005a) but this is the first study to identify an urban excess in melanoma incidence. Importantly the interaction between deprivation and population density was significant, at least in the highest deprivation category. Compared to the base categories, the parameter estimates were negative which suggests that population density is less important in explaining melanoma for those living in areas of high deprivation. In other words the social gradient in melanoma rates is greater in more urban areas of New Zealand.

The urban excess was also apparent for the earlier period (1995–1998) but population density was not significant in the later time period (1998–2000). A possible explanation for the disappearance of the urban excess is that the educational strategies developed during the 1980s through the various public awareness campaigns have had a disproportionate influence upon urban dwellers. In other words, urban dwellers have historically been more likely to be exposed to intermittent sunlight; however, the success of the public awareness campaigns among this group of people has removed this distinction.

Of course, similar to many other studies of melanoma incidence, this research also has limitations. First, there is likely to be a long lag period between carcinogenic exposure and diagnosis with melanoma. If a melanoma patient has migrated during the latency period then the CAU in which they reside when diagnosed with the disease may not correspond to the CAU in which they lived at the time of carcinogenic exposure or during the latency period. Therefore, the explanatory variables used in the regression model may be inappropriate. For example, exposure to solar radiation will not only depend upon radiation levels at a person's current residential address but upon the levels at previous addresses as well as at other important locations such as the individual's workplace. This factor will be particularly important if exposure to high levels of UV radiation during childhood is significant in the aetiology of melanoma, as migration would be expected to reduce any geographical differences in the incidence of the disease (Bulliard et al., 1994). Second, the climatic variables (mean solar radiation and mean temperature) in each CAU may not adequately control for exposure to ultraviolet radiation because a number of studies have suggested that intermittent exposure to UV radiation is a more important risk factor than total exposure (Bulliard, 2000). Third, being based on ecological correlations, the results of this study do not guarantee the same association for individuals. Furthermore, the overall explanatory power of the regression models was not high as they only accounted for less than 30% of the variance in the dependent variables. Fourth, the study covered the time period 1995–2000 and uses the 1996 census to obtain the denominator population and socioeconomic variables. It was important to use the 1996 census for all of the analysis to retain consistent geographical units but by 2000 the census data was four years old. Fifth, the two time periods are close together; therefore, it may not be too surprising that the results are similar. Future work could usefully monitor the relationship between the incidence of melanoma and deprivation.

This paper has examined the relationship between the incidence of melanoma and deprivation in New Zealand, a country with particular high rates of the disease. This research is important because it is the first study to examine the social gradient in melanoma incidence using small area estimates of solar radiation exposure. The results of the Poisson regression analysis have shown a very small but consistently significant relationship between melanoma incidence and deprivation for the period 1995–2000 and also when the periods 1995–1997 and 1998–2000 were examined separately. The relationship between melanoma incidence and deprivation is consistent with a number of previous studies in other countries and an earlier study in New Zealand during the 1980s. However, this study has found that the relationship between melanoma and deprivation is extremely small compared to the social gradients noted elsewhere. New Zealand's deprivation gradient in melanoma maybe smaller than in other countries because of a less marked social gradient in outdoor recreational activity and due to the efforts of public awareness campaigns during the 1980s and 1990s. These are likely to have had a greater impact upon the more prosperous social groups and may have led to a decrease in melanoma incidence among this cohort. We suggest that the social gradient in melanoma may be due to artefactual explanations, rather than a genuine higher risk among groups of higher social status. Previous studies have noted that melanoma remains under-reported in New Zealand and it is likely that the level of underreporting is higher among groups of lower social status. This study has found that the social gradient in melanoma is reducing to the advantage of the prosperous. It is important to monitor this relationship and the absolute numbers with the disease to prevent melanoma being added to the list of health outcomes that have created a health divide in New Zealand that favours the richest (and healthiest) over the poorest (and unhealthiest) social groups.

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