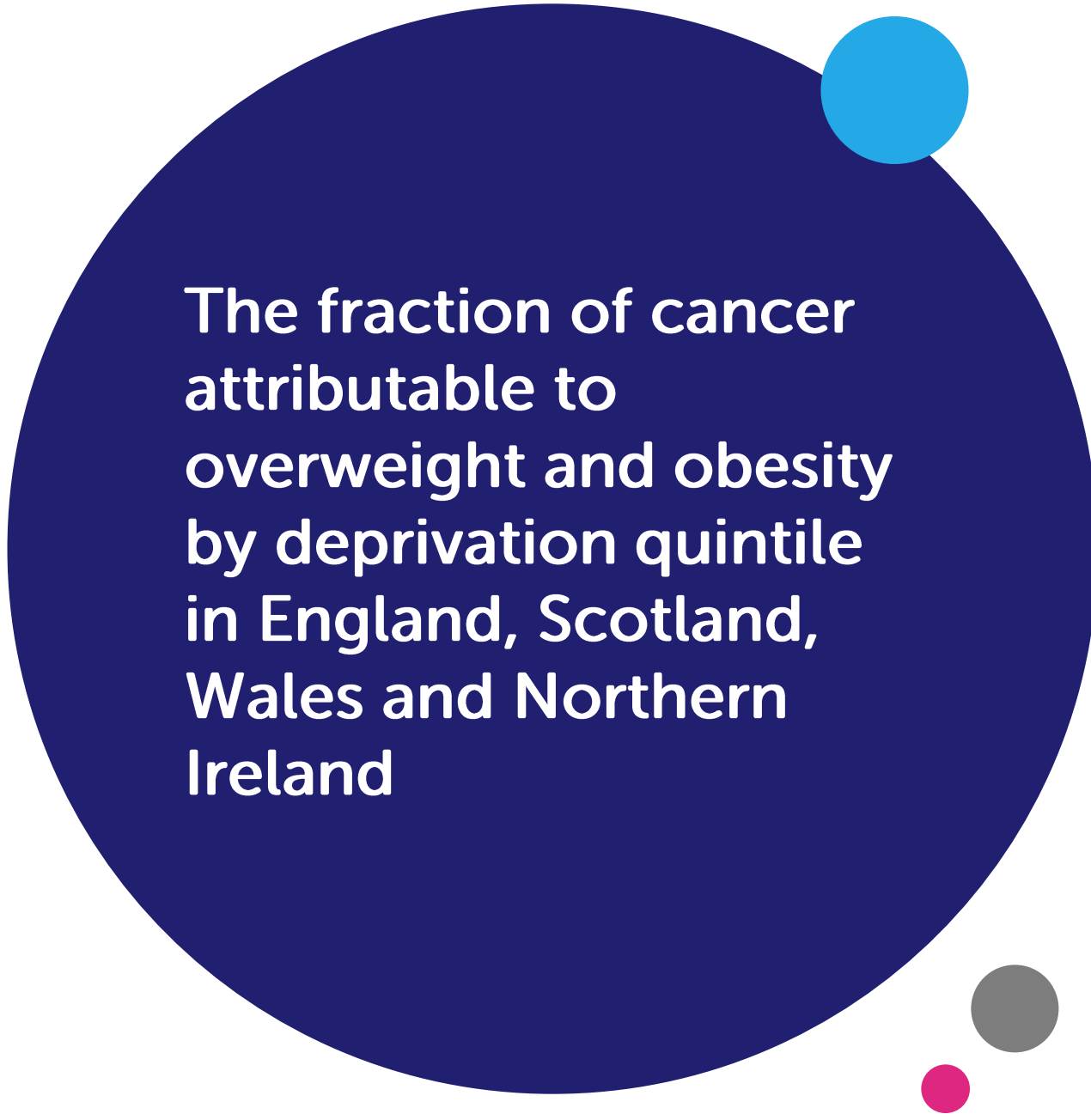




The fraction of cancer attributable to overweight and obesity by deprivation quintile in England, Scotland, Wales and Northern Ireland

October 2020

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Reference

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Authors

Nick Payne, Anne Alarilla, Christine Delon, Magda Mikolajczyk & Katrina Brown

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Karis Betts, Lindsey Frodsham, Jessica Newberry Le Vay, Ben Chiu & Malcolm Clark

Cancer Research UK

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List of acronyms

1. BMI: Body mass index
2. ERR: Excess relative risk
3. IMD: Index of multiple deprivation
4. PAF: Population attributable fraction
5. RR: Relative risk

Executive summary

Introduction

Overweight and obesity is the second biggest cause of cancer after smoking. There are clear socio-economic inequalities in cancer incidence, and in overweight and obesity prevalence. People from more deprived populations generally experience higher cancer incidence rates and higher overweight and obesity prevalence, compared to less deprived populations. It is hypothesised that more deprived populations have a higher proportion of cancer cases caused by overweight and obesity, compared to less deprived populations

Methods

Cancer incidence by deprivation data for the 13 cancer types that have a definite causal association with overweight and obesity, was taken from routine annual publications for each UK nation. Overweight and obesity prevalence by deprivation was collated from routine health surveys representative of each UK nation. Some data imputation was required to account for missing cancer incidence and overweight and obesity prevalence data. Relative risk estimates were obtained from a systematic search of the literature. Population Attributable Fractions (PAFs) were calculated using the standard formula.

Results

A moderate deprivation gap was observed between the least deprived group and the most deprived group for females across UK nations. The proportion of cancer cases attributable to overweight and obesity is 10-29% higher in the most deprived UK women versus the least deprived. For males the deprivation gap was generally much smaller.

Discussion

Deprived female populations have a higher proportion of overweight and obesity-attributable cancer cases, compared to less deprived female populations. This is because of higher obesity prevalence in more deprived versus less deprived females. In males the deprivation gap in overweight and obesity prevalence, and accordingly in overweight and obesity-attributable cancer cases, is smaller.

To our knowledge, no other study has assessed the influence of deprivation on cancers attributable to overweight and obesity in UK nations. However, the findings from this analysis are limited by the availability and quality of data. More research is needed using high quality data to form more robust conclusions.

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Introduction

Deprivation and cancer

There are clear socio-economic inequalities in cancer incidence, mortality and survival in the UK. People in the most deprived quintile are around 13-36% more likely to be diagnosed with cancer and – because of socio-economic differences in survival – around 31-73% more likely to die from cancer, compared with those in the least deprived quintile.^{1,2,3,4,5,6,7}

Higher incidence and mortality rates in more deprived groups are found across most cancer types. A notable exception is breast cancer, which is more common in less deprived women.^{1,2,3,4} Less deprived women are more likely to attend breast screening, and have higher levels of other risk factors around childbearing and exogenous hormone use.⁸

Risk factors and cancer

Potentially modifiable risk factors contribute a large proportion of cancer cases, causing around 4 in 10 cancer cases every year in the UK.⁹ Smoking and overweight and obesity are the two leading cancer risk factors in the UK, contributing 15% (around 54,300 cases) and 6% (around 22,800 cases) of overall cancer cases every year, respectively.

The large number of cancer cases caused by overweight and obesity is a result of a high prevalence of this risk factor, combined with a large number of cancer types associated with it. UK overweight and obesity prevalence is among the highest in Europe,¹⁰ with around 6 in 10 adults (60-64%) overweight (body mass index [BMI] 25-29.9) or obese (BMI 30+) in the UK.^{11,12,13,14} Overweight and obesity prevalence has increased markedly in the UK in recent decades, and although rates appear to have plateaued, they do not show signs of declining.^{12,13,14,15}

Overweight and obesity causes 13 different types of cancer, including several female-specific or female-predominant cancers.¹⁶ The only known risk factor associated with more cancer types is smoking, which causes at least 15 different types of cancer.¹⁷ Of these cancer types, there are seven which have causal links with both overweight and obesity, and smoking.

Risk factors and deprivation

Overweight and obesity prevalence varies considerably between deprivation groups, especially in the female population. Female overweight and obesity combined rates are 26-53% higher in the most deprived group compared with the least deprived group in Great Britain.^{11,12,13} This deprivation gap is driven by the obese category rather than the overweight category: female obesity rates are 75-104% higher in the least

deprived group compared with the most deprived group.^{12,12,13} In males, overweight and obesity combined prevalence is similar across deprivation groups in Great Britain; however obesity rates are 25-69% higher in the most deprived group versus the least deprived group.^{12,12,13}

Research aim

Given the deprivation gap in overweight and obesity prevalence, it is hypothesised that more deprived populations have a higher proportion of cancers caused by overweight and obesity, compared to less deprived populations. This hypothesis will be tested using standard population attributable fraction (PAF) methods.

Methods

Cancer types

The International Agency for Research on Cancer (IARC) has classified 13 cancer types as having 'sufficient' evidence of a causal association with overweight and obesity:¹⁸ oesophageal adenocarcinoma, stomach cardia, bowel, liver, pancreas, gallbladder, breast, endometrium, ovary, kidney, thyroid, myeloma and meningioma.

As previously described, breast cancer is the only one of these cancer types which is inversely associated with deprivation, due to the marked effect of screening uptake and reproductive factors. Therefore, because breast cancer contributes a large proportion of the all cancers combined total, this inverse association could obscure the association between deprivation and overweight and obesity PAFs. PAFs were calculated both including and excluding breast cancer.

Cancer incidence by deprivation

Cancer incidence data by deprivation quintile for each of the UK constituent nations was obtained from routine publications, for the most recent years available.^{23,4,19} All nations provided this data for a period of several years rather than a single year, to avoid publishing low case numbers through which individuals could possibly be identified.

There was variation in the specific type of deprivation measurement used between countries. England, Wales and Northern Ireland used the income domain of their nation-specific index of multiple deprivation (IMD). Scotland used all domains of their nation specific IMD. Quintile 1 refers to the least deprived group and quintile 5 refers to the most deprived group.

Data varied between nations in terms of time period, cancer type availability, and sex breakdown. In England, Wales and Scotland data was for patients diagnosed between 2012 and 2016, but Northern Ireland data was either for 2007 to 2017 or 2013 to 2017 depending on cancer type. Imputation methods (see Appendix 1a) were used where necessary to obtain a full dataset for analysis, comprising annual average case numbers for the 13 cancer types listed above, for males and females separately.

Overweight and obesity prevalence by deprivation

Overweight (BMI 25-29.9) and obesity (BMI 30+) prevalence data by deprivation quintile (all domains of the nation-specific IMD) was collated for each of the UK constituent nations from routine health surveys, for the period 10 years prior to the incidence data obtained above.^{20,21,22,23} A 10-year latency period (i.e. the time between exposure to overweight and obesity and subsequent cancer diagnosis) was used for comparability with previous work and compatibility with duration of follow-up in

relative risk sources.²⁴

Data varied between nations in terms of time period and sex breakdown, thus imputation methods were employed again (see Appendix 1a) to obtain a full dataset for analysis, comprising annual average prevalence of overweight and obesity, for males and females separately.

Relative risks

Relative risk (RR) estimates (see Appendix 1b) were obtained from a systematic search of the literature using previously described search terms.⁹ Sources were reviewed between two researchers to decide what was the most suitable relative risk to use based on: the recency of publication, comparability of study samples to UK population, and availability of sex-specific relative risks because relative risks can vary markedly between sexes for some cancer types (e.g. meningioma).

Population Attributable Fraction formula

To calculate the proportion of cancers attributable to overweight and obesity by deprivation quintile, the standard population attributable fraction formula was used (see Appendix 1c). PAFs were calculated for each cancer type individually and then summed to obtain figures for all cancers combined; because of low case numbers only the all cancers combined figures are reported here. The deprivation gap in overweight and obesity-attributable proportion of cases was calculated, in both absolute and relative terms, as the difference between deprivation quintiles 1 (least deprived) and 5 (most deprived). Confidence intervals were not calculated, all comparisons are based on point estimates.

Results

A summary of the results is presented in Table 1, Figures 1 and 2 (PAFs for all overweight and obesity-related cancer types excluding breast cancer), and Appendix 2 (PAFs for all overweight and obesity-related cancer types including breast cancer).

In females in all UK nations, the deprivation gap was larger when breast cancer was excluded from the calculations compared to when it was included. In all UK nations except Wales, the deprivation gap in PAFs excluding breast cancer was higher in females than in males. Only PAFs excluding breast cancer are reported below.

Table 1. Population Attributable Fractions (PAFs) for overweight and obesity for the least and most deprived quintile for UK constituent countries, all overweight and obesity-related cancer types* excluding breast cancer

Country	Sex	Deprivation quintile PAF (%)		Difference quintile 1 PAF vs quintile 5 PAF	
		1 (least)	5 (most)	Absolute (percentage points)	Relative (%)
England	Female	3.7%	4.3%	0.7	18.1%
	Male	3.5%	3.7%	0.2	6.2%
Scotland	Female	4.0%	4.4%	0.4	9.9%
	Male	4.1%	4.4%	0.2	5.9%
Wales	Female	3.5%	4.5%	1.0	29.4%
	Male	3.7%	5.0%	1.3	36.2%
Northern Ireland	Female	4.0%	4.4%	0.4	10.4%
	Male	3.9%	3.9%	-0.04	-1.0%

*oesophageal adenocarcinoma, stomach cardia, bowel, liver, pancreas, gallbladder, endometrium, ovary, kidney, thyroid, myeloma and meningioma

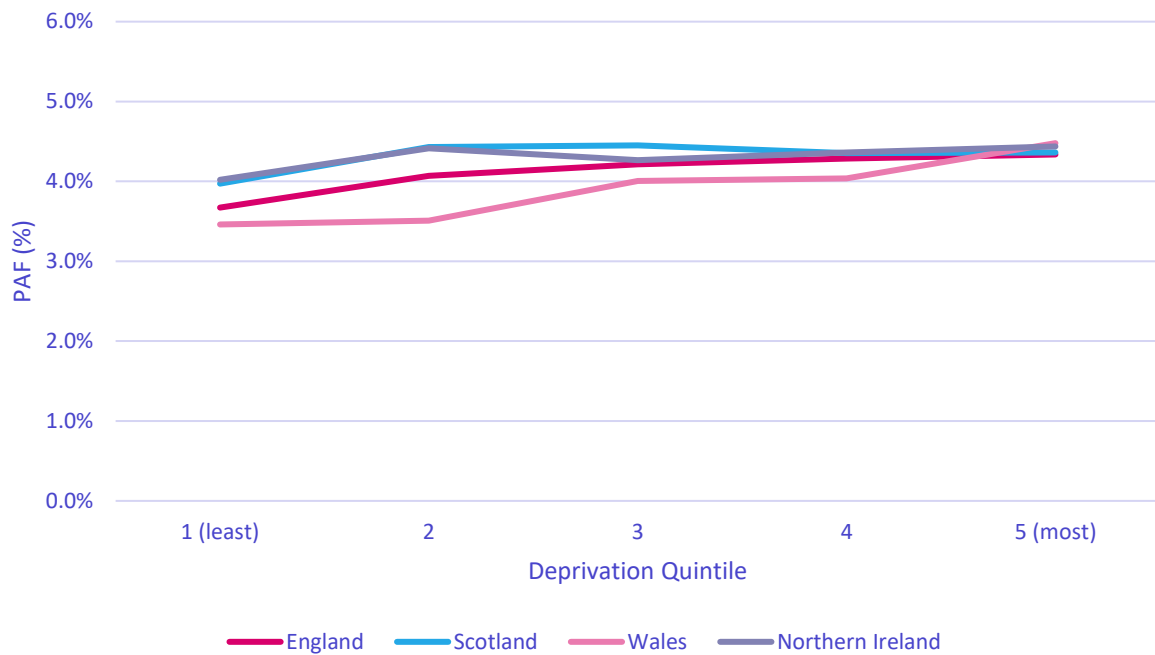


Figure 1. Population Attributable Fractions (PAFs) for overweight and obesity by deprivation quintile for females in UK constituent countries, all overweight and obesity-related cancer types excluding breast cancer

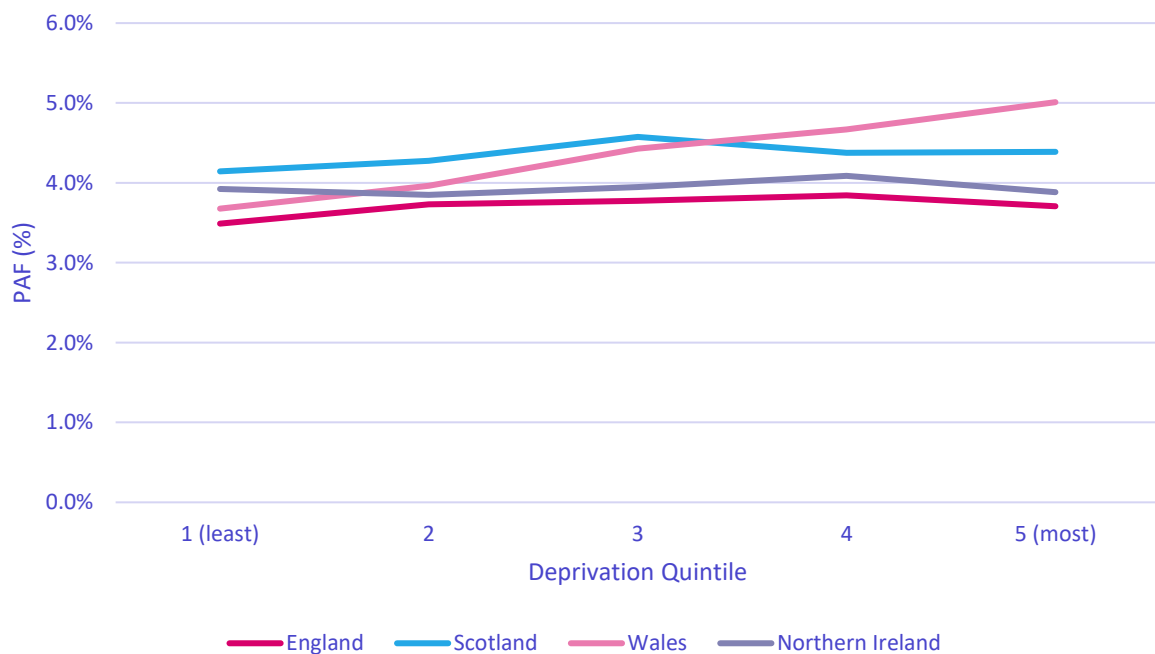


Figure 2. Population Attributable Fraction (PAFs) for overweight and obesity by deprivation quintile for males in UK constituent countries, all overweight and obesity-related cancer types excluding breast cancer

England

In females, the proportion of cancer cases attributable to overweight and obesity was 18.1% (0.7 percentage points) higher in the most deprived quintile compared with the least. In males, the proportion was 6.2% (0.2 percentage points) higher in the most deprived quintile compared with the least.

Scotland

In females, the proportion of cancer cases attributable to overweight and obesity was 9.9% (0.4 percentage points) higher in the most deprived quintile compared with the least. In males, the proportion was 5.9% (0.2 percentage points) higher in the most deprived quintile compared with the least.

Wales

In females, the proportion of cancer cases attributable to overweight and obesity was 29.4% (1.0 percentage points) higher in the most deprived quintile compared with the least. In males, the proportion was 36.2% (1.3 percentage points) higher in the most deprived quintile compared with the least.

Northern Ireland

In females, the proportion of cancer cases attributable to overweight and obesity was 10.4% (0.4 percentage points) higher in the most deprived quintile compared to the least. In males, the proportion was 1% (0.04 percentage points) lower in the most deprived quintile compared with the least.

Discussion

Aims

This analysis aimed to explore how variation in overweight and obesity prevalence between deprivation quintiles influences the proportion of cancer cases attributable to this risk factor. It was hypothesised that more deprived populations would have a higher proportion of cases attributable to overweight and obesity.

Main findings

The results showed a moderate PAF deprivation gap in females. There was a higher proportion of cases attributable to overweight and obesity in the most deprived quintile compared with the least deprived quintile. There was generally a smaller PAF deprivation gap in males, because there is a weaker deprivation gradient for overweight and obesity prevalence in males compared with females. Results were quite disparate across UK nations, but because of underlying differences in the data for each nation, direct comparison should not be made.

The females PAF analysis was run both with breast cancer included and excluded to assess the impact of breast cancer on the deprivation gap. There is an underlying inverse association between breast cancer incidence and deprivation, due to reproductive and screening characteristics. When breast cancer was excluded, the deprivation gap generally increased in both absolute and relative terms in each UK nation. Breast cancer was already excluded from both PAF analyses in males, because male breast cancer is not classified by IARC as definitely causally associated with overweight and obesity.

The proportion of cancer cases attributable to overweight and obesity was generally higher in females compared with males, as has been demonstrated previously.⁹ This is mainly because of breast cancer; the PAF sex difference reduced or even reversed when breast cancer was excluded from the calculations.

Linearity of the trend in PAFs across each deprivation quintile was not formally assessed, however visual inspection shows the female PAFs in Scotland and Northern Ireland peaked in quintile 2 or 3 instead of quintile 5 (the most deprived group). These differences are all very small, but the reason why the trend does not appear to be linear remains unclear.

Whilst smoking has been adjusted for in the relative risk figures used here, it is still important to acknowledge the possibility of residual confounding. Over half of the overweight and obesity-related cancer types are also associated with smoking, and both of these risk factors are associated with deprivation. Health related risk behaviours are not randomly distributed across the population, rather they occur in combination with other risk factors.²⁵ Around half (51%) of the English adult

population has 2 or more health risk factors (smoking, alcohol drinking, overweight or obesity, insufficient physical activity, and insufficient fruit and vegetable consumption), and this proportion is higher in the most deprived (61%) versus the least (41%).

Strengths and limitations

These are, to our knowledge, the first estimates of deprivation gaps in the proportion of cancer cases attributable to overweight and obesity in the UK. Inequalities in overweight and obesity prevalence have long been observed, but the long-term disease impacts of these inequalities have not previously been quantified. A marked deprivation gap in smoking PAFs has been reported in France,²⁶ and the current analysis adds to this emerging evidence base.

The current analysis did not look at morbid obesity (BMI 40+) separately from overall obesity (BMI 30+), and therefore the results may present an underestimation of the deprivation gap. There is a stronger deprivation gradient in the morbidly obese category, and for some cancer types the relative risk does not increase linearly (e.g. higher relative risk per 5-unit BMI increment). However, any under-estimation of PAFs as a result of this is likely to be small as morbid obesity currently contributes only a small proportion of the overall obesity prevalence total.

The robustness of these findings is determined by the quality and availability of data. Data availability was limited, meaning some cancer types' incidence and some overweight and obesity prevalence figures had to be imputed. The use of IMD 'all domains' deprivation measure in some parts of the dataset may have confounded results because it includes health aspects within the measure. Additionally, the findings assume that people remain in the same deprivation quintile during the 10-year latency period between overweight and obesity prevalence measurement and cancer incidence recording.

The PAF analysis did not include methods to examine the statistical significance (e.g. confidence intervals) of differences between deprivation quintiles. It is not sensible to calculate a boundary of uncertainty around point estimates that are already uncertain to some extent.

Conclusion

The burden of overweight and obesity-attributable cancer falls disproportionately on the most deprived people in the UK. This deprivation gap is more pronounced in women than in men. The proportion of cancer cases attributable to overweight and obesity is 10-29% higher in the most deprived UK women versus the least deprived.

These results should encourage policymakers to target deprived female populations with interventions that aim to promote and sustain weight loss, with the main goal of reducing the proportion of preventable cancers in those populations.

The evidence base needs to continue to develop through more research using better

quality data to provide more robust conclusions of the impact of overweight and obesity on cancer incidence across deprivation quintiles.

Appendices

Appendix 1a: Data imputation

Cancer type and Sex

The availability of data between UK nations varied for cancer types that were less common. Additionally, the availability of data provided by sex differed between nations. England and Scotland provided cancer incidence by deprivation for persons, whereas Wales and Northern Ireland provided cancer incidence by deprivation and sex.

Each UK nation provided data for cancer incidence by deprivation for oesophageal, stomach, bowel, liver, pancreas, kidney, breast, uterus and ovarian cancers.

Wales and Northern Ireland incidence by deprivation and sex data was used to calculate a sex breakdown for England and Scotland for the non sex specific cancers (i.e. oesophageal, stomach, bowel, liver, pancreas and kidney). Wales and Northern Ireland cases were combined to produce a robust yearly average number of cases by sex. These combined cases were converted to a proportional sex split of cases per deprivation quintile (e.g. quintile 1 female stomach cases/quintile 1 stomach cases for both sexes = quintile 1 female stomach proportion). The proportions were then multiplied with the persons cases in the corresponding quintile for England and Scotland (e.g. quintile 1 female stomach proportion * England quintile 1 persons stomach cases = England quintile 1 female stomach cases).

An additional step was implemented for oesophageal, stomach and uterus cancers to produce cases for their morphological or subsite types (i.e. oesophageal adenocarcinoma, stomach cardia, endometrium) that are explicitly linked with overweight and obesity. Firstly, oesophageal adenocarcinoma (2012-2014), stomach cardia (2012-2016) and endometrium (2012-2016) incidence by sex data was obtained for each nation. Subsequently, the proportion of morphological/subsite cancer types within their wider cancer group was calculated for both sexes from the average number of cases per year (e.g. female stomach cardia cases/female stomach cases = proportion of female stomach cardia cases). It was assumed that the proportional sex split of cases for these subtypes was the same across each deprivation quintile. Therefore, the proportions of cancer subsite/morphological type were multiplied with the average number of cases for their wider cancer group in each deprivation quintile (e.g. female stomach cardia proportion * quintile 1 female stomach cases = quintile 1 female stomach cardia cases).

Meningioma is another cancer subtype (belonging to the brain and other central nervous system cancer group) explicitly linked to overweight and obesity. England

provided meningioma incidence by deprivation for persons. To break down the data by sex it was again assumed that the proportional sex split of cases was the same across deprivation quintiles. Meningioma incidence data with a sex breakdown in England was acquired (2012-2016), **Error! Bookmark not defined.** and the proportional sex split was calculated. The sex specific proportions were then multiplied with the number of cases in each deprivation quintile in England.

There was no meningioma by deprivation breakdown for Scotland, Wales or Northern Ireland. However, Northern Ireland provided incidence data for brain and other central nervous system that formed the basis of estimations for meningioma incidence by deprivation and sex in the devolved nations. The proportion of cases by deprivation quintile was calculated for both sexes in Northern Ireland for brain and other central nervous system, and these proportions were used as a proxy for meningioma proportions (e.g. quintile 1 female brain cases/total female brain cases = quintile 1 female meningioma proportion). Subsequently, meningioma incidence by sex data (2012-2016) was obtained to produce the average number of meningioma cases per year for Scotland, Wales and Northern Ireland. Sex and quintile specific proportions from the Northern Ireland incidence by deprivation data were multiplied with the with the average number of meningioma cases from respective nations (e.g. Northern Ireland quintile 1 female 'meningioma' proportion * Scotland female meningioma cases = Scotland quintile 1 female meningioma cases).

Breast cancer also had to be altered to provide figures representative of post-menopausal women (assumed to be 50+), because there was no age breakdown in the cancer incidence by deprivation datasets. The proportion of breast cancers in women aged 50 and over was calculated from the average number of cases (2012-2016) for each nation using separate incidence by age data. The proportion of cancers for women aged 50 and over was then multiplied with the average number of cases per deprivation quintile, to produce cases by deprivation quintile for post-menopausal women (e.g. proportion breast 50+ * quintile 1 breast cases = quintile 1 breast 50+). Thus, it was assumed that the proportion of cases that were 50+ were the same across deprivation quintiles.

England, Scotland and Northern Ireland provided incidence data by deprivation for myeloma. Of these nations, Northern Ireland was the only county to provide incidence for both deprivation and sex which was used to breakdown England and Scotland persons data into each sex. The proportion of cases for each gender within each deprivation quintile was calculated for Northern Ireland (e.g. quintile 1 female myeloma cases/quintile 1 myeloma cases for both sexes = quintile 1 female myeloma proportion). The proportion was then multiplied with England and Scotland data to produce a breakdown by sex (Northern Ireland quintile 1 female myeloma proportion * England quintile 1 persons myeloma cases = England quintile 1 female cases).

Wales provided no deprivation breakdown for myeloma. Therefore, the distribution of case proportions from Northern Ireland was applied to Wales incidence by sex data (2012-2016). The proportion of cases per deprivation quintile for each sex was calculated from the Northern Ireland data (e.g. quintile 1 female myeloma cases/total female myeloma cases = quintile 1 female proportion). Subsequently, the average number of myeloma cases by sex (2012-2016) in Wales was multiplied with the sex and quintile specific proportions from the Northern Ireland data (e.g. Wales average female myeloma cases * Northern Ireland quintile 1 female myeloma proportion = Wales quintile 1 female myeloma cases).

England was the only country to provide thyroid incidence by deprivation. To break down the data by sex, the same process that was applied to meningioma in England was applied for thyroid cancer. Scotland, Wales and Northern Ireland provided no data for thyroid incidence by deprivation. Consequently, England thyroid incidence by deprivation data was used as a basis to form case estimates by deprivation quintile in the devolved nations. Firstly, the proportion of cases by deprivation quintile for persons was calculated from the England incidence by deprivation data (e.g. quintile 1 persons thyroid cases/total thyroid cases = quintile 1 persons proportion). Then the average number of thyroid cases by sex was acquired for each nation (2012-2016) and multiplied with the proportion of cases per deprivation quintile for persons from the England data (e.g. Scotland female average thyroid cases * England quintile 1 thyroid proportion = Scotland quintile 1 female thyroid cases). It was assumed that the proportional sex split of cases was the same across deprivation quintiles in each nation. Additionally, the devolved nations were assumed to have the same proportional case distribution as England across quintiles.

No countries provided data for gallbladder incidence by deprivation. Liver cancer incidence by deprivation data was used as a basis to develop estimates for gallbladder incidence by deprivation, because liver cancer is known to behave similarly to gallbladder cancer in terms of cancer incidence and associated risk factors. Gallbladder and liver incidence by sex was obtained. and the ratio of gallbladder cases to liver cases was calculated for each sex in each UK nation (e.g. female gallbladder cases/female liver cases = female gallbladder to liver ratio). The gallbladder to liver ratio was then multiplied with the number of cases per deprivation quintile to produce the number of gallbladder cases per quintile for each sex (e.g. gallbladder to liver ratio * quintile 1 female liver cases = quintile 1 female gallbladder cases).

Overweight and obesity prevalence

England was the only nation to provide overweight and obesity prevalence by deprivation quintile and sex for every year required. Scotland also provided overweight and obesity data by deprivation and sex, but only for 2003. Consequently, data for 2003 was used as a proxy of the 5-year average. This was deemed a suitable approach because the prevalence data for England showed little variation over time between sexes and deprivation quintiles. The 2003 data is already accurately broken down into deprivation and sex, and it is unlikely to deviate very far from a 5-year average.

Wales provided overweight and obesity prevalence by deprivation for persons, from 2003/4 to 2007. England data was used to provide a gender breakdown for Wales. The sex to persons ratio of both overweight and obesity prevalence was calculated for each deprivation quintile (e.g. quintile 1 female overweight prevalence/quintile 1 persons overweight prevalence = quintile 1 female overweight ratio) from the England data for 2002 to 2006. Subsequently, the gender specific ratios were multiplied with the appropriate year of persons data for Wales (e.g. England quintile 1 female ratio * Wales quintile 1 persons overweight and obesity prevalence = Wales quintile 1 female prevalence). Two years of prevalence by deprivation data was missing for Wales (2002 and 2006). As there was no other alternative, data from 2003/04 was used as a proxy for 2002, and data from 2007 was used as a proxy for 2006 because this was the next sequential survey.

Northern Ireland provided overweight and obesity prevalence by sex for 2005, but with no deprivation breakdown. England data was used to provide both a gender and deprivation breakdown for overweight and obesity prevalence in Northern Ireland. The ratio of both overweight and obesity prevalence for each sex by deprivation quintile was calculated for 2002-2006 from the England dataset (e.g. quintile 1 female obese prevalence/total female obese prevalence = quintile 1 female obese ratio). Then the female and male ratios from each survey year were multiplied to the Northern Ireland overweight and obesity prevalence data (i.e. England 2002 quintile 1 female obese ratio * Northern Ireland female obese prevalence = Northern Ireland 2002 quintile 1 obese prevalence).

It was deemed suitable to re-use Northern Ireland data across each of the necessary years because overall overweight and obesity prevalence showed little variance between 2002 and 2006 in England for each sex.

Appendix 1b: Relative risk estimates

Cancer type	Source	Relative risk per 5kg/m ³	Males		Relative risk per 5kg/m ³	Females	
			Excess relative risk			Excess relative risk	
			Overweight (BMI 25-29.9)	Obese (BMI 30+)		Overweight (BMI 25-29.9)	Obese (BMI 30+)
Oesophageal adenocarcinoma	Kyrgiou ²⁷	1.52	0.598	1.378	1.51	0.5865	1.3515
Gastric cardia	Chen ²⁸	NA	0.2	1.57	NA	0.2	1.57
Liver	Wang ²⁹	1.26	0.299	0.689	1.18	0.207	0.477
Pancreas	Kyrgiou	1.1	0.115	0.265	1.1	0.115	0.265
Gallbladder	Xue ³⁰	NA	1	1.54	NA	1.22	1.75
Uterus	Kyrgiou	NA	NA	NA	1.54	0.621	1.431
Ovary	Kyrgiou	NA	NA	NA	1.08	0.092	0.212
Kidney	Liu ³¹	1.05	0.2875	0.6625	1.06	0.345	0.795
Thyroid	Kyrgiou	1.32	0.368	0.848	1.14	0.161	0.371
Myeloma	Kyrgiou	1.12	0.138	0.318	1.11	0.1265	0.2915
Meningioma	Sergentanis ³²	NA	1	1	NA	1	1.6
Bowel	Abar ³³	1.08	0.092	0.212	1.05	0.0575	0.1325
Breast	Chan ³⁴	NA	NA	NA	1.12	0.138	0.318

Excess relative risk for overweight and obese categories calculated as excess relative risk per 5 BMI units (RR-1), divided by 5, multiplied by the number of BMI units between category BMI units mean and healthy weight BMI units mean. E.g. for male liver cancer, ERR per 5 BMI units is 0.26, so ERR per BMI unit is 0.052; difference between overweight BMI units mean (27.45) and healthy weight BMI units mean (21.7) is 5.75, multiplied by 0.052 = 0.299. For gastric cardia, gallbladder, uterus, ovary, and meningioma, published relative risks were for categories rather than per 5 BMI units.

Appendix 1c: Population attributable fraction formula

$$\frac{(p_1 \times ERR_1) + (p_2 \times ERR_2)}{1 + [(p_1 \times ERR_1) + (p_2 \times ERR_2)]}$$

Where p_1 is the proportion of population that is overweight, p_2 is the proportion of the population that is obese, ERR_1 is the excess relative risk (relative risk – 1) for overweight and ERR_2 is the excess relative risk (relative risk – 1) for obesity. The PAF formula was used to calculate excess cases and the proportion of cases attributable to overweight and obesity at each deprivation quintile.

PAF calculations using specific cancer subsite/morphological types required a small adjustment to the calculation. The number of attributable cases was calculated using the number of cases for the cancer subsite/morphology as the numerator, and the number of cases for the whole cancer type as the denominator. For example, the overweight and obesity PAF for oesophageal adenocarcinoma applied the number of cases for that morphology, divided by the total number of cases of oesophagus. The same applied to stomach cardia, meningioma, endometrial and breast.

Appendix 2: Population Attributable Fractions (PAFs) for overweight and obesity by deprivation quintile for UK constituent countries, all overweight and obesity-associated cancer types* including and excluding breast

Country	Including or excluding breast cancer	Sex	Deprivation quintile PAF (%)					Difference quintile 1 PAF vs quintile 5 PAF	
			1 (least)	2	3	4	5 (most)	Absolute (percentage point)	Relative
England	Including	Female	6.2%	6.7%	6.8%	6.7%	6.6%	0.4%	6.7%
		Male	3.5%	3.7%	3.8%	3.8%	3.7%	0.2%	6.2%
	Excluding	Female	3.7%	4.1%	4.2%	4.3%	4.3%	0.7%	18.1%
		Male	3.5%	3.7%	3.8%	3.8%	3.7%	0.2%	6.2%
Scotland	Including	Female	6.8%	7.3%	7.2%	6.9%	6.8%	0.04%	0.6%
		Male	4.1%	4.3%	4.6%	4.4%	4.4%	0.2%	5.9%
	Excluding	Female	4.0%	4.4%	4.5%	4.4%	4.4%	0.4%	9.9%
		Male	4.1%	4.3%	4.6%	4.4%	4.4%	0.2%	5.9%
Wales	Including	Female	5.7%	5.9%	6.3%	6.3%	6.9%	1.2%	20.6%
		Male	3.7%	4.0%	4.4%	4.7%	5.0%	1.3%	36.2%
	Excluding	Female	3.5%	3.5%	4.0%	4.0%	4.5%	1.0%	29.4%
		Male	3.7%	4.0%	4.4%	4.7%	5.0%	1.3%	36.2%
Northern Ireland	Including	Female	6.4%	6.9%	6.7%	6.8%	6.8%	0.4%	6.7%
		Male	3.9%	3.8%	3.9%	4.1%	3.9%	-0.04%	-1.0%
	Excluding	Female	4.0%	4.4%	4.3%	4.4%	4.4%	0.4%	10.4%
		Male	3.9%	3.8%	3.9%	4.1%	3.9%	0.0%	-1.0%

*oesophageal adenocarcinoma, stomach cardia, bowel, liver, pancreas, gallbladder, breast, endometrium, ovary, kidney, thyroid, myeloma and meningioma

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