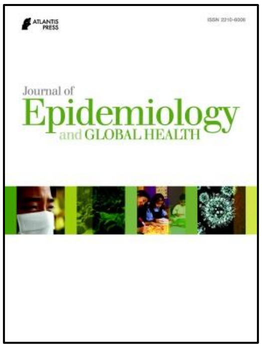

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The use of epidemiological measures to estimate the impact of primary prevention interventions on CHD, stroke and cancer outcomes: Experiences from Herefordshire, UK

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Abstract *Background:* CHD, stroke and cancers are the major causes of mortality in the UK and are responsible for significant amounts of morbidity and healthcare costs. This study examines the proportion of CHD, stroke and cancer owing to specific risk factors in Herefordshire, UK. It estimates the population impact of a number of interventions being implemented to reduce these risk factors, through the NHS Health Check program and the Herefordshire Health Improvement Plan. The present study also aims to demonstrate the value of epidemiological measures in providing evidence-based public health information in policy-making to aid decision makers when prioritizing investments and optimal use of resources.

Methods: The epidemiological measures—'Population Attributable Risk' and 'Population Impact Measures'—were used to assess the impact of interventions to reduce the burden of CHD, stroke and cancer.

Results: Implementation of the NHS Health Check program will prevent 63 CHD events, 90 MI events and 125 stroke events, and one lung cancer over a period of 5 years. Reducing specific risk factors by 5% annually through the Health Improvement Plan will prevent 65 CHD events, 25 MI events, 140 stroke events, four lung

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cancer, one breast cancer and four colorectal cancer cases in Herefordshire if targets are met over a period of 5 years.

Conclusion: Physical inactivity and obesity are the major causes of CHD and stroke events (incidence and mortality) in Herefordshire. Their impact is greater than the combined effect of hypercholesterolemia and hypertension.

Epidemiological measures used in this study proved to be excellent tools in providing evidence-based public health information. Their use is strongly recommended to support prioritization of primary prevention interventions.

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1. Introduction

Coronary Heart Disease (CHD), stroke and cancers are the biggest causes of death in the United Kingdom (UK) [1–3]. Together, they account for approximately 347,000 deaths each year (191,000 cardiovascular disease [CVD] and 156,000 cancer deaths), which are equivalent to over one-in-three of all deaths [1,2,4]. In terms of incidence, it is estimated that there are 300,000 new CVD events and 297,771 new cancer cases [1,5] in the UK every year. The social and health service costs are large [4,6–8]. It is estimated to cost the UK economy £30 billion annually, about half of which is due to direct healthcare costs [9]. Therefore, CHD, stroke and cancer prevention is a high priority in the UK.

The UK government's new white paper, ''Healthy Living, Healthy People'' recognizes the burden of lifestyle-related diseases such as CHD, strokes and cancers in the UK and the urgent need to address them [10]. The white paper outlines the government's intention to implement policies and strategies in order to reduce morbidity and mortality associated with lifestyle-driven diseases. The National Health Services (NHS) Health Check, a national vascular risk screening program, is one of the featured strategies in the new white paper [10]. It is to be offered to individuals aged 40–74 years in order to identify those at risk and provide individually tailored advice and support to help manage risks of heart disease, stroke and diabetes [11]. Other strategies the white paper highlights as important are those that positively promote healthy behaviors and lifestyles which will lead to a reduction in the burden of lifestyle-driven diseases such as CHD, strokes and cancers.

In Herefordshire, an English county with a population of 182,441, CHD, stroke and cancers are major causes of mortality. In 2009, 51.1% of all deaths in Herefordshire were a result of CHD, stroke and cancer, and these diseases are responsible for 4132 years of life lost annually. CHD, stroke and cancer also contribute to significant morbidity in Herefordshire. In 2009, there were 7930 cancer-related hospital spells (the biggest cause of hospital admissions in Herefordshire), 999 CHD-related hospital spells and 584 cerebrovascular-related hospital spells. These conditions also constitute a large proportion of NHS Herefordshire's expenditure on healthcare. Overall, CHD, stroke and cancer are responsible for 10.6% of NHS Herefordshire's total expenditure on healthcare—relatively high proportions (81.14%) of this expenditure on secondary care.

With an aim to reduce the burden of CHD, stroke and cancers and their cost implications, NHS Herefordshire plans to roll out the NHS Health Check program and a local Health Improvement Plan: NHS Herefordshire Health Improvement Plan (NHSH HIP). Both of these involve in implementing prevention interventions. To enable investment in these programs and to achieve engagement across the health and social care economy, the potential population benefits that could be achieved in terms of number of health events prevented and reduced mortality such as strokes needed to be understood. Therefore, two epidemiological tools were identified and applied: Population Attributable Risk (PAR) and Population Impact Measures (PIMs). PAR is defined as the proportion of disease in the population due to a risk factor [12], while PIMs are measures of risk and benefit for use in epidemiology which can estimate the population impact of either reduction in the prevalence of a risk factor or improved uptake of treatment [13].

Other measures such as the quality-adjusted life year (QALY) and the incremental cost effectiveness ratio (ICER) are used by organizations like the National Institute for Health and Clinical Excellence (NICE) to estimate the cost-effectiveness of interventions. However, these measures have been criticized as they are based on aggregated individual treatment benefits and lack a local context and population perspective [14]. In comparison, the epidemiological measures we chose enable us to use research data along with local data to generate evidence-based results. The use of PARs provides an estimate of the proportion of disease in the local population. While the PIMs provide a framework where local data (such as on the population size, demographics and level of inequalities) can be combined with the results of estimates of size from systematic reviews and meta-analyses to estimate the health gain that a local health-care organization can expect from the introduction of a new or alternative intervention, or an increase in the availability of an existing intervention [15].

This study examines the proportion of CHD, stroke and cancer owing to risk factors in Herefordshire and the impact of planned primary prevention interventions through the implementation of the NHS Health Check program and the NHSH HIP, using PAR and PIMs. More importantly, it demonstrated the value of epidemiological measures in providing evidence-based public health information in policy-making and to aid decision makers when prioritizing investments and optimal use of resources.

2. Methodology

PAR and PIMs were used to assess the impact of strategies to reduce the burden of CHD in Herefordshire. The two PIMs calculated in this study are the 'number of events prevented in the population' (NEPP) [13] and the 'population impact number of eliminating (or reducing the prevalence of) risk factor' (PIN-ER-*t*) [16].

PAR is described as the reduction in incidence that would be observed if the population was entirely unexposed to risk factors, compared with its current (actual) exposure pattern (e). It is calculated using the population prevalence of the exposure and the relative risk associated with the exposure (refer to Appendix 1 for formula).

The number of events prevented in the population (NEPP) can be used to estimate the impact of an intervention in populations with a specified condition. It is defined as the NEPP by an intervention which reduces or eliminates a risk factor. The calculation requires the size of the population, the proportion of the population with the disease, the proportion of those with the disease exposed to the intervention, the proportion of those who adhere to the intervention, and the reduction in the risk of death in those receiving the intervention compared with those not receiving the intervention. The PIN-ER-*t* is defined as 'the potential number of disease events prevented in the population over the next *t* years by eliminating all or a specified proportion of the risk factor' [14]. It is derived from the PAR. The calculation requires an estimation of the size of the population at risk, the incidence of the disease event in *t* years in the population, the proportion of the population exposed to the risk factor (or, for continuous variables, the proportion with levels above the threshold), and the relative risk of the disease event among the exposed compared with those not exposed [14]. Refer to Appendix 1 for PAR, NEPP and PIN-ER-*t* formulae.

Information was collected from a variety of sources to calculate the PAR and PIMs. The relative risks (RR) and relative risk reductions (RRR) were gathered by carrying out searches for published articles that reported relevant RR and RRR in Medline, NHS Evidence, Cochrane and the Centre for Reviews and Dissemination databases and the search engine 'Google'. RRs and RRRs were identified by reviewing the research literature. Parameters were selected from high level studies in line with the research question wherever possible (Please see results Table 3 for sources of each RR and RRR).

The PAR and PIMs were calculated for the two planned primary prevention programs in Herefordshire—the NHS Health Check program and the NHSH HIP. The NHS Health Check program aims to identify all people aged 40–74 with significant cardiovascular risk over a 5-year period. Using a Department of Health (DH) modeling tool, the number of people who would be identified annually with particular risk factors (see Table 1) were

Table 1 Annual number of individuals identified with vascular risk factors by the NHS Health Check program in Herefordshire using DH modeling tool.

Risk factor	Number of individuals identified Herefordshire annually	Number of individuals identified in Herefordshire over 5 years
Hypercholesterolemia	720	3600
Hypertension	985	4925
Low physical activity	3295	16,475
Smoking	356	1780
Obesity	1773	8865
Total	7129	35,645

Table 2 Targets used for modeling NHSH HIP.

Risk factor	NHSH HIP targets used for modeling % reduction in prevalence annually (%)
Low physical activity	5
Smoking	5
Low intake of fruit & vegetables	5
Obesity	5
High alcohol consumption	5

Table 3 Interventions, data, sources and outcome measures.

Disease	Risk factors	Interventions	Data, sources and outcome measures			
			PAR		PIMs	
			RR	Prevalence of risk factor	NHS Health Check program[a]	NHS Health Improvement Plan[b]
CHD	Hypercholesterolemia (>6.5 mmol/l)	Statins	2.82	36%	*Non-fatal MI (NEPP)* Pa = 0.80 [17], Pe = 720, RRR = 0.42 [18], ru = 0.03 [18] *MI deaths (NEPP)* Pa = 0.80 [17], Pe = 720, RRR = 0.40 [18], ru = 0.01 [18]	N.A.
	Hypertension (Systolic BP > 145 mmHg)	Antihypertensive therapy	1.91	15.4%	*Non-fatal MI (NEPP)* Pa = 0.69 [19], Pe = 985, RRR = 0.25 [20], ru = 0.02 [21] *MI deaths (NEPP)* Pa = 0.69 [21], Pe = 985, RRR = 0.12 [20], ru = 0.01 [21]	N.A.
	Smoking (>16 yrs)	Smoking cessation	2.84	17.5%	*CHD deaths (NEPP)* Pa = 0.11 [22], Pe = 365, RRR = 0.37 [23], ru = 0.032 [23]	*CHD deaths (NEPP)* Pa = 0.11 [22], Pe = 27,317 [24], RRR = 0.37 [23], ru = 0.032 [23]
	Low intake of fruit/veg/cereal-3 or less per day	Increase consumption of fruit and vegetables	1.16	3.54%	N.A.	*CHD events (PINER-t)* n = 147,660, Ip = 0.0095 [25], Pexp = 0.23 (26), RR = 1.16 [27]
	Low physical activity	Increase levels of physical activity	1.6	34.81%	*CHD events (PINER-t)* n = 3295, Ip = 0.0095 [25], Pexp = 1, RR = 1.6 [27]	*CHD events (PINER-t)* n = 147,660, Ip = 0.0095 [25], Pexp = 0.28 [26], RR = 1.6 [27]
	Obesity (BMI > 30 kg/m^2)	Weight management interventions for obese patients	2.13	18.8%	*MI event (PINER-t)* n = 1773, Ip = 0.0095 [25], Pexp = 1, RR = 1.3 [27]	*MI events (PINER-t)* n = 147,660, Ip = 0.0095 [25], Pexp = 0.228 [24], RR = 1.3 [27]
Stroke	Hypercholesterolemia (>6.5 mmol/l)	Statins	2.0	36%	*Non-fatal stroke events (NEPP)* P_a = 0.80 [17], P_{elig} = 720, RRR = 0.80 [18}, ru = 0.00305 [18] *Stroke deaths (NEPP)* P_a = 0.80 [17], P_{elig} = 720, RRR = 0.34 [18, ru = 0.02 [18]	N.A.
	Hypertension (Systolic BP > 145 mmHg)	Antihypertensive therapy	4.0	15.4%	*Non-fatal stroke events (NEPP)* P_a = 0.69 [19] P_{elig} = 985, RRR = 0.36 [20], ru = 0.01 [18] *Stroke deaths (NEPP)* P_a = 0.69 [19] P_{elig} = 985, RRR = 0.36 [20], ru = 0.0031 [18]	N.A.

	Smoking	Smoking cessation	1.51	17.5%	*Stroke events (NEPP)* $P_a = 0.11$ [23], $P_{elig} = 365$, RRR = 0.36 [28], ru = 0.26 [29]	
	Low intake of fruit/veg/ cereal-3 or less per day	Increase consumption of fruit and vegetables	1.26	23% (3 or less portions per day)	N.A.	
	Low physical activity	Increase levels of physical activity	2.5	89% (physically inactive)	*Stroke events (PINER-t)* n = 3295, Ip = 0.00445 [30], Pexp = 1, RR = 2.5[31]	
	Obesity (BMI > 30 kg/m^2)	Weight management interventions for obese patients	2.0	22.8% (BMI > 30 kg/m^2)	*Stroke events (PINER-t)* n = 1773, Ip = 0.00445 [30], Pexp = 1, RR = 2 [32]	
	Atrial fibrillation	Increasing anticoagulation therapy (warfarin) to eligible patients with AF (not done as part of any plan- modeled as an add on)	5.0	1.8%	*Stroke events (NEPP)* $P_a = 0.60$ [33], $P_{elig} = 97$, RRR = 0.64 [34], ru = 0.06 [35]	
Lung cancer	Smoking (>16 yrs)	Smoking cessation	26	18.5%	*Lung cancer cases(PINER-t)* n = 356, Ip = 0.000647 [30], Pexp = 1, RR = 26 [36]	*Lung cancer cases(PINER-t)* n = 147,660, Ip = 0.000647 [30], Pexp = 0.185 [23], RR = 26 [36]
Breast cancer	High alcohol consumption (>45 g per day alcohol)	Alcohol cessation	1.46	17.7%	N.A.	*Breast cancer cases(PINER-t)* n = 76,448, Ip = 0.0007833 [37], Pexp = 0.177 [24], RR = 1.46 [38]
	Diet (fat consumption)	Advice on healthy diet	1.13	NA	N.A.	N.A.
	Obesity (BMI > 30)	Weight management interventions for obese patients who are post-menopausal	1.29	NA	N.A.	N.A.
Colon cancer	Dietary fiber intake of less than 10 g per day	Increase intake of dietary fiber	1.18	NA	N.A.	N.A.
	High Alcohol consumption	Alcohol cessation	1.50	17.7%	N.A.	*Colorectal cancer cases(PINER-t)* n = 147,660, Ip = 0.000649 [37], Pexp = 0.177[24], RR = 1.52 [39]
	Obesity (BMI > 30)	Weight management interventions for obese patients	1.19	22.8%	N.A.	N.A.
	Smoking	Smoking cessation	1.25	18.5%	N.A.	*Colorectal cancer cases(PINER-t)* n = 147,660, Ip = 00.000649 [37], Pexp = 0.177[24], RR = 1.27 [40]

[a] Pe and *n* used were derived using the DH tool—see Table 1; see Appendix for P_{elig}.
[b] *n* were derived from local demographic data.

predicted. The DH modeling tool is based upon national assumptions of uptake assuming 20% of the target population is called per annum and does not take account of local implementation. As the NHS Health Check program is over 5 years old, it was decided to model the outcomes over a 5-year period. Similarly, the NHS HIP target of 5% annual reduction in prevalence for each of the risk factors was used to model outcomes over a period of 5 years (see Table 2).

PAR in Herefordshire was calculated for the following risk factors for CHD and stroke: high cholesterol (>6.5 mmol/l), hypertension (systolic BP > 145 mmHg), smoking, low intake of fruit/veg/cereal (three or less portions per day), low physical activity, and BMI > 30 kg/m^2. In addition, for strokes, PAR was calculated for atrial fibrillation (AF) as a risk factor. Using the NEPP and PINER-*t* formulas, where data were available, the number of events or deaths prevented annually for CHD, stroke and cancer was also calculated for the following interventions: statin therapy, antihypertensive therapy, smoking cessation, increase in consumption of fruit and vegetables, increase in levels of physical activity and weight management programs for obese individuals (see Table 3).

For cancers, only three types of cancer were taken into consideration: bronchus and lung, breast and colorectal, as they are responsible for the most number of deaths in Herefordshire. The PAR was calculated for the following: smoking as a risk factor for bronchus and lung cancer; high alcohol consumption (>45 g per day alcohol), diet (fat consumption), BMI > 30 for breast cancer; and dietary fiber intake of less than 10 g per day, high alcohol consumption, BMI > 30 and smoking for colorectal cancer. The number of events and deaths prevented over 5 years as a result of interventions aimed at these risk factors was also calculated.

The calculations were dependent upon epidemiological measures in the research literature. For example, data to calculate PAR and PIMs for cancer were difficult to find, therefore, the calculations were limited for cancer in comparison with CHD and stroke. Similarly, in some instances measures were found of CHD events (myocardial infarctions plus CHD deaths) while in another, measures on myocardial infarctions (MI) alone were found. These limitations were reflected in the results which were expressed either as CHD or MI events (fatal or non-fatal). In a few instances modeling was not possible owing to the lack of the necessary data for the calculations. Results of calculations where the data was available are presented below.

3. Results

The results (PAR and PIMs) are dichotomized based on the findings for each of the three conditions. Where PIMs are presented as events, this means a sum of fatal and non fatal events.

3.1. Coronary Heart Disease

Table 4 summarizes the results for CHD.

The findings of this study show that hypercholesterolemia, which is a well-known risk factor for CHD, is responsible for a significant proportion of CHD in Herefordshire (39.5%). However, it was also determined that almost as much of CHD is owing to physical inactivity (34.8%). When coupled with obesity, physical inactivity is responsible for over half of the CHD in the county. It should also be noted that another lifestyle risk factor, smoking, causes a quarter of all CHD in the county.

It is calculated that each year the NHS Health Check program in Herefordshire will identify 7129 individuals with CHD risk factors (see Table 1). Successful treatment of those with risk factors will prevent an estimated 63 CHD events and 90 MI events over 5 years (see Table 4). It is also estimated that a total of 65 CHD events and 25 MI events would be prevented if implementation of NHSH's HIP reduced CHD risk factors by 5% annually in the population over 5 years (see Table 4).

3.2. Stroke

Table 5 summarizes the results for stroke.

Physical inactivity alone is responsible for over half the cases of strokes (57.1%) in Herefordshire—this compares with 26.4% for hypercholesterolemia and 13.3% for hypertension. Similarly, obesity (18.5%) is responsible for more strokes than hypertension (13.3%).

It is calculated that each year the NHS Health Check program will identify 7129 individuals with stroke risk factors (see Table 1). Successful treatment of those with risk factors will prevent an estimated 125 stroke events over 5 years (see Table 5). It is also estimated that a total of 140 stroke events would be prevented if implementation of NHSH's HIP reduced risk factors by 5% annually over a 5-year period in the population (see Table 5). Further, if anticoagulant therapy was prescribed to all eligible AF patients, four stroke events could be prevented (see Table 5).

Table 4 Primary prevention of CHD in Herefordshire.

Intervention	Risk factor	RR[a]	Prevalence of risk factor[b](%)	PAR[c] (%)	PIMs[d]		
					Intervention[e]		Events/deaths prevented in the cohort if targets are achieved over 5 years[f]
					NHS Health Check program	Health Improvement Plan	
Statins	Hypercholesterolemia (>6.5 mmol/l)	2.82	36	39.58	If 3600 individuals are prescribed statins	N.A.	35 non-fatal MI events 15 MI deaths
Antihypertensive therapy	Hypertension (systolic BP > 145 mmHg)	1.91	15.4	13.34	If 4925 individuals are prescribed antihypertensive therapy	N.A.	15 non-fatal MI events 5 MI deaths
Smoking cessation	Smoking	2.84	17.5	24.35	If 1780 individuals are given smoking cessation intervention	N.A.	3 CHD deaths
					N.A.	Decrease in number of smokers (aged 18 years and above) by 5% annually	10 CHD deaths
Increase consumption of fruit and vegetables	Low intake of fruit/veg/cereal-3 or less per day	1.16	23	3.54	N.A.	Decrease in the number of individuals (aged 18 years and above) consuming 3 portions or less of fruit or vegetable by 5% annually	10 CHD deaths
Increase levels of physical activity	Low physical activity	1.6	89	34.81	If 16,475 individuals get physically active	N.A.	60 CHD events
					N.A.	Decrease in the number of individuals (aged 18 years and above) who are physically inactive by 5% annually	45 CHD events
Weight management interventions for obese patients	Obesity (BMI > 30 kg/m^2)	2.13	22.8	18.	If 8865 individuals subjected to weight management interventions achieve BMI < 27	N.A.	20 MI event
					N.A.	Decrease in number of individuals (aged 18 years and above) with BMI > 27 by 5% annually	25 MI events

[a] Relative risk — The risk of CHD when exposed to the risk factors.
[b] Local prevalence — The proportion of the population with the risk factor in Herefordshire.
[c] Population Attributable Risk — The proportion of disease in the population due to the risk factor in Herefordshire.
[d] Population Impact Measures — the number of events prevented in the local population by treating a given number of people with the intervention (includes NEPPs and PIN-ER-ts).
[e] Interventions based on NHS Health Check program and NHS Herefordshire Health Improvement Plan.
[f] Estimated number of events/deaths which can be prevented with intervention. Unless specified, events mean fatal plus non-fatal (i.e. total events). CHD events include ALL CHD related events.

Table 5 Primary prevention of stroke in Herefordshire.

Intervention	Risk Factor	RR[a]	Prevalence of risk factor[b] (%)	PAR[c] (%)	PIMs[d]		
					Intervention[e]		Events/deaths prevented in the cohort if targets are achieved over 5 years[f]
					NHS Health Check program	Health Improvement Plan	
Statins	Hypercholesterolemia (>6.5 mmol/l)	2.0	36	26.47	If 3600 individuals are prescribed statins	N.A.	20 non-fatal stroke events 5 stroke deaths
Antihypertensive therapy	Hypertension (Systolic BP > 145 mmHg)	4.0	15.4	13.39	If 4925 individuals are prescribed antihypertensive therapy	N.A.	10 non-fatal stroke events 5 stroke deaths
Smoking cessation	Smoking	1.51	17.5	8.19	If 1780 individuals are given smoking cessation intervention	N.A.	20 stroke events
					N.A.	Decrease in number of smokers (aged 18 years and above) by 5% annually	70 stroke events
Increase consumption of fruit and vegetables	Low intake of fruit/veg/cereal-3 or less per day	1.26	23 (3 or less portions per day)	5.64	N.A.	Decrease in the number of individuals (aged 18 years and above) consuming 3 portions or less of fruit or vegetable by 5% annually	10 stroke events
Increase levels of physical activity	Low physical activity	2.5	89 (physically inactive)	57.17	If 16,475 individuals get physically active		45 stroke events
					N.A.	Decrease in the number of individuals (aged 18 years and above) who are physically inactive by 5% annually	35 stroke events
Weight management interventions for obese patients	Obesity (BMI > 30 kg/m^2)	2.0	22.8 (BMI > 30 kg/m^2)	18.5	If 8865 individuals subjected to weight management interventions achieve BMI < 27	N.A.	20 stroke event
					N.A.	Decrease in number of individuals (aged 18 years and above) with BMI > 27 by 5% annually	25 stroke events
Anticoagulation therapy	Atrial fibrillation	5.0	1.8	6.71	Increasing anticoagulation therapy (warfarin) to eligible patients with AF (was not done as part of either intervention but as an additional intervention)		4 stroke events

[a] Relative risk — the risk of stroke when exposed to the risk factors.
[b] Local prevalence — the proportion of the population with the risk factor in Herefordshire.
[c] Population Attributable Risk — the proportion of disease in the population due to the risk factor in Herefordshire.
[d] Population Impact Measures — the number of events prevented in the local population by treating a given number of people with the intervention.
[e] Interventions based on NHS Health Check program and NHS Herefordshire Health Improvement Plan.
[f] Estimated number of events/deaths which can be prevented with intervention. Unless specified, events mean fatal plus non-fatal (i.e. total events). Stroke events include ALL Stroke related events.

Table 6 Primary prevention of cancer in Herefordshire.

Intervention	Risk factor	RR[a]	Prevalence of risk factor[b]	PAR[c]	PIMs[d]		
					Intervention[e]		Events/deaths prevented in the cohort over 5 years[f]
					NHS Health Check program	Health Improvement Plan	
Cancer of the bronchus and lungs — primary prevention							
Smoking cessation	Smoking	26	18.5%	81.39%	If 1780 individuals quit smoking		1 lung cancer case
					N.A.	If number of smokers (18 years and above) are decreased by 5% annually	4 lung cancer cases
Breast cancer — primary prevention							
Alcohol cessation	High Alcohol consumption (>45 g per day alcohol)	1.46	17.7%	7.52%	N.A.	If the number of binge drinking women reduced by 5% annually	1 breast cancer case
Advice on healthy diet	Diet (fat consumption)	1.13	N.A.	N.A.	N.A.	N.A.	N.A.
Weight management interventions for obese patients who are post-menopausal	Obesity (BMI > 30)	1.29	N.A.	N.A.	N.A.	N.A.	N.A.
Colorectal cancer — primary prevention							
Increase intake of dietary fiber	Dietary fiber intake of less than 10 g per day	1.18	N.A.	N.A	N.A.	N.A.	N.A.
Alcohol cessation	High alcohol consumption	1.50	17.7%	8.27%	N.A.	If the number of adults (18 years and above) who binge drink is reduced by 5% annually	2 colorectal cancer cases
Weight management interventions for obese patients	Obesity (BMI > 30)	1.19	22.8% (BMI > 30 kg/m2)	18.56%	N.A.	N.A.	N.A.
Smoking cessation	Smoking	1.27	18.5%	4.19%	N.A.	If the number of smokers (18 years and above) is decreased by 5% annually	2 colorectal cancer cases

[a] Relative risk — the risk of cancer when exposed to the risk factors.
[b] Local prevalence — the proportion of the population with the risk factor in Herefordshire.
[c] Population Attributable Risk — the proportion of disease in the population due to the risk factor in Herefordshire.
[d] Population Impact Measures — the number of events prevented in the local population by treating a given number of people with the intervention.
[e] Interventions based on NHS Health Check program and NHS Herefordshire Health Improvement Plan.
[f] Estimated number of events/deaths which can be prevented with intervention. Unless specified, events mean fatal plus non-fatal (i.e. total events). Stroke events include ALL Stroke related events.

3.3. Cancer

Table 6 summarizes the results for cancer.

Although the NHS Health Check program targeted reducing vascular disease, an added benefit is that if the predicted 1780 smokers identified over 5 years were helped to successfully quit, one lung cancer case would be prevented.

Similarly, if implementation of the NHSH's HIP reduces the number of smokers in Herefordshire by 5% annually over 5 years, four lung cancer and two colorectal cancer cases would be prevented.

Binge drinking is a well-known lifestyle risk factor for psychological disorders and CHD. However, this study also found it contributes to 7.5% of breast cancer and 8.2% of colorectal cancers per annum in Herefordshire (see Table 6). If a 5% annual reduction in binge drinking over 5 years is achieved, one breast cancer case and two colorectal cancer cases can be prevented in Herefordshire.

Other than being a significant risk factor for CHD and stroke, obesity also causes 18.5% of colorectal cancer cases in Herefordshire (see Table 6). Applying these figures to Herefordshire colorectal cancer mortality figures, this translates into 4 colorectal cancer deaths per annum in Herefordshire.

4. Discussion

In this study, the proportion of CHD, stroke and cancer owing to lifestyle risk factors and the number of CHD, stroke and cancer events that can be averted in Herefordshire was calculated by rolling the NHS Health Check program and NHSH HIP. This study demonstrates the application of PARs in identifying the proportion of disease owing to preventable risk factors and of PIMs in quantifying the potential impact of different preventive intervention on health outcomes at a local population level.

The idea that primary prevention interventions are required to maximize population health and minimize the economic burden of CVD is growing [41], but emphasis is given on clinical interventions. Dyslipidemia is recognized as a significant modifiable risk factor for CVD [42], and there is also good evidence to demonstrate the role of hypertension as a risk factor for stroke [42]. Statin and anti-hypertensive therapies are well recognized and widely used primary preventive treatment for CVD. However, in a large European survey of physicians and patients, 95% of patients believed they had well-controlled blood pressure and 76% of physicians agreed, but in reality only 37% of patients achieved target blood pressure [43]. Furthermore, it has been shown that even when risk factors such as dyslipidemia and hypertension are optimally treated in clinical trials, almost two thirds of patients still experience cardiovascular events [44].

In the NHS, 70% of total CVD [45], 80% of CHD [20] and 90% of diabetes [46] were attributed to not following a low-risk lifestyle. The current findings based on the PAR calculations show that in Herefordshire, physical inactivity together with obesity is a greater cause of CHD and stroke than hypercholesterolemia and hypertension. This clearly highlights the need to focus on primary prevention with regard to physical inactivity and obesity, rather than statin therapy and anti-hypertensive therapy to reduce the burden of CHD and stroke in Herefordshire. These findings are in line with Endres et al. [42], which point to the importance of lifestyle interventions as a basis for primary prevention of CVD and primary preventive actions targeting the absolute risk of cardiovascular diseases rather than individual risk factors. Endres et al. [42] estimated that as much as 70% of strokes can potentially be prevented by a lifestyle modification in their population. Many other studies have also shown that an overall healthy lifestyle, such as not smoking, diet, exercise and optimal body weight, may be more effective in lowering the risk of CVD and cancer, as well as diabetes, than any one single factor [45—50].

The benefits associated with mass screening for cardiovascular disease are unknown [51,52]. Similarly, benefits of other planned primary prevention interventions for specific populations are difficult to determine. This study shows that PIMs are useful in establishing the potential number of events through planned primary prevention interventions (NHS Health Check program and NHS HIP) for the specific population. The results of our PIMs calculations show that the actual impact in terms of events/deaths prevented is quite small in Herefordshire. Other studies in this field have also shown that when viewed at the level of a local population, the impact in terms of events/deaths prevented is quite small [13,27]. The study by Heller looks at the impact in a practice population of 10,000 [13], while the study by Gemmell et al. [27] looked at the impact in the UK, therefore the number of events prevented was greater (only because it is related to a larger population), but when the results are broken down into county level, they are small.

The UK government's new white paper, ''Healthy Living, Healthy People,'' states that the government will end central control and give local government the freedom, responsibility and funding to innovate and develop their own ways of improving public health in their area [10]. This means that local policy makers need relevant and local information to underpin their resource allocation decisions to identify diseases, risk factors, population groups and interventions. In this study, using PIMs, the impact of the planned primary prevention interventions was estimated which enables researchers to see the interventions that will prevent the most number of events in the local population. Such information can prove to be very useful to local policy makers to make informed decisions.

Baltussen and Niessen [53] highlight the fact that, currently, priority setting of health interventions is often ad hoc and resources are not used to an optimal extent. While Ham [54] and Robinson [55] point out that choices may not be based on a rational and transparent process. This study demonstrates how PAR and PIMs are calculated and how they can bring together local data and research findings to provide the evidence base to support local decision-making for improving population health through primary prevention activities eliminating ad hoc priority setting and waste of resources using a rational and transparent process.

The findings from this study are inherently dependent on the quality of the source data as PARs and the PIMs methodology use published risk estimates (i.e., baseline risk of disease, RR and the RRR of the intervention of interest), which carry a margin of error. Furthermore, published sources use different definitions of disease status and outcome and present their results over different time-frames, age groups, and may or may not split them by gender. To limit the risks associated with using published sources, the parameters used in this study were derived from systematic reviews or meta-analyses, and whose study question matched closest to this study's target population and planned interventions. However, this was not always possible owing to limitations in the availability of data in the literature, and in itself a time-consuming and challenging process, which could be seen as a limitation to the use of these epidemiological measures.

Other similar studies have looked at one or two interventions or diseases areas [14,15,17,27,56–59]. This study is the first of its kind to use both epidemiological measures (PARs and PIMs) to model outcomes of two complex public health programs. It included six interventions and three disease areas. This is advantageous as it represents real life public health programs, but it is difficult to estimate the interactions between different risk factors. Furthermore, it could not reflect the impact of combined interventions on the outcomes, for example weight management and physical activity interventions will both have an effect on the need for antihypertensive treatment in some individuals. However, an advantage of this study is that wherever possible, compliance to interventions is considered, using values derived from the literature. This does mean that where adherence to interventions was taken into account to model outcomes, these values were derived from published literature. Therefore, the outcomes are based on the assumption that health behavior factors of the local population are similar to the population included in the study.

Cost-effectiveness of the interventions was not considered in this study as it was not its primary aim. The NHS Health Check program is a national 'must-do,' and the study's aim was to achieve organizational support locally to aid implementation. However, an advantage of using the PIMs methodology is that a cost dimension can be introduced to it if an economic assessment of interventions is required by health planners. This entails a methodology called 'population cost-impact analysis' which is described by Heller et al. [60].

5. Conclusion

The findings of this study demonstrate the population impacts that can be achieved by implementation of primary prevention measures, through the implementation of the NHS Health Check program and HIP in Herefordshire. It also demonstrated that physical inactivity and obesity levels are the most significant causes of CHD and stroke events in Herefordshire. Their impact is greater than the combined effect of hypercholesterolemia and hypertension together, both of which are well recognized and treated risk factors. These findings should assist local decision makers when prioritizing investments and ensuring the optimal use of resources.

The study also demonstrates the use of PARs and PIMs in translating public health research and local data into evidence which can be used to inform local public health practice. The epidemiological measures used in this study proved to be excellent tools in providing evidence based public health information in local policy-making and their use is strongly recommended to support prioritization of primary prevention interventions.

Conflict of interest statement

None.

Key points

- It is well known that Coronary Heart Disease, stroke and cancers are responsible for significant mortality and morbidity; their trends are on the rise both in the UK and internationally.
- Prioritization of primary prevention interventions is often ad hoc and the impact of planned interventions is not taken into account in the planning process.
- This study shows that physical inactivity and obesity are responsible for more CHD and strokes than the more recognized risk factors—hypercholesterolemia and hypertension in Herefordshire. Further, the impact of preventative interventions shows that more events will be prevented by prioritizing resources on primary prevention in comparison with secondary prevention of hypercholesterolemia and hypertension.
- This study also demonstrates the value of epidemiological measures in providing evidence-based public health information in local policy-making aiding local decision makers when prioritizing investments and the optimal use of resources in Herefordshire. The methodology can also be used in order to support evidence-based public health policies and practices at the national and international level.

Appendix 1.

1.1. PAR

The PAR is calculated using the population prevalence of the exposure (P_e) and the relative risk associated with the exposure (RR), as follows:

$$\mathrm{PAR} = P_e * (\mathrm{RR} - 1)$$

$$[1 + P_e(\mathrm{RR} - 1)]$$

1.2. NEPP

The number of events prevented in the population (NEPP) to estimate the incremental change in moving from current to best practice is calculated as:

$$\mathrm{NEPP} = n * P_d * (P_b - P_t) * P_a * r_u * \mathrm{RRR}$$

where n = population size, P_d = prevalence of disease in the population, P_b = proportion treated if best practice was achieved, P_t = proportion currently treated, P_a = proportion who adhere to treatment, r_u = risk of the event of interest in the untreated group or baseline risk over appropriate time period, and RRR = relative risk reduction associated with the treatment. Please note $n * P_d * (P_b - P_t) *$ = *number of individuals eligible for intervention* = P_{elig}.

1.3. PIN-ER-*t*

The PIN-ER-*t* estimates the number of disease events prevented by eliminating the proportion of a risk factor above a certain threshold; it is calculated by subtracting the PIN-ER-*t* obtained for the new exposure prevalence from the PIN-ER-*t* for the previous exposure prevalence (for example, 24% of population smoking PIN-ER-*t* subtracted from 28% of population smoking). The PIN-ER-*t* is calculated as:

$$\text{PIN-ER-}t = n * I_p * P_{exp}(\mathrm{RR} - 1)$$

$$1 + P_{\mathrm{exp}}(\mathrm{RR} - 1)$$

where n = population size, P_{exp} = prevalence of the exposure in the population, I_{p} = incidence of the outcome in the population, and RR = relative risk of the outcome if the risk factor is present.

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