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BMC Public Health

DOI:
10.1016/j.puhe.2015.11.001

Published: 01/08/2016

Evaluation of the Cold Weather Plan for England: Modelling of Cost-Effectiveness

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Abstract

Objective

To determine the conditions under which the Cold Weather Plan (CWP) for England is likely to prove cost-effective in order to inform the development of the CWP in the short term before direct data on costs and benefits can be collected.

Study design

Mathematical modelling study undertaken in the absence of direct epidemiological evidence on the effect of the CWP in reducing cold-related mortality and morbidity, and limited data or on its costs.

Methods

The model comprised: a simulated temperature time series based on historical data; epidemiologically-derived relationships between temperature, and mortality and morbidity; and information on baseline unit costs of contacts with healthcare and community care services. Cost-effectiveness was assessed assuming varying levels of protection against coldrelated burdens, coverage of the vulnerable population and willingness-to-pay criteria.

Results

Simulations showed that the CWP is likely to be cost effective under some scenarios at the high end of the willingness to pay threshold used by National Institute for Health and Care Excellence (NICE) in England, but these results are sensitive to assumptions about the extent of implementation of the CWP at local level, and its assumed effectiveness when implemented. The incremental cost-effectiveness ratio varied from £29,754 to £75,875 per Quality Adjusted Life Year (QALY) gained. Conventional cost-effectiveness (<£30,000/QALY) was reached only when effective targeting of at risk groups was assumed (i.e. need for low coverage (~5%) of the population for targeted actions) and relatively high assumed effectiveness (>15%) in avoiding deaths and hospital admissions.

Conclusions

Although the modelling relied on a large number of assumptions, this type of modelling is useful for understanding whether, and in what circumstances, untested plans are likely to be cost-effective before they are implemented and in the early period of implementation before direct data on cost-effectiveness have accrued. Steps can then be taken to optimise the relevant parameters as far as practicable during the early implementation period.

Key words: Cold Weather Plan; winter burden, cost-effectiveness

Introduction

Preparedness for winter cold continues to be important for health protection, and the management of largely predictable seasonal pressures on health and social care services in England. Even under warming induced by climate change, prolonged periods of winter cold will persist well into the 21st century [1,2], as will the chance of disruptive extreme cold such as occurred during the winters of 1946-1947 [3], 1962-1963 [4,5], 2009-2010 [6] and 2010-2011 [7]. Although most of the health burden of cold weather in England does not occur on extremely cold days [8], extreme cold conditions can incur disproportionately severe impacts on health care services if they are unprepared when they do happen.

The Cold Weather Plan (CWP) for England, operational since 2011, was established to "... prepare for, alert people to, and prevent the major avoidable effects in health during periods of severe cold in England" [9]. It combines the Cold Weather Alert (CWA) forecasting service run by the Met Office each winter, and guidance to the NHS (community, primary and secondary health care), local authorities (social care) and other public bodies and voluntary organizations, on what actions to take in response to alert levels issued by the CWA service. The actions proposed in the CWP are set out in very general terms to allow local authorities and the NHS to tailor their plans to suit local circumstances and fit within available resources.

The CWA forecasting service issues five alert levels: "Level 0" (long-term preparedness), "Level 1" (winter preparedness), "Level 2" (alert and readiness), "Level 3" (severe weather action) and "Level 4" (national emergency). Level 0 is triggered all year. It reminds authorities of the need for long-term planning for the coming winter and entails actions that should be phased throughout the year. Level 1 is triggered on 1st November and prompts authorities to put in place general preparedness actions during the period from 1st November to 31st March. Level 2 is triggered whenever a mean temperature of 2°C and/or widespread ice and heavy snow are forecasted within 48 hours with 60% confidence. Level 3 is triggered when the conditions described in Level 2 happen. Finally Level 4 is declared by the Government when the weather conditions are very severe and/or prolonged. Levels 2 to 4 unlike 0-1 are provided on a geographical basis rather than country-wide basis.

There have been very few economic evaluations of health-related weather forecasting services in England. Sampson et al [10] carried out an exploratory analysis of the likely costs and benefits of health-related weather forecasting services. One of their key findings was that health care services need to engage with a forecasting service to realise its full potential. They identified the main value of forecasting services as helping health services plan ahead to cope with their likely workload in ways that could take account of weather conditions.

The objective of this study was to estimate the cost-effectiveness of the CWP. However, because the CWP has only been operating for three winters, there is as yet insufficient direct epidemiological evidence on its impact on health and health services and information on its costs. Our analysis was therefore carried out to explore through simulation the conditions under which the CWP is (or can be made to be) cost-effective.

Methods

Full details of the methods are provided in the Supplementary Material.

Modelling framework to calculate health benefits and costs

Figure 1 shows the modelling framework used to calculate the health benefits and direct costs of the CWP. It is divided into three main components (represented by the dashed large rectangles). The first component (block A) calculates the cold-attributable disease burden pre-CWP defined in terms of the numbers of premature deaths and emergency hospital admissions. The calculation of the daily cold-attributable disease burden is a function of the temperature-dependent fractional excess risk and the daily baseline health burden. This burden would represent the pre-CWP scenario because the exposure-response relationships used in the health impact calculations are based on epidemiological analysis of historical data before the introduction of the CWP [8].

The second component (represented by block B in the figure) takes into account the extent of implementation of the CWP, given that no plan is ever completely implemented as intended, as well as its effectiveness in preventing mortality and hospital admissions. Two unknown parameters are introduced to determine the effectiveness of the implemented CWP: (i) the upper bound of the proportion of avoidable premature deaths and hospital admissions that would be averted if the CWP were fully implemented (δ), and (ii) the average degree of implementation of the CWP(ζ). The effectiveness of the implemented CWP is the product of these two parameters ($\delta\ \zeta$) which gives the proportion of burden averted.

The third component of the framework is represented by block C in Figure 1. The numbers of premature deaths and hospital admissions averted are the product of the health burden preCWP and the effectiveness of the CWP($\delta\ \zeta$). These numbers are combined to express the health benefits in Quality Adjusted Life Years (QALYs). There is also a health benefit associated with increased contact with primary and social care services as a result of implementing the CWP (also measured in QALYs).

The cost of the additional contacts with primary and social care services depends on the degree of implementation of the CWP, and the number and nature of contacts pre-CWP. The cost savings are estimated directly from the number of reduced hospital admissions associated with successful implementation of the CWP assuming that each admission avoided leads directly to a commensurate saving (unlikely in practice).

Cost-effectiveness analysis

Cost-effectiveness analysis is concerned with analysing the incremental costs and incremental benefits of a “new intervention” compared with “current practice”. In this analysis, the “new intervention” is the CWP and “current practice” is the set of actions taken by the NHS and local authorities before the introduction of the CWP. The CWP is deemed to be cost-effective when the incremental cost-effectiveness ratio is less than the pre-specified willingness to pay per unit of health gain.

Health impact assumptions

In order to integrate the health benefits into a single metric (the QALY), a number of assumptions were made. For hospital admissions and community care contacts, we considered only COPD patients. We used figures for COPD as typical of a condition causing cold-related emergency hospital admissions and community health staff contacts. This seems reasonable because, in the UK, COPD admissions represent an eighth of all emergency hospital admissions and a fifth of bed days used for respiratory conditions [11]. There are about 900,000 diagnosed COPD patients in the UK and COPD exacerbations are significantly affected by cold weather. Of course, other respiratory conditions are also affected by cold weather, but we chose to focus on COPD as a representative condition as it represents such a large burden to the NHS and for which we have good data on anticipative healthcare. We assumed further that among COPD patients only those with exacerbations would be admitted to hospital, that community health and social care contacts would avert some patients from having exacerbations, and that the associated Quality of Life (QoL) gained would last for one year. We used relevant data from an evaluation of the Healthy Outlook® COPD health forecasting alert service to provide guidance on the likely number of additional non-hospital contacts per COPD patient [12].

For mortality, we considered all-cause mortality and assumed that most cold-related deaths occur in the elderly [13]. We used life tables [14] to estimate the population-weighted average life expectancy of people aged 75+ years. To obtain an estimate of QALYs gained due to deaths averted, we used QoL adjustment figures for COPD and multiplied the above-mentioned average life years gained by the average QoL for COPD patients with exacerbations.

Health impact calculation

We have used epidemiological thresholds rather than the decision thresholds used in the CWP alerts because less than about 3% of cold-related deaths occur on CWP alert days [8] and so the cost/benefits on those days are minimal in comparison. The model uses as input the evidencebased epidemiological thresholds which are the temperatures below which mortality and morbidity risks start to increase. The choice of the decision thresholds should ideally be informed by multiple factors in which health is only one of the factors to be taken into account. Non-health factors could include (i) the trade-offs between true positives, false positives, true negatives and false negatives of the cold weather alerts, (ii) the confidence of NHS and LA frontline workers in the accuracy of the CWP forecasts, their interpretation of the levels of uncertainty attached to the forecasts, and the impact that these factors have on their implementation of the CWP.

We used a linear-threshold model of cold temperature-mortality for the health impact calculation[8]. The epidemiological threshold temperatures for all-cause mortality and COPD hospital admissions were calculated on a regional basis using time-series regression analysis, with the best-fitting threshold common to all regions being identified by maximum likelihood estimation. At temperatures below the cold threshold, the mortality relative risk increases linearly with decreasing temperatures. We used a similar relationship for the relative risk of hospital admissions but with a different threshold temperature. The estimate of the number of pre-CWP daily premature cold-related deaths is calculated from the excess fractional risk at the temperature on the day and the baseline number of deaths. The post-CWP daily premature cold-related deaths averted is given by the product of the pre-CWP value and the two parameters defined earlier (the upper bound of the effectiveness of the CWP if fully implemented and the average degree of implementation of the CWP). A similar approach is used to calculate the post-CWP daily hospital admissions avoided.

Temperature time series

We simulated temperature based on historical temperature data. We used 100 years of the daily Central England Temperature (CET) time series record from 1878 onwards. Although the epidemiological analysis often uses mean daily temperature, for the purposes of this analysis we are more interested in the daily minima of CET to model extreme conditions. We analysed the minima of daily CET by fitting a generalized minimum extreme value distribution to the data.

Costs

Relevant primary, social and community health services costs, and hospital admission costs for 2012 were taken from PPSRU [15]. In the absence of evidence on the nature of the additional contacts with patients/clients in the community, we assumed that each additional contact would incur a cost drawn randomly from an appropriately specified distribution.

Results

Baseline estimates for key parameters

As the simulation model has many parameters, it is not possible to simulate all their possible permutations. Table 1 shows the baseline values of the main parameters, some of which are then varied in the sensitivity analysis.

Cost-effectiveness ratios

Table 2 gives the incremental cost effectiveness ratios (ICERs) for different permutations of three parameters: upper bound of the effectiveness of the CWP; proportion of the vulnerable population contacted in the community; and the time horizon of the analysis. To put the estimated ICERs in context, NICE uses an implied willingness to pay threshold between about £20,000 to £30,000 per QALY gained for health technology cost-effectiveness evaluation [16].

The results indicate that the ICERs were sensitive to two of our key model parameters (the upper bound of the effectiveness of the CWP, δ, and the proportion of the vulnerable population visited, ζ, but not to the assumed time horizon of analysis. As seems logical, the ICERs were higher with greater assumed effectiveness of the CWP, such that the cost per QALY was around 40% less at a δ of 0.45 compared with a δ of just 0.05. Similarly, ICERs were more favourable when the proportion of the population contacted was assumed to be lower. Among the permutations tabulated, only one combination was lower than the conventional NICE cut-off of £30k/QALY: a δ of 0.15 and ζ of 0.05.

Discussion

One of the earliest applications of the Met Office health forecasting alert services was targeted towards patients with chronic obstructive pulmonary disease (COPD). There have been several evaluations of this service showing mixed results on its effectiveness in reducing COPD mortality, exacerbations and hospital admissions [12,17-20]. Although the service was not associated with reductions in COPD admission rates [12,19], it was associated with lower mortality rates [17]. The Met Office has recently withdrawn this service citing its lack of commercial viability in light of the restructuring of NHS commissioning [21]. Determining the effectiveness of health forecasting alert services is important if they are to be routinely used to support the NHS and local authorities (LAs) in their preparedness for adverse weather conditions. It is also important to determine their cost-effectiveness given current resource and budgetary constraints.

In evaluating the CWP ("new intervention"), it is necessary to know what was done before introducing the CWP. Depending on the extent and nature of winter preparedness plans preCWP, and assuming that the actions lead to benefits, post-CWP could either mean consolidation of actions which may incur relatively small additional health benefits and/or costs, or extension of the actions, or introduction of new actions which could result in large additional health benefits and/or costs, or no change in actions at all. Several local authorities implement existing public health programmes (e.g. "Keep Warm Keep Well", "Warm Houses, Healthy People Fund", etc…) to protect their communities against cold weather and the guidance of the CWP is to build on these programmes [22]. Naturally local authorities vary on how they have integrated the CWP in their current practices[23].

We have shown that the CWP is likely to be cost-effective *if* certain assumptions are met about the effectiveness of the programme in preventing cold-related deaths and hospital admissions, if only a relatively small fraction of the population in the potential at risk group need to be contacted by local health and care staff, and if willingness-to-pay thresholds at the middle to high end of the those used by NICE are used. The scenarios were defined in the simulation by different combinations of three model parameters: upper bound of effectiveness of the CWP(δ); proportion of population potentially at risk contacted/visited(ζ); and time horizon for analysis(y). The baseline value of ICER was shown to be £64,199 per QALY gained. In the sensitivity analysis, the ICERS were shown to vary between £29,754 and £75,875. The ICERs were not sensitive to the time horizon of analysis (1-20 years) but were sensitive to the other two parameters (effectiveness and proportion of potentially at risk contacted). In one way sensitivity analysis, the ICER is shown to decrease with increasing δ (becomes more cost-effective) and increase with increasing ψ (becomes less cost-effective).

The model has a number of limitations. For example, while it uses as inputs robust evidence on the temperature thresholds below which mortality and morbidity risks start to increase, the simulation did not test the sensitivity of the ICER to the decision thresholds of CWP for triggering the alert levels, primarily because the alerts are only one part of CWP activities and the health burdens associated with such days are actually quite minimal.[8] Practicably, the decision thresholds are informed by multiple factors, of which potential ill-health effects is only one. As with any early warning system, there are economic and societal consequences if true positive forecasts are ignored or if false positive forecasts are acted upon displacing other necessary activities. We have not quantified the consequences of false positives or false negatives because of a lack of sufficient data on the accuracy of the forecasts and on health workers' understanding of the effects of not taking due actions or of taking unnecessary actions. The model is based on many assumptions and parameters. It was not feasible to determine the sensitivity of the ICERs to all possible permutations of the parameters. We only used data for COPD as typical of patients with chronic conditions who are admitted to hospital or contacted in the community during winter. Not all costs were taken into account. We excluded the cost of management time to set up local plans, the cost to the Met Office of providing the cold weather alert service, or the cost of additional medication given to patients/clients during visits. Finally we have not costed in our evaluation long-term interventions. Long-term intervention strategies (such as in improving housing insulation) and general winter preparedness (levels 0 and 1 of the current CWP) are more likely to be important than short-term interventions triggered by the CWP alerts [8].

Despite the lack of direct evidence, this type of assessment has wide applicability since new public health plans are being developed worldwide in response to extreme weather events. It is important to establish how to increase the likelihood that these untested plans will prove to be effective and cost-effective over the long term. One way to do this is to undertake *ex ante* and early stage modelling in order to explore which parameters are likely to be critical in influencing the effectiveness and cost-effectiveness of a policy. In the current example, the analyses highlight the importance of a set of conditions relating to the effectiveness of the CWP in preventing cold-related burdens and the efficiency of targeting of the true vulnerable population which are pre-requisite for a cost-effective service. Steps can then be taken to ensure that these parameters are optimised as far as practicable. This evaluation can help to inform the economic evaluation of cold weather plans being developed in other countries [24-25].

Conclusion

A mathematical model was developed to simulate the daily health benefits and costs of the CWP over time horizons ranging from 1 to 20 years. Incremental cost-effectiveness ratios (ICERs) were calculated from which cost-effectiveness was established for given willingnessto-pay thresholds. In some situations, the CWP is cost-effective at the middle to high end of the range of willingness-to-pay thresholds used by NICE for comparative evaluation of health care technologies in the English NHS. The ICERs were not found to be sensitive to the time horizon of the analysis.

Acknowledgements

This work is funded by the Policy Research Programme of the Department of Health for England via its core support for the Policy Research Unit in Policy Innovation Research. This is independent research commissioned and funded by the Department of Health. The views expressed are not necessarily those of the Department. Ethical approval was obtained from the Observational Research Ethics Committee of the London School of Hygiene & Tropical Medicine. There are no competing interests.

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Table 1: Baseline values used in the model simulation

Parameter	Value
CWP parameters	
Effectiveness of CWP if fully implemented (between 0 and 1 where 0 is not effective and 1 is fully effective)	0.15 (15%)
Degree of implementation of CWP (between 0 and 1 where 0 is not implemented and 1 is fully implemented)	0.5 (50%)
Vulnerable patients/clients (based on number of COPD patients in the UK)	900,000
Proportion of vulnerable population visited pre-CWP	0.3 (30%)
Time horizon of analysis	10 years
Epidemiological parameters	
Threshold temperature for mortality	5°C
Percent change in mortality risk per 1°C decrease in temperature below threshold	3.84%
Threshold temperature for COPD hospital admissions	8°C
Percent change in risk of COPD hospital admissions per 1°C decrease in temperature below threshold	8.4%
National average number of daily deaths during winter	1,495
National average number of COPD hospital admissions during winter	308

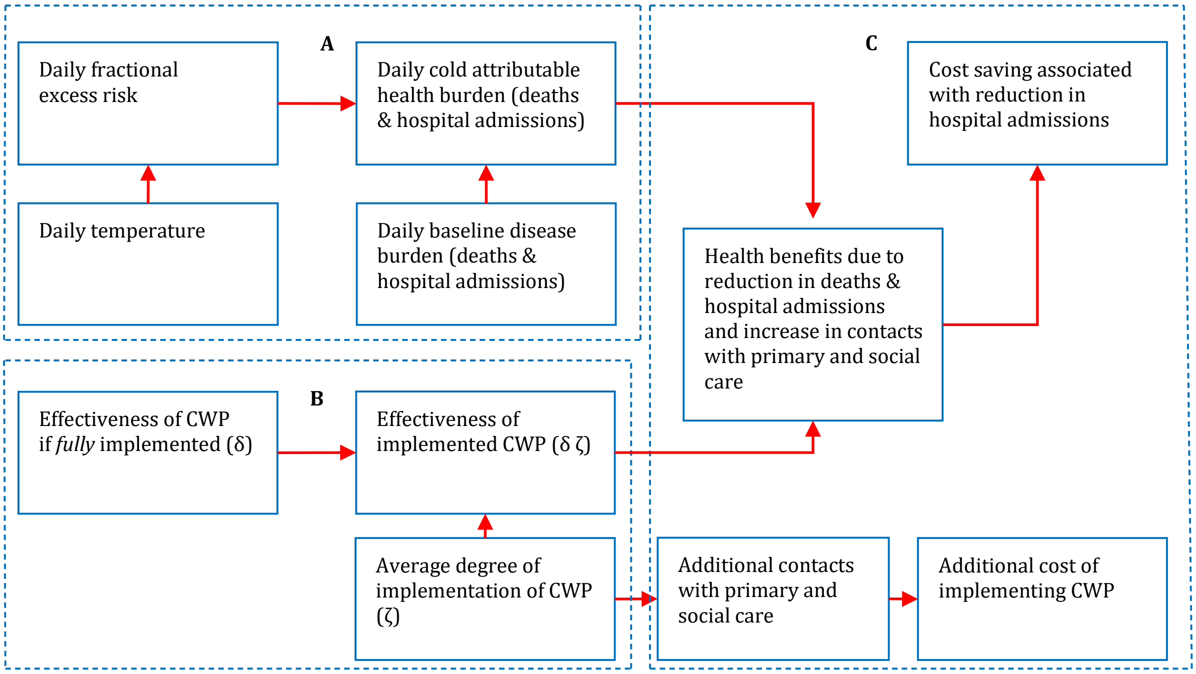
Table 2: Sensitivity of Incremental Cost Effectiveness Ratios (ICER) to changes in three key parameters.

Upper bound of effectiveness of CWP (δ)	Proportion of vulnerable population contacted/visited (ζ)	Time horizon in years (y)	Incremental costeffectiveness ratio (ICER) (£ per QALY)
Sensitivity to δ			
	0.30	10	75,875
	0.30	10	64,199*
	0.30	10	55,632
	0.30	10	49,078
	0.30	10	43,903
0.05			
0.15			
0.25			
0.35			

0.45			
	Sensitivity to ζ		
	0.05	10	29,754
	0.10	10	43,903
	0.20	10	57,553
	0.30	10	64,199*
	0.40	10	68,131
0.15			
0.15			
0.15			
0.15			
0.15			
	Sensitivity to y		
	0.3	1	65,024
	0.3	5	62,650
	0.3	10	64,199*
	0.3	15	62,291
	0.3	20	64,001
0.15			
0.15			
0.15			
0.15			
0.15			

*The baseline value.

Figure 1: The modelling framework for cost-effectiveness analysis. The three components of the framework are represented by the dashed large rectangles.


A
Daily fractional excess risk
Daily cold attributable health burden (deaths & hospital admissions)
Daily temperature
Daily baseline disease burden (deaths & hospital admissions)
B
Effectiveness of CWP if *fully* implemented (δ)
Effectiveness of implemented CWP (δ ζ)
Average degree of implementation of CWP (ζ)
C
Cost saving associated with reduction in hospital admissions
Health benefits due to reduction in deaths & hospital admissions and increase in contacts with primary and social care
Additional contacts with primary and social care
Additional cost of implementing CWP