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The association between smoke alarm presence and injury and death rates: A systematic review and meta-analysis

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ABSTRACT

Mounting evidence suggests that smoke alarms play a key role in reducing the number of deaths and injuries associated with household fires each year. This study brings together the current literature on smoke alarm effectiveness. In particular, we are interested in determining whether or not smoke alarms decrease death and injury rates and if so, to what extent. A systematic search of the literature uncovered 13 studies concerned with examining the link between smoke alarm presence and death and/or injury rates. Following further screening, 4 studies were found to meet the inclusion criteria for the death meta-analysis and 3 studies were deemed suitable for the injury meta-analysis. Overall we found the death rate in households with working smoke alarms to be half the death rate of households without working smoke alarms. In contrast, our injury meta-analysis uncovered no significant link between smoke alarm presence and injury rates. We critically discuss these findings and highlight areas for future investigation.

1. Introduction

Over the last three decades, fire death rates have fallen consistently across industrialized nations [1]. Between 1979 and 2007, many countries including the United States (US), the United Kingdom, Austria, Spain and the Netherlands saw fire death rates halve [1]. The introduction of smoke alarms in residential homes during the 1970s coincided with this decline in fire fatalities. In 1977, just 22% of households in the US were equipped with fire detectors [2]. Since then, this figure has grown exponentially with an estimated 96% of homes fitted with smoke alarms in 2004 [2].

Yet there remains a relatively high degree of variation in fire death rates across countries. In 2007, fatal fires accounted for just 2 deaths per million people in Switzerland and 4.7 deaths per million people in Australia [1]. By comparison, fire death rates were considerably higher in the US and Finland, responsible for 12.4 deaths and 18 deaths per million people respectively [1]. These varying rates across countries may in some part be attributable to differences in fire safety awareness; building and housing regulations; building types and construction materials; and the presence of smoke alarms in residential homes.

While smoke alarms alone cannot combat household fires, a growing body of empirical evidence indicates that they are an effective tool in reducing the number of associated deaths and injuries [3–5]. Compared to households without working smoke alarms, studies in the US find households with functioning devices experience half the rate of deaths [3,4]. Injury rates also appear to be lower in households with working smoke detectors [5]. Taken together, these findings suggest smoke alarms play a key role in improving survival chances and minimizing injuries in the event of a household fire.

Yet despite increasing evidence that smoke alarms reduce residents' risk of death and injury, there is currently no systematic compilation of data and research on this topic. Instead, systematic reviews in this area have thus far focused on the success of interventions that promote the installation of smoke alarms in residential homes [6,7]. To bridge this gap, this systematic review brings together the available empirical literature that considers the link between smoke alarms and reduced deaths and injuries. To determine the strength of this association, data from studies sharing a similar outcome variable are utilized to perform two meta-analyses (one meta-analysis focused on death rates and the other meta-analysis focused on injury rates). In addition to establishing whether smoke alarms are an effective lifesaving device, these meta-analyses help quantify the degree to which working smoke alarms are associated with lower numbers of deaths and injuries caused by residential fires.

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2. Methods

2.1. Search strategy

To retrieve relevant, published studies on this topic, key search terms were determined following a preliminary review of the literature. These broad search terms include: "smoke alarm", "smoke detector" and "fire alarm." The search was conducted in October 2013 at the University of Queensland. The following databases were searched with the bracketed figure indicating the number of results for each source: Pubmed (253); Web of Science (1175); Web of Science–Science Citation Index (SCI) (707); Web of Science–Social Science Citation index (SSCI) (157); Proquest (536); and Cochrane library (2). Using the Endnote software package, duplicates were removed, resulting in a total of 1820 documents. A diagram outlining the search and screening procedure is given in Fig. 1. No searches were conducted in languages other than English. Thus, these search results are limited to studies published in English.

Queensland Fire and Emergency Service (QFES): this project took place in collaboration with the Queensland Fire and Emergency Service (QFES), which enabled access to a dataset that provides information on all reported fire incidents in Queensland from calendar years 1997–2013. As this review is particularly interested in datasets detailing deaths and injuries in houses with and without functioning smoke alarms, the QFES dataset was added to the documents for screening (refer to Fig. 1).

2.2. Inclusion and exclusion criteria

We included original studies in the meta-analyses if the following four conditions were met: (1) the study included data on deaths and/or injuries caused by household fires; (2) the study compared households with functioning smoke alarms to those without; (3) the study counted fire death and injury rates per incident rather than per household; and (4) the study included data on residential fires with and without fatalities and/or injuries. Due to changes in fire technologies, studies published before 1990 were excluded from the review.

2.3. Data collection and analysis

The first author screened the 1821 documents retrieved from the systematic search. Documents were first screened for eligibility on title and subsequently on abstract. Following the title screening, 46 documents were advanced to the abstract screening stage. After abstracts were screened, the full text of 13 documents was retrieved and reviewed. Of these, 4 datasets met the inclusion criteria for the meta-analysis on deaths and three datasets met the inclusion criteria for the meta-analysis on injuries. Two datasets were suitable for both [3,8] including the raw QFES dataset from which effect sizes were calculated [8]. It should be noted that no randomized control trials on smoke alarm effectiveness were identified as part of the systematic search. Therefore, we resort to identifying associations in observational studies. While useful in identifying consistent trends, the quality of these studies limits our ability to draw causal inference due to the possibility of confounding factors.

The meta-analyses were conducted to compute a confidence interval over the odds ratio for the intervention group (households with working smoke alarms) compared to the non-intervention group (households without working smoke alarms). The two meta-analyses capture the effect of smoke alarm installation on death and injury rates. The random effects model was employed with inverse variance weighting using the DerSimonian–Laird model [9] in the R statistical computing environment [10]. This commonly used method recognizes the heterogeneity of the included studies and the differences in the underlying populations. Specifically it includes a statistical parameter accounting for the inter-study variation.

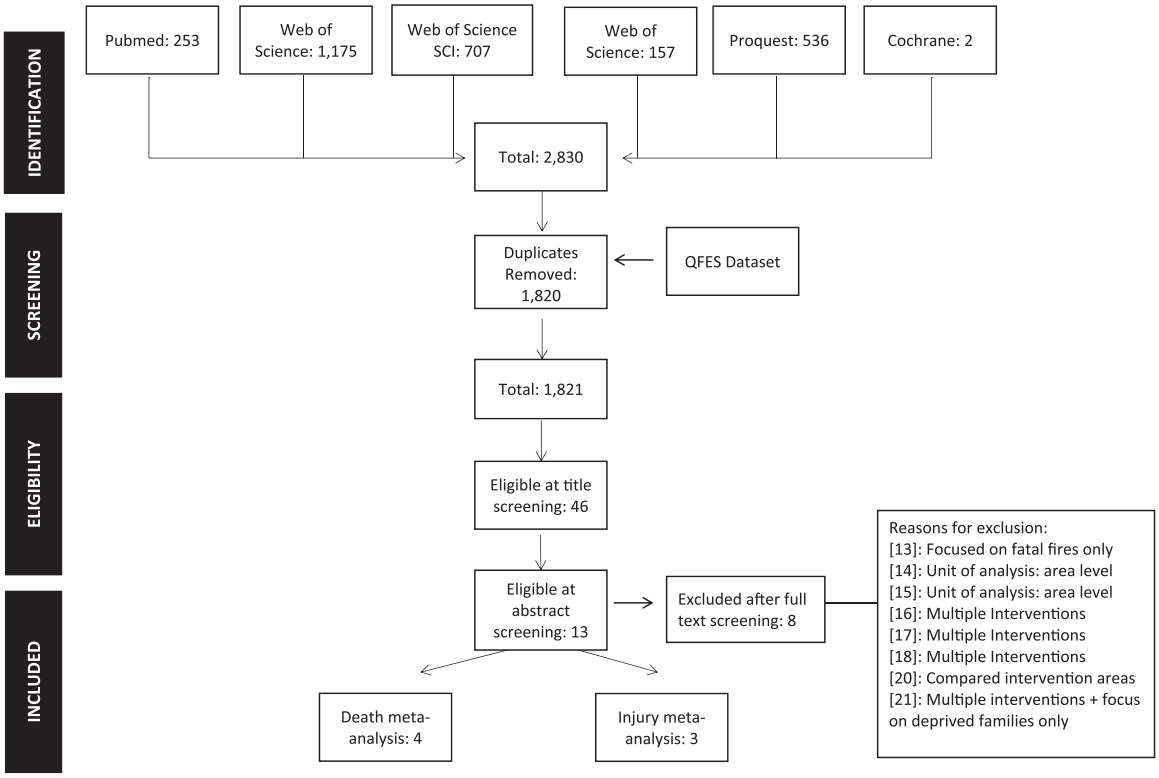

Fig. 1. Systematic search process.