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## Review article

## The impact of strengthening cigarette pack warnings: Systematic review of longitudinal observational studies



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## ABSTRACT

**Objectives:** Cigarette pack warnings are a tobacco control strategy used globally. To understand their impact, we systematically reviewed longitudinal observational studies examining national implementation of strengthened warnings.

**Methods:** We used comprehensive search procedures to identify observational studies examining the impact of strengthening cigarette pack warnings. We report longitudinal changes in knowledge, beliefs, attitudes, intentions, and behavior.

**Results:** We identified 32 studies conducted in 20 countries with 812,363 participants. Studies commonly examined changes from text to pictorial warnings (64%); the remainder examined strengthened text or strengthened pictorial warnings. Knowledge increased in all 12 studies that assessed it. Studies of beliefs/attitudes and intentions showed mixed results. Quitline calls increased in four of six studies, while foregoing of cigarettes did not increase. Cigarette consumption decreased in three of eight studies; quit attempts increased in four of seven studies; and short-term cessation increased in two of three studies. Smoking prevalence decreased in six of nine studies.

**Conclusions:** Strengthening warnings was associated with longitudinal increases in knowledge, quitline calls and reductions in smoking behavior. Strengthening warning policies should be a priority for tobacco control globally.

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Tobacco use is the leading cause of preventable death and disease in the world, causing nearly six million deaths each year (World Health Organization, 2013). Health effects of tobacco use include non-communicable diseases such as cardiovascular disease, cancer, respiratory disease, and reproductive complications. Tobacco use can also exacerbate communicable diseases like tuberculosis and respiratory tract infections (US Department of Health and Human Services, 2004; World Health Organization, 2012). Globally, tobacco use is responsible for 71% of lung cancer deaths and 42% of chronic obstructive pulmonary disease cases (World Health Organization, 2012). In the United States alone, cigarette smoking causes about one in five deaths overall, or more than 480,000 deaths per year (US Department of Health and

Human Services, 2014).

Tobacco product packaging is a key part of marketing efforts to make tobacco use appealing (Moodie and Hastings, 2010; Wakefield et al., 2002). However, regulators can use that same packaging to communicate the health risks of tobacco product use to consumers (Centers for Disease Control and Prevention, 2009). A pack-a-day smoker potentially sees a cigarette pack an estimated 7300 times per year (20 views/day × 365 days/year). Messages on these packs generate exposure that far outweighs exposure from other anti-tobacco communications, such as mass media campaigns, and at essentially no cost (Durkin et al., 2012).

The combination of high exposure, nearly universal reach, and very low cost has made health warnings on cigarette packs a core tobacco control strategy globally. Many countries have implemented and then revised cigarette pack warning policies, progressing through five phases (Hilamo et al., 2014). The first warnings, introduced by the US in 1966, were vague, simple

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warnings on the sides of cigarette packs (e.g., “cigarette smoking may be hazardous to your health”). In the next phase, countries adopted warnings that were clearer about health hazards and more definitive in linking smoking to specific diseases. In the third phase, countries moved warnings to the front of the pack. In the fourth phase, countries required that the warnings contain multiple, rotating messages. Finally, countries added pictures to what had previously been text-only warnings. Iceland in 1986 became the first country to implement warnings with pictures, but these warnings were black and white. Canada in 2001 became the first country to implement full-color pictorial warnings (Hiilamo et al., 2014).

The World Health Organization (WHO) Framework Convention on Tobacco Control (FCTC) requires implementation of large (30% and preferably 50% of pack) warnings on tobacco products, which may include pictures (World Health Organization, 2003). This framework has spurred numerous countries to strengthen their cigarette warning policies over the past decade or more. Between 2001 and 2015, 77 countries and jurisdictions implemented pictorial warning policies, and these countries are home to more than 40% of the world's population (Canadian Cancer Society, 2014). Although the US Food and Drug Administration (FDA) planned to implement pictorial warnings on cigarette packs in 2012, lawsuits from the tobacco industry thwarted implementation (Kraemer and Baig, 2013).

Recently, narrative reviews of the cigarette pack warnings literature have suggested that cigarette pack warnings can be effective in promoting smoking cessation, especially when warnings are large, prominent, full color, and use graphic images (Hammond, 2011, 2012). However, reviews that systematically locate and synthesize the evidence are needed to comprehensively evaluate the impact of warnings and warning policies. To date, we are aware of only two reviews that have systematically examined this literature. The first review quantitatively synthesized the experimental literature on pictorial warnings (Noar et al., 2016b), meta-analyzing results from 37 experimental studies. Pictorial warnings were more effective than text warnings on most outcomes studied, including attention, cognitive elaboration (e.g., thinking about smoking harms), negative affective reactions (e.g., fear), intentions to not start smoking, and intentions to quit smoking. However, this set of studies assessed only the immediate impact of warnings in experimental settings and did not shed light on the possible longer-term impact of warnings when implemented on smokers' packs.

The second study was a systematic review of published studies examining the effects of pictorial warnings on smoking behavior (Monarrez-Espino et al., 2014). This review examined a variety of observational studies looking at the effects of real-world implementation of warning policies and also included some warning experiments. Twenty-one articles that assessed one or more of three outcomes were included: reducing smoking (15 studies), quit attempts (11 studies), and smoking cessation (nine studies). This review concluded that due to low methodological quality, the literature is inconclusive regarding the impact of pictorial warnings on smoking behavior. The authors of this review were critical of studies that were not randomized controlled trials; they were also critical of studies that did not provide explicit assessments of behavior and those that reported on contaminated comparison conditions (Monarrez-Espino et al., 2014). However, the selection of such a diverse set of studies in this review might have made it difficult to synthesize the literature and draw insights from it (Noar et al., 2015). Moreover, this review did not examine factors that are likely precursors to cessation behavior, such as changes in knowledge, beliefs, and intentions (Noar et al., 2015), nor did they examine smoking prevalence.

Although a large observational literature has examined the longitudinal impact of strengthened cigarette pack warnings, no systematic review has examined this literature. We define strengthened warnings as cases where countries implement improvements to text warnings, implement pictorial warnings, or improve pictorial warnings. Strengthened warnings are nearly always larger in size, are typically on the front and back of the cigarette pack, and they may more effectively motivate quitting smoking while reducing the appeal of the cigarette pack itself (Hammond, 2011; Noar et al., 2016b). This literature is compelling because it examines the pre-post impact of national implementation of strengthened warnings. Thus, the purpose of our systematic review was to examine whether national implementation of strengthened cigarette pack warnings affects knowledge, beliefs, attitudes, intentions, and behavior.

## 1. Method

### 1.1. Search strategy

We used a comprehensive search strategy to systematically locate relevant studies. The search strategy involved five steps. First, we searched PsycINFO, PubMed, Embase, Web of Science, and Business Source Complete computerized databases in February of 2014. We used the following terms: (cigarette\* OR tobacco) AND (warning\* OR label\* OR pictorial OR graphic) (supplementary Appendix A). Second, we examined the reference sections of five narrative reviews of cigarette pack warnings (Centers for Disease Control and Prevention, 2011; Davis et al., 2008; Hammond, 2011, 2012; Monarrez-Espino et al., 2014; National Cancer Institute, 2009). Third, we examined the reference lists of the final set of articles included in our review. Fourth, we searched the first 100 results of our search terms in both Google Scholar and Google. Fifth, we contacted the authors of the final set of articles and posted on five relevant listservs to request studies. All studies were considered for inclusion – including unpublished/grey literature as well as non-English study reports.

The review had three inclusion criteria. First, a study had to be observational in nature and report data on the impact of a change in the implementation of national cigarette pack warning policy. Second, a study had to report data from at least one assessment before the change in warning policy and at least one assessment during or after implementation of the change. Third, a study had to report one or more outcomes from the knowledge/attitudes/beliefs, intentions, or behavioral categories from the message impact framework (Noar et al., 2016b). A companion review is examining outcomes from the attention/recall and warning reactions categories of the framework (Noar et al., 2016a).

Two reviewers independently examined all study titles for the 6241 references we identified (Fig. 1), reducing the number to 1215. They then reviewed abstracts, further reducing the number to 87. During this process, we excluded articles only if both reviewers independently determined the article to not be relevant. The two reviewers independently examined the full text of 87 articles and tracked reasons for study exclusion. If the two reviewers made a different determination about a particular article classification, they consulted with a third referee to resolve the discrepancy and make a final determination. This process identified 30 articles reporting on 32 independent samples. All but four of the samples were reported in published articles.

### 1.2. Article coding

#### 1.2.1. Study characteristics

Two coders independently coded article features, including

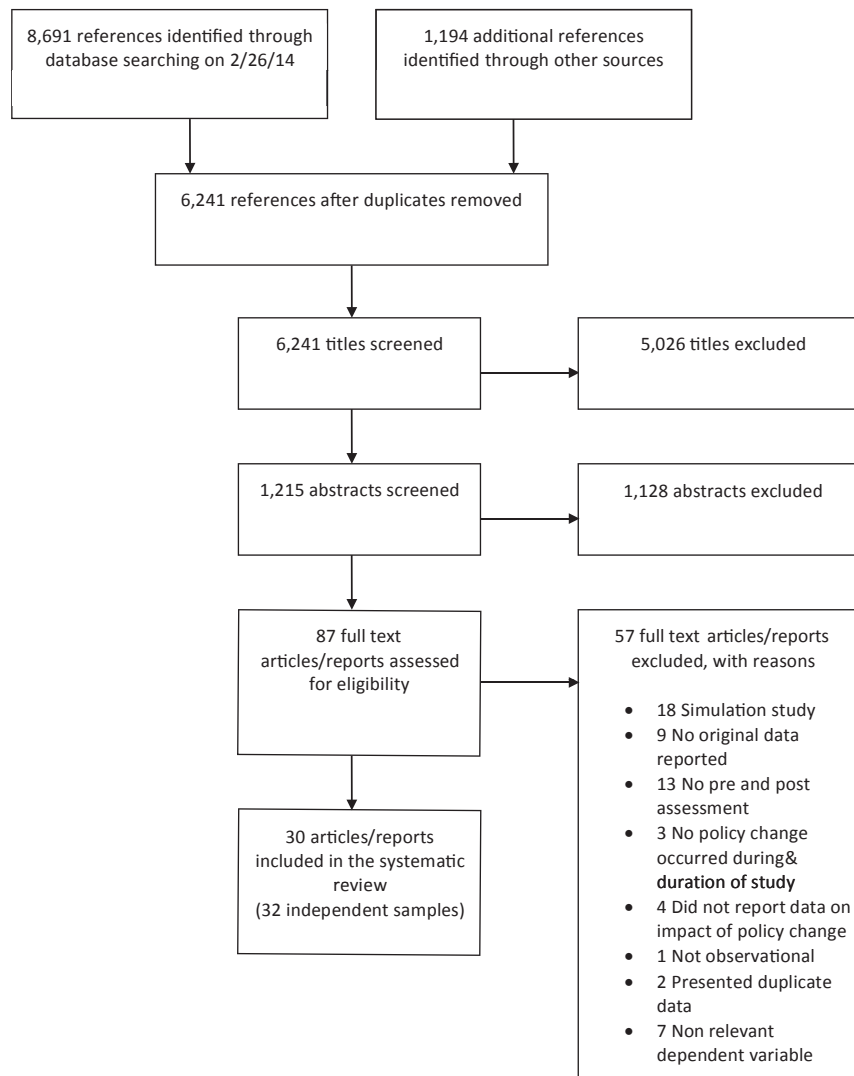


Fig. 1. PRISMA flow diagram showing the study screening process.

*study characteristics* such as country of policy change and control country (if any) and *sample characteristics* such as age range, income level, and smoking status (supplementary Appendix B). The coders also coded *study design characteristics* such as sample size, sampling and data collection mode, response rate, and design type (supplementary Appendix B and C), as well as *warning policy characteristics* such as previous warning description, new warning description, dates of policy implementation, number of warnings on pack, and whether the new warnings met WHO warning criteria (supplementary Appendix D). Discrepancies between coders were resolved through discussion between the two coders and the first author. We calculated inter-coder reliability for each characteristic. Most categories had perfect agreement; the mean kappa across all coding categories was 0.95.

### 1.2.2. Summarizing study findings

We developed a list of outcome variables assessed in cigarette pack warning studies, with definitions for each, based on the literature and our previous work in this area (Noar et al., 2016b). All outcomes were self-reported with the exception of quitline data (supplementary Appendix E). We summarized the main results of studies on each of these outcomes, noting which findings were

statistically significant. For the 11 studies that did not report significance tests for some outcomes, we computed them when the necessary data were reported (Lipsey and Wilson, 2001). Also, most studies did not include control countries, and thus results are from intervention countries only (except where noted in results and supplementary Appendix E).

### 1.2.3. Pooled results

We extracted quantitative data directly before and after warning implementation in cases where we had five or more observations and where data were reported in a form that allowed for synthesis (pre-post changes in intervention countries only). For knowledge, we used the average of the proportions of all *health effects of smoking* that were assessed. For quit attempts, we used the proportion of participants who reported a quit attempt – typically defined as a 24-hour quit attempt in the past six or 12 months. For smoking prevalence, we used the proportion of participants who reported current smoking. In each case, we weighted the before, after, and difference proportions by their inverse variance using the logit method and computed random effects meta-analytic models (Lipsey and Wilson, 2001).

When reporting all results, we organized outcome variables

using the message impact framework (Fig. 2). The first group of outcomes (*knowledge/attitudes/beliefs*) consisted of knowledge, risk beliefs, and smoking attitudes. The second group of outcomes (*intentions*) were intentions to quit smoking, intentions to not start smoking, and quitline calls. The third group (*behavior*) consisted of foregoing cigarettes, cigarette consumption (typically quantity), quit attempts, short-term cessation behavior, and smoking prevalence. We characterize a change as an increase or decrease that was statistically significant ( $p < 0.05$ ) in the original study or in our own calculations.

## 2. Results

The 32 studies were published between 1997 and 2014, with a median publication year of 2011 (Table 1). Studies were conducted in 20 different countries; the most commonly studied countries were Australia (26%), Canada (12%), the United Kingdom/England (10%), and the United States (6%). While most studies (81%) had no control country, 12% had one and 6% had three control countries. The United States was always included as a control country; the next most common control country was Canada (two of six were as a control). While seven studies (22%) contained multiple countries, in virtually all of those studies only a single country met our criteria as an intervention country (i.e., reported pre and post data on a change in warnings); the exception was one study in which the impact of quitline calls was examined across several countries' warning changes (Bot et al., 2007).

Most studies (81%) used probability sampling. The most common data collection mode was phone (46%), and the most common data type was multiple cross-sectional (44%), while 31% used panels (same participants over time) and 12% used both. The cumulative sample size across all studies was 812,363. Studies most commonly examined young adults and adults (38%). While 31% of studies included adolescents with other age groups, only 12% of studies were solely of adolescents. Half (50%) of studies were of smokers, and the remainder (50%) included both smokers and non-smokers. Only 12% of studies reported including low-income participants.

The most common policy implementation was to change warnings from text to pictorial (64%). Some studies, however,

examined change from pictorial to strengthened pictorial warning (21%), such as when Australia increased the size of their pictorial warnings from 30% to 75% in 2012 (Zacher et al., 2014). Other studies (14%) examined the change from text to strengthened text, such as when the United Kingdom strengthened text from 6% to 30% on the front and 6% to 40% on the back of the pack in 2002 (Hassan et al., 2008). Only one study (in Australia) examined the implementation of plain packaging along with strengthened pictorial warnings (Zacher et al., 2014).

When countries changed their warning policies, many also increased the number of warnings. The mean number of warnings pre-policy change was 6.82 ( $SD = 2.83$ ), while post-policy it was 8.71 ( $SD = 4.13$ ). Policy changes typically allowed countries to meet the WHO warning criteria (World Health Organization, 2003). That is, after policy changes took place, all countries had warnings in the country's principal language, all had them on the front and back of packs, 94% covered at least 30% of the pack, and 84% had full-color pictorials. Also, while English was the most common language for warnings (44%), several warnings were in other languages (28%) or appeared in both English and another language (25%).

Studies ranged from as few as two data points (53%) to as many as 12 data points (3%). The mean number of data points across studies was 3.50 ( $SD = 2.31$ ). The mean interval between data points was 19.55 months ( $SD = 40.77$ ). After removing one study (Szklo et al., 2012) that had a much longer interval (i.e., 20 years), the mean was 12.11 months ( $SD = 7.57$ ).

### 2.1. Warning policy changes

#### 2.1.1. Knowledge

Twelve studies assessed one or more forms of knowledge, and all of these studies showed increases in knowledge after the change in cigarette pack warnings (supplementary Appendix E). Eleven studies reported specifically on *knowledge about the health effects of smoking*, and all found increases on some smoking health effects. For example, knowledge that smoking causes oral cancer, gangrene, blocked arteries, blindness, emphysema, and harm to unborn babies increased in Australia after the implementation of pictorial warnings in 2006. Similarly, studies from Thailand, Canada, Mexico,

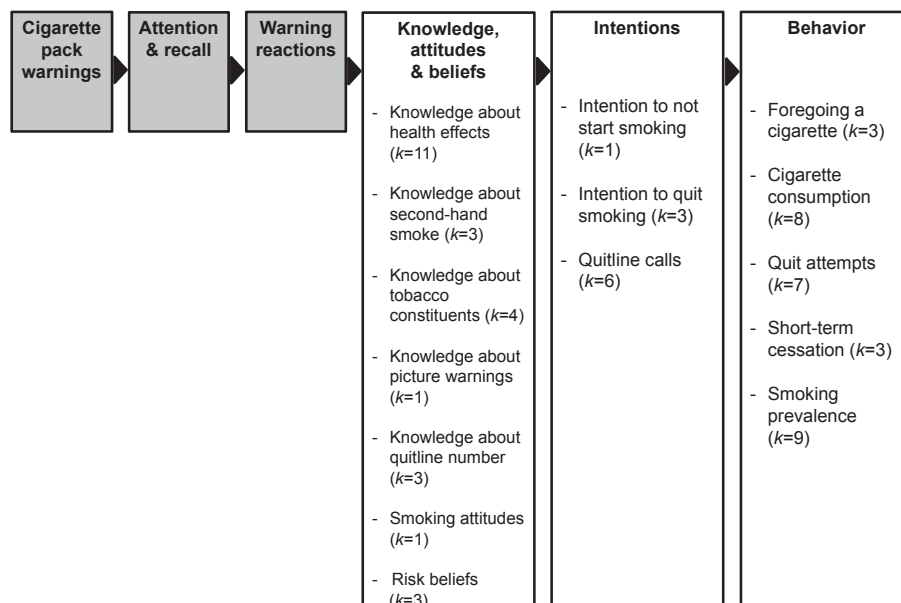


Fig. 2. Message impact framework showing outcomes assessed in the set of studies.

**Table 1**  
Characteristics of studies (k = 32).

Variable	k	%
<b>Participant characteristics</b>		
<i>Age groups</i>		
Young adults and adults	12	38
Adolescents, young adults, and adults	10	31
Adolescents only	4	12
NR	6	19
<i>Smoking status</i>		
Smokers only	16	50
Smokers and non-smokers	16	50
<b>Study characteristics</b>		
<i>Country<sup>a</sup></i>		
Australia	13	26
Canada	6	12
United Kingdom/England	5	10
United States	3	6
New Zealand	3	6
Uruguay	3	6
Taiwan	2	4
Thailand	2	4
Argentina	2	4
Other countries each studied once (Mexico, China, Malaysia, Brazil, Denmark, France, Iceland, Netherlands, Norway, Poland, Sweden)	11	22
<i>Number of control countries</i>		
None	26	81
One	4	12
Two	0	0
Three	2	6
<i>Sampling</i>		
Probability	26	81
Convenience	1	3
NR	5	16
<i>Data collection mode</i>		
Phone survey	15	46
Quitline calls	5	16
Paper survey	5	16
In-person interview	5	16
Observations by fieldworker	1	3
Medical records	1	3
<i>Study data</i>		
Multiple cross sectional (different people)	14	44
Panel (same people)	6	19
Panel with replenishment	4	12
Both (panel and multiple cross sectional)	4	12
NR	4	12
<i>Number of data points</i>		
2	17	53
3	3	9
4	5	16
5	2	6
6	3	9
9	1	3
12	1	3
<b>Warning characteristics</b>		
<i>Warning policy change<sup>b</sup></i>		
Text to pictorial	27	64
Pictorial to strengthened pictorial	9	21
Text to strengthened text	6	14
<i>WHO warning criteria</i>		
Appear in country's principal language	32	100
Appear on front and back of pack	32	100
No less than 30% of principal display	30	94
Full color pictorial	27	84
<i>Plain packaging with warnings change</i>		
No	31	97
Yes	1	3
<i>Warning language</i>		
English only	14	44
Non-English only	9	28
English and non-English	8	25
NR	1	3

Note. WHO = World Health Organization. NR = not reported.

<sup>a</sup> The country category sums to 50 because some studies included more than one country (this count includes both intervention and control countries). Control countries were United States (k = 3), Canada (k = 2), United Kingdom (k = 2), Argentina (k = 1), and Malaysia (k = 1).

<sup>b</sup> Warning policy sums to 42 because multiple policy changes occurred throughout the duration of some studies.



and England showed an increase in knowledge about health effects such as impotence in men, lung cancer, heart disease, and damage to organs after implementation of pictorial warnings in those countries. In some studies, some health effects knowledge decreased, although this was always in the context of knowledge increases, and appeared to take place because warnings had not been fully rotated in (Brennan et al., 2011) or the decreased knowledge was for content featured in older warnings (White et al., 2008). Ten of 11 relevant studies provided suitable data on pre-post changes in *knowledge about the health effects of smoking*. Knowledge increased from 49% before implementation to 54% after implementation of strengthened warnings (Fig. 3). This represented a statistically significant absolute increase of 4% (relative increase of 10%), which was statistically heterogeneous (Table 2). We also examined only knowledge about health harms featured in new warning content (i.e., new text statements; supplementary Appendix E). As expected, effects on knowledge were larger, with a 7% absolute increase (32% relative increase; Fig. 4).

Three studies reported on knowledge about the health effects of secondhand smoke. Both studies from England found an increase in this outcome after implementation of pictorial warnings in 2008. The Canadian study, on the other hand, found no impact on most types of knowledge after pictorial warnings were implemented in 2001.

Four studies reported on knowledge about tobacco constituents, and two studies showed increases. One study found increases in knowledge about the effects of tar, nicotine, and carbon monoxide after Australia strengthened text warnings in 1995, while another found an increase in knowledge that cigarettes or cigarette smoke contained cadmium, ammonia, and cyanide, after Mexico implemented pictorial warnings in 2010.

Only one study looked at knowledge about pictures used in the warnings. That study, from Australia, showed an increase in knowledge that the warnings had images of the effects of smoking.

Three studies—in Australia, Mexico, and New Zealand—also assessed knowledge about the quitline number, and all showed increases after implementation of pictorial warnings.

### 2.1.2. Beliefs and attitudes

Four studies looked at beliefs and attitudes (supplementary Appendix E). The one study of smoking attitudes in favor of cessation found increases among individuals in Thailand after implementation of pictorial warnings in 2005. Of the three studies assessing risk beliefs, two studies observed some evidence of increases. The belief that smoking had damaged your health increased among adults in England after implementation of pictorial warnings in 2008, and the belief that getting gangrene, emphysema, and clogged arteries would be one of the worst things that could happen (*perceived severity*) increased after Australia implemented pictorial warnings in 2006. However, studies provided no evidence that warnings impacted *perceived likelihood* of harm from smoking, finding either no effects on these beliefs or in one case, decreases in beliefs that smokers are more likely than non-smokers to have fertility problems, after England implemented pictorial warnings.

### 2.1.3. Intentions

The one study of intentions to smoke found that intentions decreased among Australian adolescents after implementation of pictorial warnings in 2006 (supplementary Appendix E). Of three studies assessing intentions to quit smoking, the Canadian study reported an increase after pictorial warnings were implemented in 2001, while studies in Thailand (compared to Malaysia) and Mexico reported a decrease after pictorial warnings were implemented in 2005 and 2010, respectively.

Quitline calls increased in four of six studies. For example, one study reported that, after Australia implemented pictorial warnings in 2006, quitline calls nearly doubled from 84,422 in 2005 to

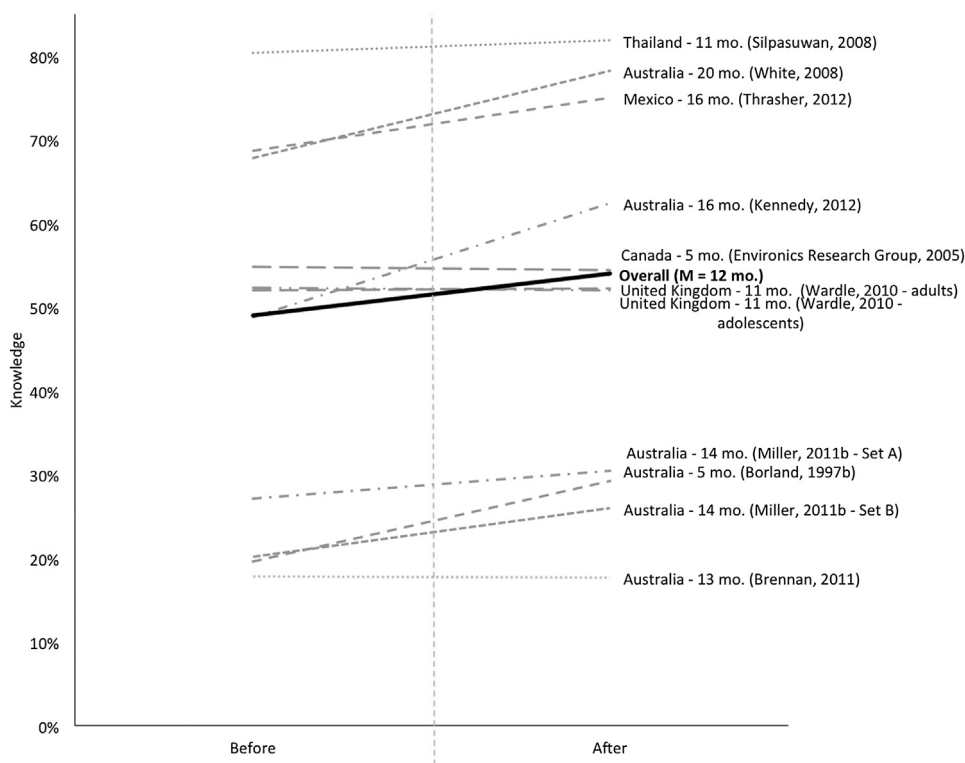


Fig. 3. Knowledge about the health effects of smoking before and after implementation of strengthened warnings.

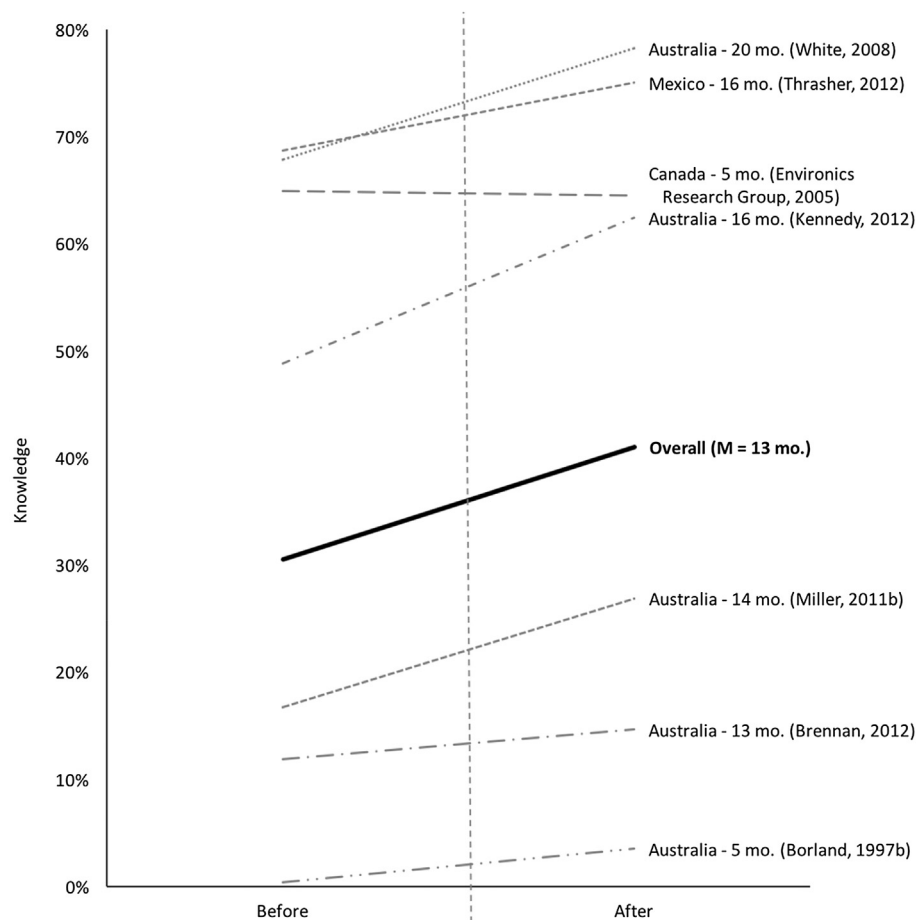
**Table 2**  
Effectiveness of strengthening cigarette pack warnings.

	<i>k</i>	<i>N</i>	%	95% CI	<i>p</i>	<i>Q</i>	<i>p</i>	<i>I</i> <sup>2</sup>
<i>Knowledge of health effects of smoking</i>	10							
Before		13,421	0.49	[0.38, 0.59]	0.789	1237	0.001	99
After		10,728	0.54	[0.40, 0.66]	0.602	1443	0.001	99
<b>Difference</b>		—	<b>0.04</b>	<b>[0.01, 0.08]</b>	<b>0.01</b>	<b>65</b>	<b>0.001</b>	<b>86</b>
<i>Knowledge of novel health effects of smoking<sup>a</sup></i>	7							
Before		10,585	0.31	[0.19, 0.45]	0.001	1045	0.001	99
After		7,840	0.41	[0.23, 0.62]	0.410	1445	0.001	100
<b>Difference</b>		—	<b>0.07</b>	<b>[0.03, 0.10]</b>	<b>0.001</b>	<b>61</b>	<b>0.001</b>	<b>90</b>
<i>Quit attempts</i>	7							
Before		12,518	0.44	[0.32, 0.56]	0.334	1014	0.001	99
After		12,168	0.48	[0.37, 0.60]	0.739	888	0.001	99
<b>Difference</b>		—	<b>0.04</b>	<b>[0.02, 0.07]</b>	<b>0.001</b>	<b>24</b>	<b>0.001</b>	<b>75</b>
<i>Smoking prevalence</i>	9							
Before		71,007	0.19	[0.15, 0.25]	0.001	1857	0.001	99
After		66,672	0.16	[0.13, 0.20]	0.001	967	0.001	99
<b>Difference</b>		—	<b>−0.04</b>	<b>[0.02, −0.09]</b>	<b>0.17</b>	<b>1083</b>	<b>0.001</b>	<b>99</b>
<i>Smoking prevalence<sup>b</sup></i>	8							
Before		31,038	0.18	[0.13, 0.24]	0.001	1121	0.001	99
After		28,211	0.16	[0.12, 0.22]	0.001	873	0.001	99
<b>Difference</b>		—	<b>−0.02</b>	<b>[−0.004, −0.04]</b>	<b>0.02</b>	<b>68</b>	<b>0.001</b>	<b>90</b>

Note. *k* = number of effect sizes; *N* = number of participants; % = weighted proportion (pooled effect size). When the differences analyses were computed only with studies that examined text-to-pictorial changes, results did not substantively change and were as follows: knowledge of health effects (0.04 [0.01, 0.08], *p* = 0.02, *k* = 9); knowledge – novel health effects<sup>a</sup> (0.07 [0.03, 0.11], *p* < 0.001, *k* = 6); quit attempts (0.05 [0.02, 0.08], *p* < 0.001, *k* = 5); smoking prevalence (−0.04 [0.02, −0.10], *p* = 0.18, *k* = 8); smoking prevalence<sup>b</sup> (−0.03 [−0.001, −0.05], *p* = 0.04, *k* = 7).

<sup>a</sup> This analysis examines knowledge for new warning content only; see text for details.

<sup>b</sup> This analysis examines smoking prevalence without the Szklo et al. study.



**Fig. 4.** Knowledge about novel health effects of smoking before and after implementation of strengthened warnings.

164,850 in 2006. Another study found an 82% increase in weekly calls after Australia implemented pictorial warnings in 2006 and an 80% increase after implementation of strengthened pictorial warnings in 2012. Quitline calls modestly increased in most European countries after implementation of strengthened text warnings, including in Finland, France, Iceland, Netherlands, Sweden, and Poland, although tests of statistical significance were not available for those outcomes.

### 2.1.4. Behavior

Nineteen studies assessed smoking behavior (supplementary Appendix E). Three studies, all from England or the United Kingdom, looked at foregoing cigarettes. They found foregoing either decreased or did not change after implementation of strengthened text warnings in 2002 and newly implemented pictorial warnings in 2008.

Among the eight studies assessing cigarette consumption, three found a decrease. For example, cigarette consumption decreased from 22.0 to 20.5 cigarettes per day after Australia strengthened text warnings in 1995, while it decreased from 28.9 cigarettes per week in 2005 to 22.1 in 2006 after Australia implemented pictorial warnings. An additional two studies found what appear to be meaningful decreases, but did not provide significance tests. One study found that cigarette consumption decreased from 24.2 cigarettes per week in 2000 to 22.1 in 2001 after Canada implemented pictorial warnings, while the other found that the percentage of those who smoked 10 or more cigarettes per day dropped from 24% in 2010 to 22% after implementation of pictorial warnings in Mexico in 2011. Additional studies – such as those conducted in England and Taiwan – found no evidence of a reduction in cigarette consumption.

Of the seven studies assessing quit attempts, four studies showed increases after implementation of strengthened warnings. Quit attempts increased from 39% in 2007 to 43% in 2010 after implementation of pictorial warnings in Taiwan; from 25% in 2007 to 31% in 2009 after implementation of strengthened text warnings in China; from 35% in 2000 to 40% in 2002 after implementation of pictorial warnings in Canada; and from 56% in 2005 to 60% in 2006 after implementation of pictorial warnings in Australia. However, a study in Canada in 2001 found no change in quit attempts (77%–79%), while studies in Australia in 1995 and 2006 observed no change in quit attempts after strengthened warnings were implemented. Across the seven studies, quit attempts increased from 44% before implementation to 48% after implementation of strengthened warnings (Fig. 5). This represented a statistically significant absolute increase of 4% (9% relative increase), which was statistically heterogeneous (Table 2).

Of the three studies of short-term cessation, two found increases after implementation of pictorial (Taiwan) or strengthened pictorial (Uruguay) warnings. One study found increases in short-term cessation among pregnant women, from 15% in 2007 to 42% in 2012 after Uruguay strengthened pictorial warnings. A study in Taiwan found short-term cessation increased from 7% to 9% after implementation of pictorial warnings in 2009. A third study found no change in short-term cessation after implementation of pictorial warnings in Australia in 2006.

Nine studies assessed smoking prevalence. Six of these studies found decreases in smoking prevalence. For example, decreases from 25% in 2000 to 23% were observed in 2001 after Canada implemented pictorial warnings; decreases from 25% in 2005 to 18% in 2009 among adolescents and from 35% in 2005 to 29% in 2009 among adults after Uruguay implemented pictorial warnings; and decreases in smoking prevalence from 8.3% in 2012 to 6.6% in 2013 after Australia strengthened their pictorial warnings and implemented plain packaging. However, one study found no

change in smoking prevalence among adults in Canada after implementation of pictorial warnings in 2001. A study of adolescents in England found no change in prevalence, and a study of adolescents in Taiwan found no change in prevalence after implementation of pictorial warnings. Across the nine studies, smoking prevalence decreased from 19% before implementation to 16% after implementation of strengthened warnings. The Szklo et al. (2012) study had a longer timeframe than the other studies; with that study removed, there was a statistically significant absolute prevalence reduction of 2% (relative reduction of 13%), which was statistically heterogeneous (Table 2; Fig. 6).

## 3. Discussion

After synthesizing the findings from 32 studies from 20 countries with more than 800,000 participants, we found that strengthening cigarette pack warnings was associated with 1) increased knowledge about smoking risks; 2) increased quitline knowledge; 3) increased calls to quitlines; 4) reductions in cigarette consumption; 5) increased quit attempts; 6) increased short-term smoking cessation, and 7) reduced smoking prevalence.

Our results demonstrate that strengthening cigarette pack warnings may contribute to increased population-wide knowledge about the health risks of smoking, the risks of secondhand smoke, and the risks of tobacco constituents. Virtually all of these findings were in countries that newly implemented pictorial warnings; thus, implementation of pictorial warnings may be an important strategy for helping increase knowledge about the health risks of smoking. Changing warning statements to include novel content may particularly increase knowledge of the content covered in the messages, a finding consistent with a recent three-country warnings study (Swayampakala et al., 2015).

Increasing knowledge about the health risks of smoking is a stated goal of international tobacco control efforts (Hammond and Reid, 2012). The WHO Framework Convention on Tobacco Control requires that tobacco products “carry health warnings describing the harmful effects of tobacco use” (World Health Organization, 2003) as a way to increase knowledge about smoking health risks (World Health Organization, 2003). FCTC Principle 3 states, “Globally, many people are not fully aware of, misunderstand or underestimate the risks for morbidity and premature mortality due to tobacco use and exposure to tobacco smoke. Well-designed health warnings and messages on tobacco product packages ... increase public awareness of the health effects of tobacco ...” (World Health Organization, 2003). The findings of this review are consistent with these assertions. In the United States, one goal of the Family Smoking Prevention and Tobacco Control Act is to “promote greater public understanding of the risks associated with the use of tobacco products,” (United States Public Laws, 2009) and the courts appear to agree that increasing population-wide knowledge is a substantial government interest (Kraemer and Baig, 2013). Our findings on knowledge increases support strengthened cigarette warnings – and particularly pictorial warnings – as a tool to help achieve these goals (Swayampakala et al., 2015).

Findings on the association of strengthened warnings with changes in beliefs and attitudes were mixed. We found improved smoking attitudes in favor of cessation after implementation of pictorial warnings in Thailand (Silpasuwan et al., 2008). However, consistent with our earlier meta-analysis of experimental studies (Noar et al., 2016b), we did not find support for strengthened warnings increasing perceived likelihood of harm – i.e., the belief that smoking cigarettes is likely to lead to health-related harms. While warnings appear to improve knowledge of what smokers’ know *could* happen to them, they do not appear to increase the perception that these negative consequences *will* happen to them.



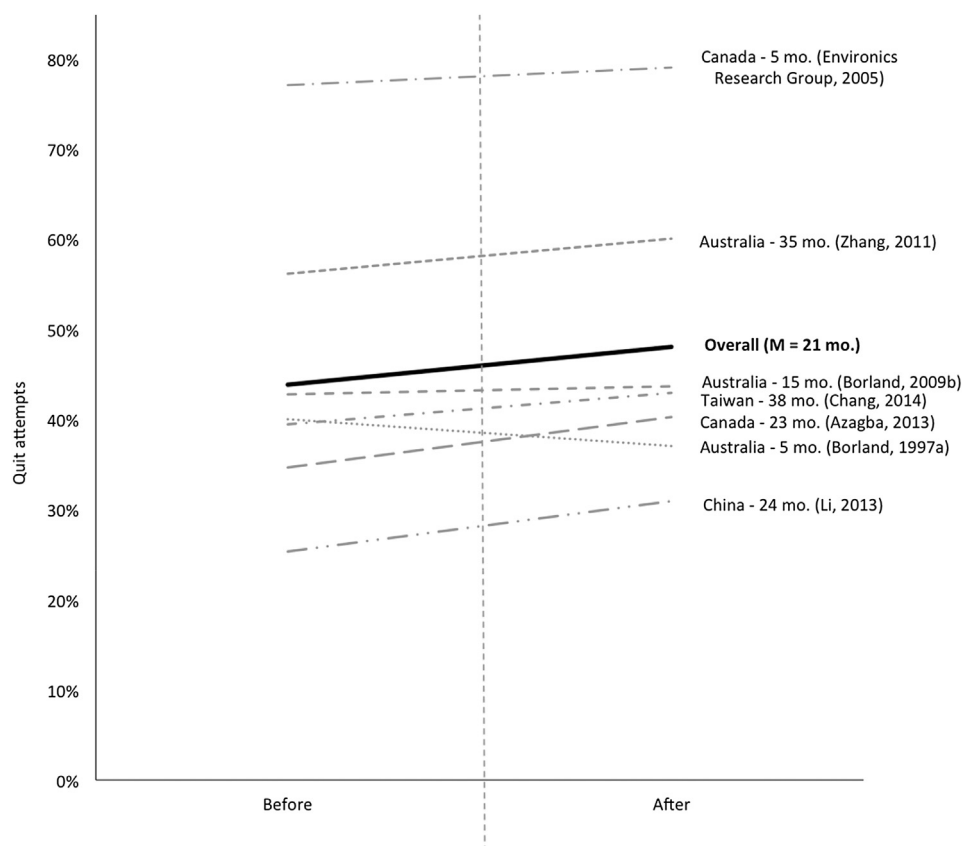


Fig. 5. Quit attempts before and after implementation of strengthened warnings.

However, one study in our review provided support for warnings improving perceived *severity* of harm – i.e., the belief that health-related harms from cigarettes are serious. That is, after Australia implemented pictorial warnings, beliefs that getting gangrene, emphysema, and clogged arteries would be one of the worst things that could happen increased (Miller et al., 2011). These findings are similar to an experimental study of pictorial warnings conducted in Germany, which also demonstrated impact on perceived *severity* but not perceived *likelihood* (Schneider et al., 2012). The proposition that warnings may impact perceived *severity* but not perceived *likelihood* is consistent with the nature of many pictorial warnings, which provide gruesome images of serious harm but do not give objective or implied information on frequency of harm. Given the few studies that have carefully examined the impact of cigarette warnings on risk beliefs, however, additional research on these and other theoretical mechanisms is needed (Noar et al., 2016b).

A compelling feature of warnings is that they can provide support to those who wish to quit by promoting quitline numbers on packs. We found strengthened warnings were associated with higher knowledge about tobacco quitlines and more calls to quitlines. This is likely because strengthened warnings themselves garner more attention (Noar et al., 2016a,b), and also because quitline information tends to be strengthened along with new warnings. Knowledge about the quitlines increased in three countries – Australia (Miller et al., 2011), Mexico (Thrasher et al., 2012), and New Zealand (Wilson et al., 2010) – after implementation of pictorial warnings. While enhancing text warnings was associated with increased quitline calls (Bot et al., 2007), one of the largest increases in quitline calls took place when Australia implemented pictorial warnings (with a more prominently featured quitline number) in 2006 and saw call volume nearly double, from 84,442

calls in 2005 to 164,850 calls in 2006 (Miller et al., 2009). This suggests that the combination of a prominently featured quitline number along with pictures may be a particularly effective method for motivating people to call tobacco quitlines. In the United States, a quitline number was included on cigarette packs as part of FDA's proposed pictorial warnings. However, given the legal issues emanating from the tobacco industry's challenge to those warnings (Kraemer and Baig, 2013), it is unclear if FDA will pursue inclusion of the quitline number in its next round of proposed warnings. Our findings suggest that *not* including a quitline number on packs may be a missed opportunity to link those interested in quitting smoking with resources to help them quit.

Perhaps our most important findings concerned smoking behaviors. While we found little evidence that foregoing of cigarettes increased, we found fairly consistent evidence that cigarette consumption decreased, quit attempts increased, short-term cessation increased, and smoking prevalence decreased after several countries implemented strengthened cigarette pack warnings. However, several factors need to be considered when interpreting these results; indeed, estimating the unique impact of warnings on smoking behaviors is a difficult matter.

Three key requirements in demonstrating causation are association, temporality, and ruling out third variable explanations. We have produced fairly strong evidence that strengthening cigarette warnings is *associated* with reductions in smoking behaviors (i.e., consumption, prevalence) and increases in cessation-related behaviors (quitline calls, quit attempts, short-term cessation). We have also demonstrated *temporality* – i.e., smoking behaviors were initially higher before implementation and became lower after implementation of strengthened warnings. The challenge is that some countries implemented other tobacco control policies

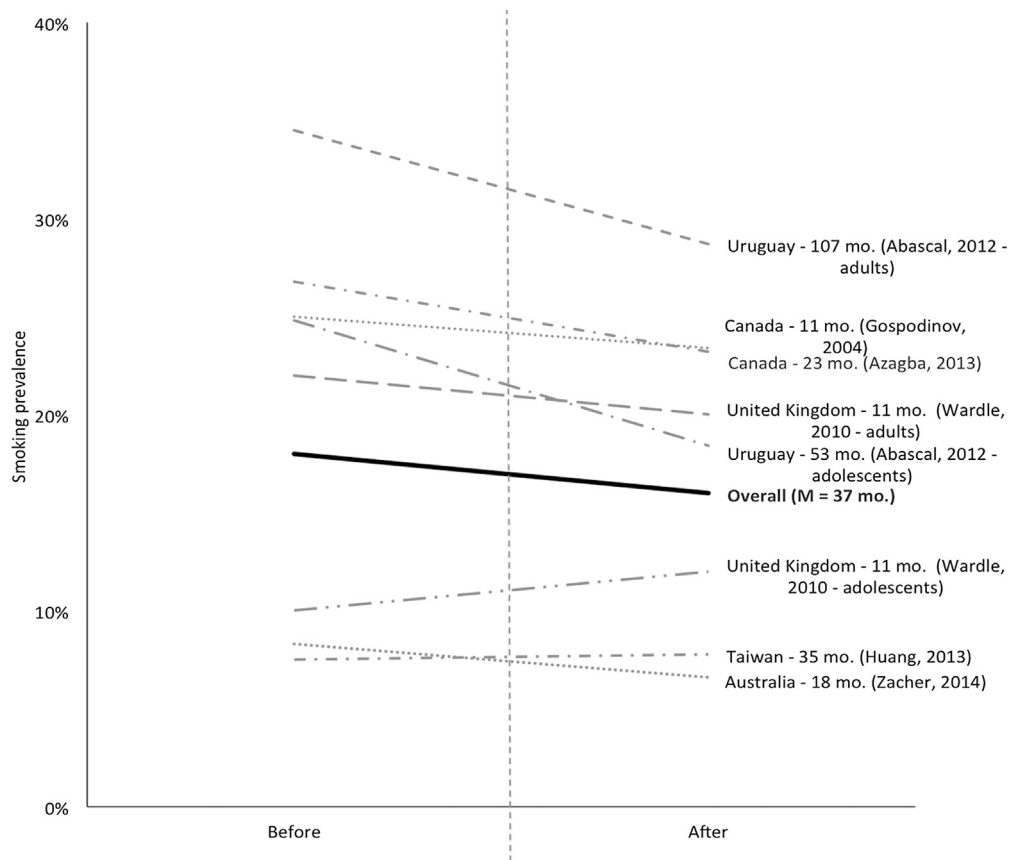


Fig. 6. Smoking prevalence before and after implementation of strengthened warnings.

alongside strengthened warnings (i.e., confounding variables). While the impact of differing tobacco control policies varies, evidence suggests that some policies – smoke free air laws and increased price in particular – have a sizable impact on smoking behavior (Bonnie et al., 2007; Hopkins et al., 2010; US Department of Health and Human Services, 2014).

The small number of studies assessing smoking behavior, combined with the diversity of other tobacco policies implemented, precluded a systematic analysis of the impact of strengthening warnings in the absence of changes to these other policies. However, a narrative examination of our findings reveals that while many changes in smoking behavior occurred in the context of other tobacco control policies, in other cases changes in behavior occurred in the absence of other major policy changes (Table 3). For example, Uruguay demonstrated some of the strongest findings in the wake of its 2005 implementation of pictorial warnings, with a nearly 8% reduction in daily cigarette consumption and greater than 5% smoking prevalence reductions among both adolescents and adults (Abascal et al., 2012). However, Uruguay implemented the new warnings at the same time as several other tobacco control policies (Abascal et al., 2012; Harris et al., 2014) including tax increases. In contrast to this, Australia's implementation of pictorial warnings was accompanied by only a mass media campaign to promote the new warnings and some advertising restrictions (Brennan et al., 2011). Despite this dearth of other policy changes, Australia saw a 6.8 cigarette per week reduction (White et al., 2008), a near doubling of quitline calls (Miller et al., 2009) and between a 1% (Borland et al., 2009) and 4% (Zhang et al., 2011) increase in quit attempts. No increases in short-term cessation were observed, however (Borland et al., 2009).

Another commonly studied country in our review was Canada, where the first full-color pictorial warnings were implemented in 2001. In the wake of this warnings change, Canada saw a two cigarette per week reduction in cigarette consumption (Gospodinov and Irvine, 2004), a nearly 6% increase in quit attempts (Azagba and Sharaf, 2013), and 2–4% reductions in smoking prevalence (Azagba and Sharaf, 2013; Gospodinov and Irvine, 2004). Again, this change in warnings happened alongside several other tobacco control policies, including tax increases and smoke-free air laws (Bonnie et al., 2007; Hopkins et al., 2010; US Department of Health and Human Services, 2014). In contrast, Australia strengthened their pictorial warnings and implemented plain packaging in 2012 and saw a reduction in prevalence of 1.7% (Zacher et al., 2014); no other policy changes were implemented except an internet advertising ban, suggesting that the pack warnings may have played a direct role in the decrease. Other recent data from Australia also find that the 2012 warnings' implementation was associated with increased quit attempts (Durkin et al., 2015).

These findings appear to show a pattern of larger changes in smoking behavior when warnings are implemented alongside other major tobacco control policies, and smaller (but still meaningful) changes in smoking behaviors when strengthened warnings are implemented by themselves. A strength of our review is one of multiple observations and replication – i.e., we were able to look across policy changes in multiple countries and studies, and we saw consistency in both the pattern and direction of findings. Another strength of the existing evidence is the demonstration of the pathways through which strengthened warnings may have impact – from large increases in attention and message reactions (Noar

**Table 3**  
Summary of changes in smoking behavior.

Country	Warnings change	Changes in smoking behavior		
		Consumption	Quit attempts	Prevalence
Taiwan	Pictorial, 2009	No change <sup>8</sup>	3.5% increase <sup>5</sup>	No change <sup>8</sup>
Canada	Pictorial, 2001	2.1 cig per day reduction <sup>7</sup> ; no change <sup>6</sup>	2% increase <sup>6</sup> ; 5.6% increase <sup>2</sup>	1.6% decrease <sup>7</sup> ; 3.6% decrease <sup>2</sup>
Uruguay	Pictorial, 2005	7.8% daily reduction <sup>1</sup>	—	5.8% decrease <sup>1</sup> ; 6.4% decrease <sup>1</sup>
China	Text, 2008	—	5.6% increase <sup>9</sup>	—
Australia	Text, 1995	1.5 cig per day reduction <sup>3</sup>	3% decrease <sup>3</sup>	—
	Pictorial, 2006	6.8 cig per week reduction <sup>12</sup>	1.2% increase <sup>4</sup> ; 3.9% increase <sup>14</sup>	—
	Pictorial, 2012	—	—	1.7% decrease <sup>13</sup>
England	Pictorial, 2008	No change <sup>11</sup>	—	2% decrease <sup>11</sup> ; 2% increase <sup>11</sup>
Mexico	Pictorial, 2010	2% reduction <sup>10</sup>	—	—

Note. Warnings change column denotes strengthened warnings change.

Sources: <sup>1</sup>Abascal et al. (2012), <sup>2</sup>Azagba and Sharaf (2013), <sup>3</sup>Borland (1997a), <sup>4</sup>Borland (2009b), <sup>5</sup>Chang (2014), <sup>6</sup>Enviro-nics Research Group (2005), <sup>7</sup>Gospodinov and Irvine (2004), <sup>8</sup>Huang (2013), <sup>9</sup>Li (2013), <sup>10</sup>Thrasher et al. (2012), <sup>11</sup>Wardle (2010), <sup>12</sup>White et al. (2008), <sup>13</sup>Zacher et al. (2014), and <sup>14</sup>Zhang et al. (2011).

et al., 2016a,b), to enhanced knowledge and beliefs (current study and our previous meta-analysis (Noar et al., 2016b), and finally to downstream impact on behavior. Changes in smoking behavior may be larger when countries implemented comprehensive tobacco control policies, which is consistent with prior tobacco control policy research (Bonnie et al., 2007; Hopkins et al., 2010; US Department of Health and Human Services, 2014). However, additional work on the unique impact of warnings, as well as their synergy with other tobacco control policies, is needed.

### 3.1. Limitations

A key limitation of our review was that studies were observational in nature; thus, it is possible that other unknown factors contributed to changes in variables assessed in these studies, and most studies had no comparison groups. However, these studies were conducted in the real world, an important strength as previous systematic review work has demonstrated the efficacy of pictorial warnings in experiments (Noar et al., 2016b). Our review extends previous work by demonstrating the longer-term impact of warnings after real-world implementation in numerous countries. Another limitation has to do with variations in researchers' selection, conceptualization, and measurement of outcome variables, which may contribute to additional between-study variability in findings. Studies varied greatly with regard to the number of outcomes assessed, and thus there were varying levels of data available for different outcome variables of interest. In particular, the research evidence was limited by the modest number of studies that examined smoking and cessation-related behavioral outcomes, and no single study assessed all of the outcomes examined in this review, which may reduce the generalizability of our findings.

### 3.2. Conclusion

In summary, the evidence suggests that strengthened cigarette pack warnings — especially pictorial warnings — are associated with increases in knowledge about smoking harms, knowledge of quitlines, and quitline calls, as well as increases in cessation-related behavior and reductions in smoking behavior. Changes in smoking-related behaviors may be particularly evident when warnings are strengthened in the context of comprehensive tobacco control policy changes (Bonnie et al., 2007; Hopkins et al., 2010; US Department of Health and Human Services, 2014), although they appear to have an impact in and of themselves. This conclusion about the impact of warnings is consistent with 1) meta-analytic work demonstrating the short-term impact of pictorial warnings on a series of quit motivation outcomes (Noar et al., 2016b); 2) our

companion systematic review showing the consistent impact of strengthened warnings on attention, thinking about quitting, and perceptions that warnings motivate quitting (Noar et al., 2016a); 3) other observational studies demonstrating pictorial warnings' association with quit attempts, often through mediational mechanisms such as thinking about (Fathelrahman et al., 2013; Thrasher et al., 2015; Yong et al., 2014), worrying about (Yong et al., 2014), feeling motivated by (Brennan et al., 2015), and talking about (Thrasher et al., 2015) cigarette warnings; and analyses that parse out the effect of other tobacco control policies and suggest a unique impact of warnings on smoking prevalence (Huang et al., 2014). Our findings suggest that strengthening cigarette pack warning policies should be a priority for tobacco control globally, including in the United States where federal law requires implementation of pictorial warnings on cigarette packs.

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### Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.socscimed.2016.06.011>.

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