Ticking All the Boxes? A Systematic Review of Education and Communication Interventions to Prevent Tick-Borne Disease

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Abstract

Tick-borne disease has become increasingly prevalent across Europe. Despite the effectiveness of protective behaviors, relatively few people adopt them when in areas where ticks are known to be present. In this systematic review we identified studies that assessed the impact of any educational or behavioral interventions intended to encourage the widespread use of protective behaviors against tick-borne disease. An extensive search of electronic databases returned a total of only nine such studies. Only two of these were fully randomized controlled trials, with the remaining studies using weaker designs and often relying solely on self-reports to assess behavior. The majority of research in this area has not explicitly noted the consideration of any formal psychological theory on how best to promote behaviors that protect health. Nonetheless, the results show that both knowledge of and attitudes towards tick-borne disease are amenable to change, although the stability of these changes over time has not yet been determined. Not all intervention strategies have proved effective, with some producing detrimental effects. More theory-based, methodologically-robust studies are urgently required if we are to gain a better understanding of the most effective strategies for encouraging members of the public to adopt behaviors known to protect against tick-borne disease.

Key Words: Communication interventions—Behavior change—Educational interventions—health belief model—tick-borne disease.

Introduction

FOLLOWING ITS DISCOVERY IN THE LATE 1970S, LYME DISEASE has become the most common tick-borne disease in both North America and Europe (de Vries and van Dillen 2002), although tick-borne encephalitis (TBE) and Crimean Congo hemorrhagic fever (CCHF) are both also prevalent in parts of Europe. Studies have shown that improved knowledge of the basic protective behaviors that can be taken to reduce tick bites may decrease the risk of tick-borne disease (Ergonul 2006; Mead 2011). Certainly in the case of Lyme disease, our understanding of the tick vector life cycle and the effectiveness of prevention strategies should make it a preventable illness, yet the incidence of the disease continues to increase (Corapi et al. 2007).

Low uptake of protective behaviors among the general public lies at the heart of this problem. Observational studies conducted in areas with endemic tick-borne disease repeat-

edly find that a large proportion of people fail to take even the most basic of precautions, such as wearing long trousers, using repellent, or avoiding locations of highest risk (Herrington et al. 1997; Phillips et al. 2001), a finding echoed in national surveys (Herrington 2004). Self-reported checking for ticks after potential exposure is also low, despite the fact that removal of a tick within 24 h may effectively prevent transmission of the bacteria and infection (Mawby and Lovett 1998). In light of the low level of protective behaviors seen among the general public, various initiatives have been attempted to improve their uptake. For example, the European Centre for Disease Control (ECDC) has produced a communication toolkit on tick-borne diseases, including templates that can be adapted to fit the needs of particular countries (http://www.ecdc.europa.eu/en/healthtopics/tick_borne_diseases/public_health_measures/Pages/communication_toolkit.aspx), the Centers for Disease Control and Prevention (CDC) in the U.S. has developed a series of resources that

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include educational materials for both the public and medical professionals (http://www.cdc.gov/ncidod/dvbid/lyme/ld_resources.htm), while in the U.K. various materials have also been produced by official agencies (for example, http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1271256716650). Not all materials that are put into the public domain have been evaluated, however. This is concerning, as previous attempts to provide the public with information materials about health threats have not always been successful. Indeed, on occasion such attempts may even have detrimental effects (McKenna and Williams 1993; Glik et al. 2008; Gould et al. 2008).

One way to increase the chances of success of public education campaigns is to ensure that they are well grounded in empirically tested psychological theories of behavior change. A number of such theories exist that propose different factors that may drive behavior change. Although numerous theories exist, many of the components of which they are composed are similar. The theory of planned behavior (Ajzen 1991), for example, suggests that a given behavior is likely to occur if a person is confident that they can effectively perform the behavior, has a favorable attitude towards the desired behavior, and believes that others would view them positively if they engaged in that behavior (Conner and Sparks 2005).

A similar, and perhaps more widely used approach, is the "health belief model." Perceptions of the individual are again central to this model, which posits that an individual's beliefs about their own susceptibility to a health threat, their perceptions about the severity of that threat, and their perceptions about the benefits and barriers associated with a particular protective action, will determine whether they adopt that action. Extensions to the model suggest that an individual's "self-efficacy" (their belief in their own ability to perform a given behavior) also plays a strong role in determining whether a behavior is adopted, as does the existence of cues to action that prompt or remind someone to engage in the behavior (Abraham and Sheeran 2005).

Social cognitive theory identifies behavior as an interaction between personal, behavioral, and environmental factors, but explains that the components of self-efficacy, outcome expectancies, and impediments and facilitators, all work together to influence behavior (Luszczynska and Schwarzer 2005).

Protection motivation theory has been used both as a framework for the development and evaluation of persuasive communication, as well as a model for predicting health behavior (Norman et al. 2005). A threat appraisal is formed by an individual based on their perceived likelihood of a particular event occurring and their perceived severity of the event (Norman et al. 2005). The way in which an individual chooses to respond to a threatening situation is termed their coping appraisal, and is based on both the belief that uptake of a recommended behavior will resolve the threat (response efficacy), and an individual's belief in their own ability to effectively perform the behavior (self-efficacy; Cameron 2009).

These four theories do not provide an exhaustive list of all theories of behavior change. However, while several psychological theories exist that could be used to inform campaigns designed to improve uptake of behaviors that protect against tick-borne disease, the extent to which these theories have been used in practice is unclear. It is equally possible that other factors unique to tick-borne disease may play a role in determining whether people adopt appropriate protective

behaviors. We conducted a systematic review of all previous studies that have assessed the impact of educational or behavioral interventions on uptake of behaviors intended to protect against tick-borne disease. Our aim was to assess the state of the art in this field, and to identify those interventions which have been shown to improve the use of protective behaviors.

Materials and Methods

Search strategy for the identification of studies

We searched the following electronic databases from inception to December 2010 for potentially relevant studies: ISI Web of Knowledge, Medline, PsycINFO, Embase, and Scopus. These were searched for articles containing MeSH terms or keywords relating to tick-borne diseases such as "tick" or "Lyme," and also containing MeSH terms or keywords relating to behavioral interventions; for example, "risk communication," "campaign," "poster," or "leaflet." The full search is available on request from the authors. In addition, we examined the reference sections of any pertinent studies and reviews for other references. As a check for completeness, we also discussed our review with 13 experts in tick-borne diseases and asked them to suggest any other published or unpublished material that we might have missed. These experts were from a range of specialties, including entomology, public health epidemiology, ecology, land management, deer management, parasitology, and public health sciences.

Inclusion criteria

Eligible studies needed to contain data concerning the impact of any communications-based public health intervention that was aimed at preventing tick-borne disease. We excluded research that assessed knowledge, attitudes, and behaviors about tick-borne disease, but which did not test the efficacy of an intervention strategy. We included both efficacy and effectiveness studies. Any study design was acceptable for inclusion.

Results

Search results

In total, approximately 1800 titles or abstracts were examined, from which 386 articles were selected as potentially relevant to the review. Of these, 208 were excluded because they were editorials or duplicate publications. A further 169 were reviews or educational materials targeted toward health professionals. Details relating to nine individual studies were included. Of these, five had a "before and after" design, four of which assessed the effectiveness of an educational intervention, and one of which assessed the mode of communication. The other four studies were controlled trials of educational interventions.

Before and after studies

Table 1 provides a summary of the before and after studies that we identified.

A study of Connecticut residents tested the effectiveness of an intensive community-based intervention designed to increase awareness of Lyme disease, and through this effort, to

TABLE 1. BEHAVIORAL INTERVENTION STUDIES FOR TICK-BORNE DISEASE: BEFORE AND AFTER STUDIES

Reference	Design, sample and country	Intervention	Procedure	Outcomes examined and effect of intervention (significant effects in bold, no significant effect unless stated otherwise, effect sizes given for significant effects where known)
Fox, 2008	Before and after; 56 children aged 8–10 years old; U.S.	Two to four sessions (180 min in total) about ticks and LD, using videos and interactive workbooks	Questionnaires given pre (t1) and post (t2) intervention	Twelve items of knowledge or protective behavior, or which two are noted as significantly different at t2: I know how to wear clothing that will make it easier to find ticks and I need help to find ticks on my body .
Gould et al. 2008	Before and after; new, random samples of approximately 400 people selected at each time point from three geographical regions (r1 (WWHD), r2 (LLHD), and r3 (TAHD) , U.S.	"Intensive education campaigns [using] a multitude of diverse educational methods, including billboards, flyers, newspaper articles, presentations etc." Interventions stressed use of protective behaviors	Telephone interviews administered just before the campaign (t1) 2 to 3 years later, (t2) and for r1, 5 years later (t3)	Knowing "a lot" or "some" about LD (improved in r1 at t3, $p=0.05$; reduced in r2 at t2, $p=0.004$; improved in r3 at t2, $p=0.004$). Perceived severity of, and likelihood of getting LD (reduced likelihood in r2 at t2 $p=0.003$; increased likelihood in r3 at t2, $p=0.0002$). Reporting avoiding wooded areas (decreased in r2, $p=0.02$; decreased in r3 $p=0.003$), tucking pants into socks (decreased in r2, $p<0.001$), performing tick checks (increased in r3, $p=0.02$), or using repellent (increased in r3, $p<0.001$). Using environmental control of ticks by: spraying pesticide (improved in r1 at t2, $p<0.001$), removing brush or leaf litter (improved in r1 at t2, $p<0.001$), using wood chip or gravel borders (improved in r1 at t2, $p<0.001$), keeping deer out of property (improved in r1 at t2, $p<0.001$). Being willing to spend at least \$100 on tick control (increased in r3 at t2, $p=0.002$). Approving of community efforts to reduce deer population, provide information, use pesticides on deer, or use pesticides.
Gray et al. 1998	Before and after. 31 Irish agriculture students, 11 Irish biology students, 75 British biology students. U.K. and Ireland.	LD information leaflet or lecture containing the same information as in the leaflet.	Questionnaire given "before and a week after issue of the leaflet."	Four questions on LD: have you ever heard of a tick , have you heard of LD , do ticks transmit LD , does LD occur in this country? (knowledge improved for all four items in each sample, no statistical test reported).
Jenks and Trapasso 2005	Before and after. 40 recent immigrants to the U.S. attending a primary health clinic.	One-to-one education by a physician covering basic facts about LD. Take-home education sheet on LD recognition and prevention.	Brief questionnaire pre-intervention and 2.3 months later.	Identification of LD rash , knowing that ticks transmit LD , knowing that engorged ticks are more dangerous and knowing how to remove a tick (knowledge improved for all four items, $p<0.001$).
Maher et al. 2004	Before and after. 295 children aged 8–12 years. U.S.	"Fun and interactive" program teaching children "how to protect themselves against ticks and to do effective checks."	A questionnaire was administered before and after the intervention.	Knowledge of how a tick gets on you ($p<0.0001$), how long a tick has to be attached to transmit LD ($p<0.0001$) and how to find a tick on self ($p<0.0003$), all improved post-intervention. Frequency of tick checking ($p=0.02$) and children's confidence in ability to find a tick ($p=0.04$) improved. No effect on feeling it is easier to remember to do tick checks.

LD, Lyme disease; WWHD, Westport Weston Health District; LLHD, Ledge Light Health District; TAHD, Torrington Area Health District.

increase the uptake of preventive behaviors (Gould et al. 2008). Three locations with endemic Lyme disease were involved, each of which developed their own educational campaign. At pre-test each community had similar baseline levels of knowledge, attitudes, and behavior regarding ticks and Lyme disease. Two years after the campaigns began the survey was administered again. The effects of the campaigns showed important differences between the three regions. In two regions, people were more likely to report increased knowledge, feeling more at risk, and being more likely to engage in activities such as performing tick checks, using repellent, or spraying pesticide in outside areas. In one region the campaign appeared counter-productive, reducing knowledge and decreasing perceptions about the likelihood of catching the disease. No description was included regarding the actual interventions developed and implemented at each of the three locations. This makes it difficult to assess why the differences occurred, but the authors speculated that it could have reflected decreased personal preference regarding the recommended protective behaviors, or that it could be a result of the relative emphasis placed on these behaviors by each area's education program.

A study in New York State explored the effectiveness of an educational intervention among an immigrant population (Jenks and Trapasso 2005). This population was at particular risk of contracting a tick-borne disease because of the outdoor nature of their work, and because Lyme disease is not endemic in their countries of origin, meaning that awareness of the disease was low. Eighty participants, recruited from a community health center, were asked four questions about ticks and Lyme disease. A clinician then discussed their answers with them, provided basic information about Lyme disease, and gave them a take-home information sheet. One to three months later, participants who returned to the clinic for routine appointments ($n=40$) completed the same test. Prior to the intervention none of the participants were aware of Lyme disease or were able to identify its distinctive erythema migrans rash. Following the intervention, all were able to do so. Unfortunately, the lack of any control group for this study makes it difficult to assess the effectiveness of the intervention. In addition, it is likely that a non-response bias may have artificially inflated the apparent efficacy of the intervention, with participants who were less interested in their health being less likely to attend the clinic on both occasions and to complete the study.

During the 1990s, the European Concerted Action on Lyme Borreliosis (EUCALB) was formed with members from across Europe. EUCALB developed a new leaflet about tick-borne disease and a questionnaire to assess levels of Lyme awareness (Gray et al. 1998). Three groups of British and Irish agriculture and biology students completed the questionnaire, and were then provided with the leaflet (two groups), or a lecture based on the leaflet's contents (one group). The questionnaire was completed again 1 week later. The results indicated a marked improvement in awareness following the intervention. However, no attempt was made to assess the use of protective behaviors. The choice of sample also makes it difficult to generalize from the results, as agriculture and biology students may be more interested in tick-borne disease than the general public, they may have different levels of existing knowledge to draw on when interpreting new in-

formation, and may be more used to being tested on information that they are given.

Fox (2009) studied 56 eight-, nine-, and ten-year-old children to test whether an educational curriculum provided in written, verbal, and video form could improve knowledge of Lyme disease or prevention behavior. A pre-test showed little or no knowledge of Lyme disease or prevention, but 70% responded that they "often" or "sometimes" practiced protective behaviors. The post-test, conducted 7–10 days later, showed that children reported being significantly more likely to know which clothing to wear to make ticks visible, and that they needed the help of an adult to remove a tick. There was some decrease in the reports of performance of preventive behaviors, indicating that the intervention may also have had a negative effect, this was not significant.

The final before and after study also evaluated the effectiveness of an educational intervention in changing knowledge, attitudes, and behaviors among children (Maher et al. 2004). Schoolchildren between the ages of 8 and 10 years were recruited from four elementary schools within a Lyme endemic area. The intervention was a fun and interactive curriculum focused on how participants could protect themselves from ticks and perform effective tick checking behavior. All 295 participants completed the same questionnaire before and after the intervention. The children reported a significant increase in the frequency of performing tick checks, and more confidence in their ability to find a tick on themselves. Overall, the researchers reported that their intervention increased knowledge, attitudes, and precautionary behaviors among children. However, because the study was published as a poster abstract, the methodology was not entirely clear. There was no indication of the follow-up period, or how long these apparently beneficial effects persisted.

Controlled Trials

Methodological details relating to the four controlled trials are given in Table 2.

The first, by Lawless and colleagues (1997), used an instructional video with a mock horror movie theme to improve knowledge, attitudes, and behaviors towards Lyme disease prevention among 13- to 16-year-olds from four Connecticut towns. Participants were randomly assigned to intervention groups who viewed the video, or control groups who received no intervention. All participants completed a questionnaire to assess their knowledge, attitudes, and behaviors prior to the intervention. One month and 6 months after the video, knowledge had increased significantly in the intervention group, but not in the control group. Although intervention group knowledge had decreased by the 6-month follow-up, it remained higher than in the control group. While there was some increase in self-reported protective measures, such as wearing trousers tucked into socks and avoidance of stone walls, during the initial post-intervention test, no significant self-reported behavior changes were evident at the 6-month follow-up.

In 1998, the U.S. Food and Drug Administration licensed a vaccine for Lyme disease. Delivered over time through three separate injections, the vaccine was eventually removed from the market in 2002 due to poor demand (Nolan and Mauer 2006). In 1999, the New York State Department of Health offered the vaccine to employees considered at occupational

TABLE 2. BEHAVIORAL INTERVENTION STUDIES FOR TICK-BORNE DISEASE: CONTROLLED TRIALS

Reference	Design, sample, and country	Outcomes examined and effect of intervention (significant effects in bold, no significant effect unless stated otherwise, effect sizes given for significant effects where known)	
		Intervention	Procedure
Daltroy et al. 2007	Cluster RCT. 13,562 intervention and 16,602 control participants, recruited on ferries to Lyme-endemic island. U.S.	15-min show about the severity and likelihood of LD, benefits of preventive behaviors, practice of removal, and take home-material. Similar intervention for controls, but about bike safety.	A questionnaire delivered 2 months after the intervention.
Lawless et al. 1997	Cluster RCT. 142 intervention and 111 control participants, all schoolchildren. U.S.	16-min 'mock horror' education video. No intervention for control participants.	A questionnaire administered pre-intervention (t1), 1 month post-intervention (t2) and 6 months after intervention (t3).
Malouin et al. 2003	RCT, 148 intervention and 169 control participants, randomly selected from an endemic area. U.S.	Ten mailings over 5 months with information about ticks and LD, reminders, insect repellent samples, tweezers, and t-shirts. Similar material for control group, but related to diet, dental health, or UV light.	Questionnaires and blood samples before (t1), during (t2), and after (t3) the mailings.
Nolan and Mauer 2006	Controlled trial with self-allocation to conditions. 81 intervention and 109 control participants, all employees at risk of exposure to TBI. U.S.	In-person education session focusing on the nature of LD and LD vaccine. Similar information in control condition, but in written format delivered by mail.	Telephone interviews pre-education (t1), after second dose of vaccine is given (t2), and after third dose (t3).
<p>Self-reported tick-borne illness (TBI) among long-term visitors to the island (lower, $p < 0.05$), self-reported TBI among short-term visitors, self-reported TBI among residents of the island, taking precautions (use of repellent, protective clothing, or limited time in tick-infested areas) (reported every day or most days: intervention 58% of participants, control 39% participants, $p < 0.0001$), checking self for ticks (reported every day or most days: intervention 51%, control 37%, $p < 0.001$), amount of time spent in tick-infested areas.</p> <p>Knowledge (better at t2 [mean difference 4.17 on a 12-point scale, $p < 0.05$] and t3 (md = 0.98, $p < 0.05$)), attitudes (better at t2 [md = 0.17 on a 4-point scale, $p < 0.001$]), avoid people with LD, use flea and tick collars, look for insects on pets, wear pants tucked into socks (more likely at t2 and t3, $p < 0.05$), check self for ticks, use insecticide on skin (more likely at t2, $p < 0.05$), use spray in yard (more likely at t2 and t3, $p < 0.05$), avoid woods, change clothes, have someone else check for ticks (more likely at t2 and t3, $p < 0.05$), avoid woodlands, avoid stone walls (more likely at t2, $p < 0.05$), avoid squirrels, avoid farm animals, avoid wooded areas, use alcohol to remove ticks, squeeze to remove ticks (more likely at t2, $p < 0.05$), grasp to remove ticks, use spray to remove ticks (more likely at t2 and t3, $p < 0.01$), and taking actions in the past year to prevent LD (more likely at t2 and t3)</p> <p>Three items of knowledge, including knowing the amount of time needed for transmission of LD (better knowledge at t2 and t3, $p < 0.01$). Seventeen items relating to knowledge of and reported performance of tick checks, including checking at home (better knowledge at t2 and t3, $p < 0.05$), and using a mirror to check (better knowledge t2 and t3; $p < 0.01$). Eight items on knowledge of and use of repellents and acaricides (of which five were better at t1 and t2, $p < 0.01$). Overall, the data provided little evidence that change in [knowledge, attitude, or behavior] was associated with changes in anti-recombinant tick calreticulin antibody.</p> <p>Five items of knowledge about the vaccine (all more likely to be correct in the intervention group): vaccine uptake.</p>			

wLD, Lyme disease; RCT, randomized controlled trial; UV, ultraviolet.

risk of contracting Lyme disease, and a study was undertaken to assess the factors that affected employee decisions to accept or decline the vaccine. Eligible employees were asked to attend an education session, where they were given information about Lyme disease and the vaccine. Of the 190 eligible employees, 43% chose to attend the education session, while the remaining 57% received the information by mail. Given the nature of their employment, 74% of participants were male; however, the majority of those who attended the education session were female. Overall, only 30 participants decided to have the vaccine. Vaccine uptake did not differ significantly between the session participants and those who received the information by mail. Both groups had roughly the same level of knowledge about vaccination pre-intervention, but post-intervention knowledge significantly improved only among the education session participants. It is difficult to draw any conclusions from this study regarding the merits of in-person versus postal information; however, given that participants themselves chose whether to attend the education session, attendance probably reflected pre-existing interest in Lyme disease and/or vaccination.

Another study investigating the effectiveness of an educational intervention aimed at increasing precautionary behaviors regarding tick-borne disease was carried out in the Lyme-endemic area of Nantucket Island, Maryland, first as a pilot study (Daltroy et al. 1998), and then as a full-scale randomized controlled trial (Daltroy et al. 2007). Over 30,000 passengers on ferry boats to the island over three consecutive summers were randomized into either the control or experimental group. Controls received education about bike safety, while intervention participants received information on preventing tick-borne disease, particularly Lyme disease. Information was delivered on board each boat by entertainers hired to make the messages more compelling. The entertainers also spent time demonstrating and modeling tick removal behaviors and allowing participants to practice the removal process. The theory behind the presentation and the hands-on interaction was to relate existing health protection behaviors such as applying sunscreen or checking the body for moles, to new tick prevention behaviors such as applying tick repellent or checking the body for ticks. Before leaving the boat participants were given materials such as a pamphlet on Lyme disease, a map of tick hot spots on the island, coupons for tick repellent and removal tools, and a card showing the actual size of the ticks. Two months after the intervention, all participants were sent a follow-up questionnaire asking them about any occurrence of tick-borne infection, preventive behaviors while on the island, and any visits to their primary care physician. No overall significant difference was detected in the self-report of tick-borne illness between the experimental or control participants, although there was evidence of lower rates of illness among the subgroup of participants classified as long-term visitors to the island. Nonetheless, experimental participants were more likely than controls to adopt precautionary behaviors, as well as to check themselves daily for ticks.

A study conducted in a different Lyme-endemic area of Maryland went further than other studies by trying to determine whether the implementation of an educational intervention could actually reduce the incidence of objectively assessed tick bites among the study sample (Malouin et al. 2003). Participants were first selected from the region using

random digit dialing before being randomly assigned to either the intervention or comparison group, while matching for age, gender, and zip code. All participants received materials by mail every 2 weeks between April and September 1999, for a total of 10 mailings. Participants also received and completed a monthly survey of their preventive behaviors. For the intervention group, the mailings included material such as a Lyme disease brochure and tick repellent sample. The control group received a variety of non-tick-related materials, such as a brochure about exercise and fitness and a toothpaste sample. All participants were asked to attend a clinic on three occasions to have their blood tested for the presence of antibodies that signal a tick bite. At each visit participants completed a questionnaire to assess their knowledge, attitudes, and behaviors towards ticks and Lyme disease. A difference between the intervention and control groups was shown over time in terms of knowledge, positive attitudes towards repellents, and the self reported use of the prevention methods; however, this was not associated with any change in the serological samples. Entomologists reported that there had been low tick activity due to a very dry summer, so it is possible that this could account for the lack of change in the serological samples. The most significant changes in knowledge, attitudes, and prevention occurred between the first and second visits to the clinic. These changes coincided with the receipt of the majority of intervention messages, and were also at the time of year when people would have been most engaged in some sort of outdoor activity. It is noteworthy that the intervention may have removed some barriers to the adoption of repellent use by providing free samples, but that this removal would have been only temporary; it is possible that the inconvenience of having to actively acquire and pay for any further repellent may result in a future drop in use, even if attitudes remain positive.

Discussion

Current evidence

Improving the uptake of protective behaviors among members of the public is an important challenge for those working to reduce the incidence of tick-borne disease. It is therefore remarkable that so few good-quality studies have assessed the effectiveness of educational interventions in improving this uptake. We identified only nine such studies in our systematic review, of which only three took the form of a randomized controlled trial (Lawless et al. 1997; Malouin et al. 2003; Daltroy et al. 2007). Although we cannot be certain that we included every relevant study in our review, the nature of publication bias makes it unlikely that we missed any well-designed studies that described a successful intervention. As such, the level of research in this field is disappointing. The success of health education campaigns is never guaranteed. Sometimes, even the most well-planned of campaigns can yield poor value for money, while in the worst-case scenario they may even backfire by reducing performance of the very behaviors that they were meant to endorse. Indeed, at least one intervention described in the tick literature appears to have resulted in precisely this type of effect, being associated with reduced knowledge about tick-borne disease, and decreased perceptions about the likelihood of personally contracting it (Gould et al. 2008). Greater emphasis on evaluating

health promotion material relating to tick-borne disease is clearly required.

Yet despite the paucity of evidence, we did find suggestions that educational material can be effective. In terms of behavior, the interventions that have been tested to date have noted shifts in uptake of a range of personal protective measures, including the use of insecticide (Lawless et al. 1997; Malouin et al. 2003; Daltroy et al. 2007), better checking for ticks (Lawless et al. 1997; Malouin et al. 2003; Daltroy et al. 2007), and avoidance of areas where one might encounter ticks (Lawless et al. 1997; Daltroy et al. 2007). Changes have also been observed in a range of variables relating to knowledge of and attitudes towards ticks, tick-borne disease, and protective behaviors. For example, changes have been noted in perceptions about the likelihood of contracting Lyme disease (Gould 2008), the risks and benefits of tick repellent use (Malouin 2003), and confidence in one's ability to perform tick checks (Maher 2004), together with basic knowledge about ticks, tick-borne disease, and protective behaviors (Lawless et al. 1997; Gray et al. 1998; Malouin et al. 2003; Maher et al. 2004; Jenks and Trapasso 2005; Nolan and Mauer 2006; Gould et al. 2008; Fox 2009). Given that such perceptions may serve as precursors for behavior changes (Abraham and Sheeran 2005), the finding that these variables are amenable to change via the use of health promotion material in this field is encouraging.

Suggestions for future research

Plenty of scope exists for future work to expand this literature and advance our knowledge of how best to encourage members of the public to take protective action when exposed to the risk of tick-borne disease. Future studies could be improved by learning several methodological lessons from those studies that have already been completed.

First, randomized controlled trials are still largely absent in this area, with only three notable exceptions. The use of before and after studies, or self-allocation to experimental groups, makes it difficult to determine whether any behavioral changes that are observed occur because of pre-existing differences between participant groups, are due to the passage of time, or if they represent a genuine effect of the intervention. While before and after studies, together with cross-sectional surveys or qualitative research, may be useful for pilot studies, full studies on the efficacy or effectiveness of an intervention should make use of the best-quality experimental designs, with their final reports following well-defined best practices (www.consort-statement.org; Evans 2003). Despite their relative expense in comparison with other study designs, randomized controlled trials provide the most accurate assessment of the efficacy of a given intervention and usually represent value for money.

Second, the majority of the studies conducted to date have relied on self-reports to measure behavior. This poses limitations. Self-reports may reflect actual behavior, but can also be heavily influenced by numerous other factors, including the social desirability of reporting good behavior, recall bias, and systematic changes in a participant's understanding of what counts as effective behavior. To take one example, while Fox (2009) reported a trend toward reduced self-reported checking for ticks by children following her educational intervention, it is unclear if this is because the behavior changed, or if the intervention changed participant's perceptions as to what

a check for ticks actually is. While obtaining objective measures of behavior is difficult, attempts should be made to at least validate any self-report measures that are used. Ensuring that questions about behavior accurately reflect the changes that may be brought about by an intervention is also important. It is possible that some tick protective behaviors may also be practiced for reasons other than tick avoidance, for example, wearing trousers because of colder weather. Unless questions specifically refer to practicing behaviors for tick avoidance, then it is possible that results may be inaccurate in assessing the efficacy of an intervention.

Third, two studies (Gray et al. 1998; Jenks and Trapasso 2005) did not assess behavior at all, but instead focused solely on measures of knowledge. While increased knowledge may lead to behavior change, improved knowledge by itself is a poor proxy for improved protective behavior. For example, a study at three recreational parks in New Jersey found that 84% of participants were able to name at least one precautionary behavior against tick bites, but despite this only about half actually engaged in any of the behaviors (Hallman et al. 1995).

Fourth, studies involving different sample populations have shown the importance of designing and evaluating interventions with multiple audiences in mind. Different populations will differ in terms of both their pre-existing level of knowledge, and perceptions about tick-borne disease and their risk of contracting a disease. The same intervention may have different effects depending on who it is tested on (Daltroy et al. 2007), and may need to be adjusted depending on which population is the target. Immigrant populations in Lyme-endemic areas have little if any knowledge of tick-borne disease, but this can be raised through targeted interventions (Jenks and Trapasso 2005; Heller et al. 2010). Visitors to tick-endemic areas also show a similar lack of knowledge, but may require more specific interventions (Shadick et al. 1997). Perhaps most challenging from a health education perspective may be those living in tick-affected areas, who may already have their own idiosyncratic views of the risks associated with ticks and how best to reduce them, views that will not always correspond to those held by health experts, but which might prove difficult to change. Knowledge of tick-borne disease among health professionals should also not be overlooked, as this has been shown to be low, even in endemic areas. This is true of both Lyme disease in North America (Capps et al. 1999) and CCHF in Eastern Europe (Rahnavardi et al. 2008). Surprisingly, 22% of Turkish health care workers fail to take any precautionary measures when in contact with CCHF patients, despite the contagious nature of the disease (Rahnavardi et al. 2008).

Fifth, the follow-up period used by studies in our review varied. A relatively lengthy follow-up is important, as at least one study has demonstrated that significant changes identified 1 month after the intervention had greatly reduced 6 months later (Lawless et al. 1997). While triggering behavior change may be possible, maintaining it in the long-term is likely to prove more difficult. Related to this, the timing of any follow-up should also correspond to the local tick season. Behavior is not expected to differ from normal outside of the tick season, so any follow-up conducted outside of the season may not detect any changes (Malouin et al. 2003). Where interventions are applied at a population level, surveillance systems may provide one option for follow-up.

Sixth, the explicit use of psychological theory to inform intervention development has been limited in this literature,

again with a few notable exceptions (Maher et al. 2004; Jenks and Trapasso 2005; Daltroy et al. 2007). Theories such as the health belief model, the theory of planned behavior, and others have shown much success in helping to improve the uptake of protective behaviors across a wide range of health topics, from condom use to smoking cessation to exercise (Armitage and Conner 2000). Designing an intervention on the basis of qualitative interviews with the target population, and a consideration of the mechanisms for behavior change suggested by these theories, is likely to give the best chance of success, as demonstrated by the studies in this review. For example, the study by Daltroy and associates (2007), which described the inclusion of psychological theory as guidance for the development of interventions, produced more in depth and targeted interventions which resulted in changes in behavior in addition to increased knowledge and awareness.

Seventh, the quality of reporting in this field regarding the exact interventions that were used is poor. Several studies failed to provide sufficient detail for a reader to understand the nature of their intervention or how to replicate it, and while it is possible that some studies that did not mention using any theoretical model to guide their interventions were indeed informed by a theory of behavior change, we were unable to determine this from the information provided. Without details about the nature of the interventions and the processes driving their design it is difficult to interpret the results (Michie et al. 2009).

Finally, those randomized controlled studies that do exist have been well designed, but have tended to focus on a complex combination of both interventions and outcome variables. Multi-modal interventions involving the use of reminder cards, entertainers, free samples of repellent, leaflets, maps of tick hot spots, and other materials may be effective, but are clearly labor-intensive and costly (Malouin et al. 2003; Daltroy et al. 2007). There may be some aspects of these multi-modal interventions that are more effective than others. Identifying them might allow for a more focused and efficient intervention. Additional research to determine which type of material is most effective at eliciting the desired behavioral changes would be of use. This could be conducted in the form of component studies, which help to identify the feasibility, acceptability, and effectiveness of the individual parts of a larger intervention (Simon et al. 2001).

Conclusions

Our systematic review could find only nine studies that have been undertaken to assess the effectiveness or efficacy of an educational intervention regarding protection against tick-borne disease. These ranged from large-scale randomized controlled trials to weaker before and after designs. There is a pressing need for further work in this area. To date research has focused on Lyme disease, but the fundamentals of effective communication strategies that they highlight might be applied to any tick-borne disease, assuming that other appropriate intervention options, such as land management, have been taken into account (Quine et al. 2011). Future research should focus on robust methodological designs and theory-based interventions.

Acknowledgments

Fiona Mowbray has received research funding from King's College London and the Health Protection Agency, U.K. G.

James Rubin is funded under the terms of a Career Development research training fellowship issued by the National Institute for Health Research. The views expressed in this publication are those of the authors and are not necessarily those of their funders or employers.

Author Disclosure Statement

No competing financial interests exist.

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