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The heat is on: Killing blacklegged ticks in residential washers and dryers to prevent tickborne diseases

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ABSTRACT

Reducing exposure to ticks can help prevent Lyme disease and other tickborne diseases. Although it is currently recommended to dry clothes on high heat for one hour to kill ticks on clothing after spending time outdoors, this recommendation is based on a single published study of tick survival under various washing conditions and a predetermined one-hour drying time. We conducted a series of tests to investigate the effects of temperature, humidity, and drying time on killing nymphal and adult blacklegged ticks (*Ixodes scapularis*). Muslin bags containing 5 ticks each were washed then dried or dried only with six cotton towels during each drying cycle. All nymphal and adult ticks were killed when exposed to wash cycles when the water temperature reached ≥54 °C (≥130 °F); however, 50% of ticks survived hot water washes when the water temperature was <54 °C. The majority (94%) of ticks survived warm washes [temperature range, 27–46 °C (80–115 °F)] and all ticks survived cold washes [15–27 °C (59–80 °F)]. When subsequently dried on high heat setting [54–85 °C (129–185 °F)], it took 50 min to kill all ticks (95% confidence limit, 55 min). Most significantly, we found that all adult and nymphal ticks died when placed directly in the dryer with dry towels and dried for 4 min on high heat (95% confidence limit, 6 min). We have identified effective, easily implemented methods to rid clothing of ticks after spending time outdoors. Placing clothing directly in a dryer and drying for a minimum of 6 min on high heat will effectively kill ticks on clothing. If clothing is soiled and requires washing first, our results indicate clothing should be washed with water temperature ≥54 °C (≥130 °F) to kill ticks. When practiced with other tick-bite prevention methods, these techniques could further reduce the risk of acquiring tickborne diseases.
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1. Introduction

Blacklegged ticks (*Ixodes scapularis*) are known to transmit the pathogens that cause Lyme disease, anaplasmosis, babesiosis, Powassan virus disease, and *Borrelia miyamotoi* disease (Clark and Hu, 2008; Shah and Sood, 2013). In the United States, an estimated 300,000 persons are diagnosed with Lyme disease and nearly 3,000 cases of anaplasmosis are reported each year (Adams et al., 2015; Hinckley et al., 2014; Nelson et al., 2015). Infections transmitted by blacklegged ticks have caused substantial morbidity and even death (Centers for Disease Control and Prevention, 2013; Rothermel et al., 2001; Vannier and Krause, 2012). Therefore, tick bites and the pathogens transmitted by them represent a major public health concern.

A variety of personal protection measures can be used to prevent tick bites when spending time outdoors, including conducting daily tick checks, using repellents on clothing and skin, and showering within two hours after coming indoors (Connally et al., 2009; Hayes and Piesman, 2003; Vazquez et al., 2008). Additional measures such as avoiding tick-infested habitat, wearing long pants and long-sleeved shirts, and tucking pants into socks have also been recommended (Clark and Hu, 2008; Hayes and Piesman, 2003). Unfortunately, these personal tick bite prevention measures are inconsistently practiced by individuals due to safety concerns, time constraints, and other factors (Gould et al., 2008; Herrington, 2004; Mowbray et al., 2014; Valente et al., 2014; Butler et al., 2016). Fur-

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thermore, the steadily increasing incidence of tickborne diseases (TBDs) and lack of vaccines for TBDs in the United States highlight the need for additional effective, easily implemented techniques to prevent tick bites (Mead et al., 2015).

I. scapularis ticks quest openly in leaf litter or from emergent vegetation (Schulze et al., 2011); therefore, any human activity involving close proximity to tick habitat can lead to acquisition of ticks on skin or clothing. In one Maryland study, an investigator simulated outdoor activities such as gardening or clearing brush by crawling through leaf litter for 30-s time periods. *I. scapularis* nymphs were acquired in 58% of crawls, and the majority of ticks were found on pant legs and socks (Carroll and Kramer, 2001). In another study, investigators who walked a series of 100 m transects through a wooded area in New Jersey found an average of nine *I. scapularis* adults on their clothing afterward (Jordan et al., 2012). Ticks that remain on clothing can be carried indoors and potentially bite, underscoring the need to rid clothing of ticks after coming indoors.

The Centers for Disease Control and Prevention currently recommends drying clothes on high heat for one hour after spending time outdoors in order to kill ticks on clothing. This recommendation is based on a single study which investigated survival of *I. scapularis* nymphs under various washing conditions, followed by a predetermined one-hour drying time (Carroll, 2003). There are no published data, however, on adult ticks or the effects of shorter drying times on tick survival. The objective of this study was to determine optimal wash and dry times and conditions necessary to effectively kill ticks on clothing.

2. Materials & methods

Testing was performed using laboratory-reared, uninfected, unfed *I. scapularis* nymphs, adult males, and adult females obtained from the Oklahoma State University Tick Rearing Facility. The ticks were maintained under optimal conditions prior to testing and were 30–60 days post-molt, during which they are in their prime and also most likely to bite humans. Although they do not pose a risk to humans, adult male ticks were used in this study since adults were only available for purchase as a 1:1 sex ratio. Survival of adult ticks was subsequently analyzed by sex in order to determine whether survival in the dryer differed by sex.

Three different standard-sized, residential washers and dryers in Vermont, Maine, and Massachusetts were used for testing [washers: Kenmore model 110.26832691 (Sears, Hoffman Estates, IL), General Electric model PTWN6050MWT (General Electric, Fairfield, CT), and Fisher & Paykel model IWL16 (Fisher & Paykel, Auckland, NZ); dryers: Admiral model AED4675YQ1 (Whirlpool, Benton Harbor, MI), General Electric model DPSE810EGWT, and Maytag model MDE5500AYW (Whirlpool, Benton Harbor, MI)].

Muslin cloth bags were constructed to contain the ticks during washing and drying. During testing, five ticks were placed into each bag and the opening was secured with a plastic clip and rubber band (Fig. 1). For the majority of trials, five bags of five ticks each were placed in each wash/dry cycle together. In some cases (e.g., when testing detergent and dryer sheets), a smaller number of bags were washed and/or dried together.

Following each wash and dry cycle, tick survival was assessed by observing the ticks for normal behavior and movement. If ticks appeared to be moribund and movement was not readily apparent, ticks were lightly probed with forceps, exposed to carbon dioxide through exhalation, and observed for several additional minutes. To verify that motionless ticks were in fact dead and not simply stunned, ticks were then placed in petri dishes with a piece of wet paper towel and reassessed 20–24 h later.

Water temperature was measured during washing at the beginning of each wash and rinse cycle using the Cooper-Atkins SRH77A Thermo-Hygrometer. Temperature and humidity were also measured inside the dryers before removing the ticks at each predetermined drying time (Fig. 1).

During each round of testing, 10–20 ticks (50 total) were also secured in petri dishes with a piece of moist paper towel to serve as controls. The ticks remained at room temperature in the laundry area and were assessed for survival 20–24 h later. A total of 50 nymphs and adults combined were also dried on fluff cycles (i.e. no heat) for 60 min to ascertain whether agitation alone without heat affected tick survival.

2.1. Washer and dryer trials

A total of 650 ticks (355 nymphs and 295 adults; 55% of adults were female) were washed with cotton towels at hot, warm, or cold temperature settings. All bags were removed to assess tick viability after completion of the wash cycle. Live ticks were then secured in the bags and transferred to the dryer along with six wet towels.

Drying cycles were run on low or high heat for 20–70 min. During initial trials, ticks were removed from the dryer at predetermined time points and assessed for survival immediately after removal from the dryer, then stored as described previously and reassessed 20–24 h later. This allowed us to establish survival proportions over time in the dryer and determine that ticks initially appearing active versus motionless remained alive or dead, respectively, after 20–24 h. During subsequent stages of testing, we focused on determining the amount of time necessary to kill all ticks in the dryer; therefore, if a bag was removed from the dryer and noted to contain live ticks, the bag was dried for additional time until all ticks were dead.

2.2. Dryer only trials

To test survival of ticks on clothing that has not been previously washed, we also conducted trials by placing muslin bags containing ticks directly in the dryer along with six dry towels. A total of 275 ticks (145 nymphs and 130 adults; 54% of adults were female) were dried at either low heat or high heat for 1–7 min (time range was selected based on results of pilot studies). Ticks were assessed for survival immediately after the dry cycles then stored and reassessed 20–24 h later. During later stages of testing, if a bag was removed from the dryer and noted to contain live ticks, the bag was dried for additional time until all ticks were dead.

2.3. Additional variables

Additional trials were conducted to determine the effect of laundry detergent and dryer sheets on tick survival during washing and drying. A total of 30 nymphal and 15 adult ticks were washed with Tide Original liquid laundry detergent (Procter & Gamble, Cincinnati, OH) and dried according to the protocol described above. In addition, 50 nymphal and 40 adult ticks were washed then dried or dried alone with Bounce dryer sheets (Procter & Gamble, Cincinnati, OH).

Ticks were also washed and dried with thin or thick clothing to assess the impact of clothing type on tick survival in the dryer. A total of 40 nymphs and 40 adults were washed then dried or dried alone with thin clothing consisting of polyester, rayon, and nylon fabric. An additional 40 nymphs and 40 adults were washed then dried or dried alone with thick clothing consisting of bulky fleece coats.