

## Duration of Tick Bites in a Lyme Disease-endemic Area

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Regression equations, based on scutal index (body length/scutal width), were developed to determine the duration of attachment for nymphal and adult female *Ixodes scapularis* ticks. Feeding times were calculated for 444 nymphal and 300 female ticks submitted by bite victims between 1985 and 1989 in Westchester County, New York, an area where Lyme disease is highly endemic. Nymphs were attached for a mean of 34.7 hours, with 26.8% removed after 48 hours, the critical time for transmission of *Borrelia burgdorferi*. Attachment times increased with victim age class (Kruskal-Wallis test,  $p < 0.05$ ). Mean duration of attachment for female ticks (28.7 hours) was significantly less (Kruskal-Wallis test,  $p < 0.05$ ) than that for nymphs, with 23.3% attached for more than 48 hours. The 0- to 9-year age class had the highest proportion (37.1%) of females attached for more than 48 hours. Nymphs remain attached to adult tick-bite victims longer than they remain attached to children. However, children have a high risk of acquiring Lyme disease because they receive more nymphal bites and also because they are less likely to have female ticks removed in time to prevent transmission. *Am J Epidemiol* 1996;143:187-92.

Lyme disease; tick-borne disease; ticks

Lyme disease, caused by the spirochete *Borrelia burgdorferi* is the most frequently reported vector-borne disease in the United States (1). The spirochete is transmitted to people by the bite of infected ticks belonging to the *Ixodes persulcatus* group (2, 3). In the Northeast, where almost 80 percent of the Lyme disease cases in the United States are reported (4), the vector is *Ixodes scapularis*, formerly *Ixodes dammini* (5). Spirochete transmission occurs primarily in the summer months through the bite of nymphal ticks, although adult females may also serve as vectors in the spring and fall (2, 6).

Bites from *I. scapularis* ticks are common in Lyme disease-endemic areas, accounting for almost 80 percent of all tick bites (7). In Westchester County, New York, where Lyme disease is endemic (8), it was

estimated that there were 14,000 victims of *I. scapularis* bites during a single year (1985) (9).

Since bites from vector ticks are common in Lyme disease-endemic areas, clinicians often are confronted with the problem of managing tick bites. Recent case-control studies have questioned the effectiveness of prophylactic antimicrobial therapy after a known tick bite (10, 11). However, a decision analysis study suggests that such therapy may be in order when the probability of *B. burgdorferi* infection is greater than 0.01 (12).

Several factors can influence a decision regarding prophylactic antimicrobial therapy for tick bites. These factors affect the probability of spirochete transmission and include the following: species identification, developmental stage of the tick, regional prevalence of *B. burgdorferi* infection in ticks, and the duration of attachment to the victim. Identification and the *B. burgdorferi* infection status of ticks have been the focus of previous studies of human tick bites (7, 10, 13, 14). The focus of this study is the length of time an *I. scapularis* tick feeds on human hosts before it is detected and removed.

Spirochetes are not transmitted immediately after an infected tick is attached. Experimental evidence suggests that both nymphs and females require a feeding duration of more than 48 hours for efficient transmission of *B. burgdorferi* (2, 15, 16). Because removal of attached *I. scapularis* ticks within 48 hours will effectively prevent Lyme disease (2, 15, 16), knowledge of

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Abbreviations: ANOVA, analysis of variance; SE, standard error.

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the duration of attachment would be useful information for physicians deciding how to manage tick bites.

We have developed a predictive equation, based on measurements of tick body length and scutal width, that can determine the length of time a nymphal or female *I. scapularis* tick has been attached. We also have applied this model to ticks found attached to people in order to describe the epidemiology of *I. scapularis* bites in a Lyme disease-endemic area.

## MATERIALS AND METHODS

### Tick feedings

Nymphal and female *I. scapularis* ticks were collected by drag sampling at a previously described study site in Westchester County, New York (17). Thirty nymphs and 20 females were placed in 70 percent ethanol to be used as unengorged (0 hours) controls. A minimum of 20 nymphs also were fed on each of four Syrian hamsters. Ticks were placed inside capsules glued to the body of each host. This capsulation permitted easy retrieval of ticks and minimized loss due to host grooming. Approximately 10 nymphs that were feeding on the first hamster were removed 24 hours after attachment. Nymphs on the remaining hamsters were similarly removed after 48, 72, and 96 hours. All ticks were placed in 70 percent ethanol for preservation. The experiment was repeated with four different hamsters. Ticks obtained from both trials were combined for data analysis ( $n = 86$ ).

A minimum of 15 female ticks were placed on each ear of two New Zealand white rabbits and contained by a cloth bag attached over the ear. Approximately 10 females attached to one ear were removed 24 hours after attachment and placed in 70 percent ethanol. Ticks on the other ears were removed after 48, 72, and 96 hours. The experiment was replicated with two different rabbits. Samples from both trials were combined for data analysis ( $n = 83$ ).

### Engorgement indices

An engorgement index was calculated for nymphal and female *I. scapularis* ticks by measuring with an ocular micrometer the body length from the base of the basis capitulum to the tip of the abdomen and the width of the scutum at its widest point. Indices were expressed as the ratio between body length and scutum width (18, 19). Because during feeding body length increases while scutal width remains constant, this index provides a measurement of increased body size relative to the initial size of an unfed tick.

## Regression analysis

Scutal indices of nymphal *I. scapularis* ticks fed on hamsters and female *I. scapularis* ticks fed on rabbits were regressed against time by using linear, exponential, and reciprocal models (20). The model with the highest  $r^2$  value provided an equation for determining duration of attachment, based on scutal indices, of ticks that parasitized humans.

## Epidemiologic studies

As part of an ongoing study begun in 1985, ticks submitted by the general public and local physicians to the Westchester County Department of Health and the New York Medical College Medical Entomology Laboratory were identified and stored in 70 percent ethanol. Background information, including the age of the victim and the location where ticks attached, were obtained when possible. Samples of intact ticks, collected between 1985 and 1989, were randomly selected for this study. The scutal indices of 444 nymphal and 300 female *I. scapularis* ticks were calculated, and the duration of attachment was calculated on the basis of regression analysis. Duration of attachment findings were then examined for the entire population, as well as analyzed by age class of the tick-bite victim and attachment site.

## RESULTS

### Tick feedings

Mean scutal indices ( $\pm$  standard error (SE)) for attachment intervals of experimentally fed nymphs are given in table 1. Analysis of variance (ANOVA) on the normally distributed data indicates a significant effect of attachment time on scutal index ( $p < 0.05$ ). ANOVA on the scutal indices of ticks removed at 0 and 24 hours showed no significant effect of time on tick size ( $p > 0.05$ ). However, ANOVA comparing tick sizes at 24 and 48 hours, 48 and 72 hours, and 72 and 96 hours showed significant differences for each grouping ( $p < 0.05$ ).

TABLE 1. Mean scutal indices for unengorged *Ixodes scapularis* and those fed on hamsters (nymphs) and rabbits (females) for each attachment interval, Westchester County, New York, 1985–1989

Hours attached	Nymphs		Females	
	No.	SI* $\pm$ SE*	No.	SI $\pm$ SE
0	30	2.09 $\pm$ 0.020	20	2.40 $\pm$ 0.047
24	22	2.12 $\pm$ 0.029	22	2.37 $\pm$ 0.046
48	22	2.81 $\pm$ 0.065	18	2.76 $\pm$ 0.074
72	22	4.07 $\pm$ 0.197	22	3.91 $\pm$ 0.167
96	20	4.58 $\pm$ 0.106	21	4.80 $\pm$ 0.223

\* SI, scutal indices; SE, standard error.

Mean scutal indices ( $\pm$ SE) for attachment intervals of females appear in table 1. ANOVA indicated a significant difference in scutal index among all time intervals ( $p < 0.05$ ). ANOVA further showed no difference in scutal indices of ticks removed at 0 hours and 24 hours ( $p > 0.05$ ). However, ANOVA comparing 24 and 48 hours, 48 and 72 hours, and 72 and 96 hours showed significant differences for each group ( $p < 0.05$ ). As with nymphs, these data suggest that the difference in scutal indices of female *I. scapularis* ticks at 24-hour intervals is large enough to discriminate between ticks at all but the 0- and 24-hour intervals.

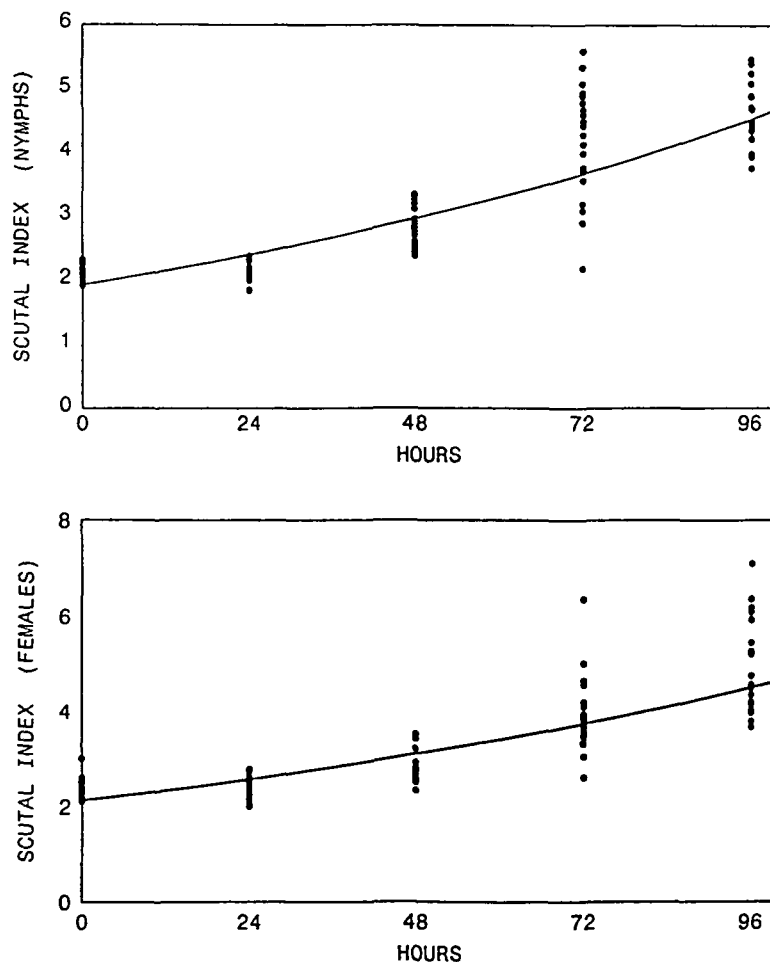
### Regression analysis

On the basis of the magnitude of  $r^2$  values, an exponential regression model was best at predicting the duration of tick attachment based on scutal index. For nymphs, this resulted in a positive relation

( $\log y = (8.896 \times 10^{-3}x + 0.660)$ ) with a significant slope ( $p < 0.05$ ) and an  $r^2$  value of 0.81 (figure 1). For females, the result was also a positive relation ( $\log y = 7.769 \times 10^{-3}x + 0.755$ ) with a significant slope ( $p < 0.05$ ) and an  $r^2$  value of 0.72 (figure 1, bottom).

### Nymphs parasitizing humans

Durations of attachment were calculated from the regression equation (figure 1, top) for 444 nymphs parasitizing humans. Nymphs were found to have been attached for a mean ( $\pm$ SE) of 34.7 (+ 1.46) hours. More than one half (53.6 percent) of these nymphs were attached for less than 24 hours, with 73.2 percent removed within 48 hours (table 2). When attachment times were analyzed with respect to victim age, times increased significantly with age (Kruskal-Wallis test,  $p < 0.05$ ). Furthermore, the age class 50–59 years accounted for the highest percentage of nymphs (51.6



**FIGURE 1.** Top: exponential regression of scutal index on time for nymphal *I. scapularis* experimentally fed on hamsters ( $\log y = 8.896 \times 10^{-3}x + 0.660$ ;  $r^2 = 0.81$ ). Bottom: exponential regression of scutal index on time for female *I. scapularis* experimentally fed on rabbits ( $\log y = 7.769 \times 10^{-3}x + 0.755$ ;  $r^2 = 0.72$ ).

percent) attached for more than 48 hours (table 3). When the site of attachment was examined, no differences were found with respect to duration of attachment (Kruskal-Wallis test,  $p > 0.05$ ), although the legs (34.8 percent) and chest (30.8 percent) had relatively high percentages of nymphs attached for more than 48 hours (table 4).

### Females parasitizing humans

Durations of attachment were calculated from the regression equation (figure 1, bottom) for 300 female *I. scapularis* ticks parasitizing humans. These females were attached for a mean ( $\pm$ SE) of 28.7 ( $\pm$ 2.62) hours, with 73.0 percent attached for less than 24 hours. A total of 76.7 percent were removed within 48 hours (table 2). Attachment times differed significantly with victim age (Kruskal-Wallis test,  $p < 0.05$ ), and the 0- to 9-year age class accounted for the highest percentage of females attached for more than 48 hours (37.1 percent, table 3). In contrast to the findings with nymphs, there was a significant difference among attachment sites with respect to duration of attachment (Kruskal-Wallis test,  $p < 0.05$ ), with the head (49.2 percent) having the highest proportion of females attached for more than 48 hours. (table 4). Durations of attachment for nymphal and female *I. scapularis* were significantly different (Kruskal-Wallis test,  $p < 0.05$ ).

### DISCUSSION

There was a significant difference between nymphal (mean = 34.7 hours) and female (mean = 28.7 hours) attachment times of ticks found parasitizing humans, indicating that, on average, females were found and removed sooner than nymphs. In fact, 73.0 percent of the females were removed within 24 hours, while only 53.6 percent of the nymphs were found within 1 day. This disparity is likely due to the larger size of female ticks, which enables victims to locate and remove them earlier in the feeding process. An additional 19.6 percent of nymphs were removed during the second

**TABLE 2. Attachment durations of *Ixodes scapularis* nymphs ( $n = 444$ ) and females ( $n = 300$ ) found parasitizing humans in Westchester County, New York, 1985–1989**

Hours attached	Nymphs		Females	
	No.	%	No.	%
0–24	238	53.6	219	73.0
>24–48	87	19.6	11	3.7
>48–72	59	13.3	10	3.3
>72–96	32	7.2	15	5.0
>96	28	6.3	45	15.0

24-hour period. Therefore, repeated body checks appear to be especially important in decreasing the risk of contracting Lyme disease from nymphal bites. Overall, 73.2 percent of nymphs and 76.7 percent of females were removed within 48 hours. These data suggest that when ticks are found and removed, it is usually done before transmission of *B. burgdorferi* has occurred. This would explain the apparently low rate of spirochete transmission resulting from known tick bites (7, 11, 12).

For nymphs, attachment times increased significantly with the age of the victim; only 18.7 percent of children under age 10 years had ticks attached for more than 48 hours compared with 51.6 percent of victims between ages 50–59 years (table 3). These findings suggest that young children in Westchester County are being inspected for ticks during the summer months. However, children under age 10 years also account for the highest percentage of nymphal bites (44.8 percent, table 3). Consequently, young children are at a high risk for Lyme disease on the basis of a higher frequency of tick bites. In fact, this group accounts for the highest percentage of Lyme disease cases in Westchester County (8).

The data for female ticks indicate that children under age 10 years account for the highest percentage of ticks attached for more than 48 hours (37.1 percent, table 3), followed closely by the age class 60 years and older. Children also receive the most bites from female

**TABLE 3. Attachment duration of *Ixodes scapularis* with respect to victim age, Westchester County, New York, 1985–1989**

Age class (years)	Nymphs			Females		
	No.	No. > 48 hours	% > 48 hours	No.	No. > 48 hours	% > 48 hours
0–9	182	34	18.7	105	39	37.1
10–19	46	10	21.7	21	0	0.0
20–29	39	9	23.1	16	0	0.0
30–39	49	16	32.7	39	7	17.9
40–49	30	13	43.3	30	2	6.7
50–59	31	16	51.6	28	6	21.4
≥60	29	13	44.8	26	7	26.9

**TABLE 4.** Attachment duration of *Ixodes scapularis* with respect to site of attachment, Westchester County, New York, 1985–1989

Body site	Nymphs			Females		
	No.	No. > 48 hours	% > 48 hours	No.	No. > 48 hours	% > 48 hours
Head	39	9	23.1	63	31	49.2
Neck	36	7	19.4	23	6	26.1
Shoulder/back	42	11	26.2	34	11	32.4
Arms	90	20	22.2	39	3	7.7
Chest	13	4	30.8	16	2	12.5
Abdomen/groin	43	12	27.9	32	4	12.5
Legs	115	40	34.8	56	9	16.1
Buttocks	6	0	0.0	4	0	0.0

ticks, possibly because they are less frequently inspected for ticks in the fall, when adult ticks are active. These data suggest that adult victims are more likely to find and remove adult ticks, while small children and older adults may need help with inspections.

Another factor that may influence the duration of tick attachment is the location of the tick bite. Examination of attachment sites with respect to feeding time indicated that, although the highest proportion of nymphs attached for more than 48 hours were found on the legs (34.8 percent) and chest (30.8 percent) (table 4), ANOVA comparing attachment sites for nymphs showed no significant difference.

For female *I. scapularis* ticks attached for more than 48 hours, we found that if the tick is attached to the head (49.2 percent), neck (26.1 percent), or back (including the shoulders) (32.4 percent), the likelihood of finding the tick within 48 hours diminishes (table 4). However, for female ticks, the ANOVA results are significant, suggesting that the site of attachment influences the probability of finding the tick after 48 hours. These results indicate that people exposed to female ticks in the fall and spring are not inspecting themselves adequately for the presence of attached ticks. Because of the relatively large size of the adult ticks, compared with that of larvae and nymphs, such inspections should be largely successful. Additionally, searches for attached adult *I. scapularis* ticks should concentrate on the head, the most common place of attachment (7).

We believe that the attachment times for *I. scapularis* ticks calculated here are a reasonably accurate reflection of feeding duration. The regression equations used to make these predictions were based on indices from nymphs feeding on hamsters and females feeding on rabbits. There is presently no published evidence that ticks parasitizing these hosts feed at a significantly different rate than those that feed on humans. There were significant differences in scutal indices among all but the ticks measured at 0 and 24 hours. Thus, this method appears sensitive enough to

detect differences in both nymphal and female feeding times. It is particularly important that, in both cases, the scutal indices at 24 hours were significantly different than those at 48 hours, the time necessary for *B. burgdorferi* transmission. However, because the potential for geographic variation in tick size and feeding rate is unknown, it may be necessary to modify equations for local tick populations.

Results of this study suggest that increased awareness of tick bite risk and knowledge of the importance of removing attached ticks early should significantly reduce the risk of acquiring Lyme disease in endemic areas. This is especially important for children, who are particularly vulnerable to tick bites because of outdoor activity and/or inadequate inspection and removal of attached ticks.

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