



Risk Factors for Bed Bugs Among Urban Emergency Department Patients

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Abstract

Bed bugs are a significant and under-studied public health nuisance. We surveyed 706 emergency department patients and found bed bug infestations were more likely ($p < 0.05$) among subjects having persons 19–64 years of age in the house, living in a group home, a previous history with bed bugs, and knowing someone who currently has bed bugs. Sleeping in a hotel, recent homelessness, obtaining used clothing or furniture and using a laundromat were not associated with increased risk ($p > 0.05$) for infestation. Individuals with less education and income were more likely ($p < 0.05$) to have bed bugs and express concern about getting bed bugs. Younger persons were more likely to correctly identify a picture of a bed bug compared to those over the age of 60 years ($p < 0.001$).

Keywords *Cimex lectularius* · Bed bug · Emergency department · Survey · Bedbug · Epidemiology

Introduction

The common bed bug, *Cimex lectularius* L., is a hematophagous temporary ectoparasite of humans [1, 2]. Bed bug infestations have risen dramatically over the past two decades and are now one of the most common parasites encountered by healthcare providers in industrialized nations [3–6]. Adult *C. lectularius* females lay eggs in the environment in proximity to their human host [1]. After hatching, bed bugs molt through five instars before becoming sexually mature adults [1]. At each life stage bed bugs will take a blood meal [1]. Unlike some other human ectoparasites, bed bugs do not jump or fly. Bed bugs move extensively within infested apartments and between infested and non-infested apartments in multi-occupancy buildings [7, 8]. Passive mechanisms of dispersal such as infestation of common room

furniture, transportation of infested furniture into a building, and the use of infested wheelchairs have also been observed [8]. Additionally, bed bugs prefer harborage in soiled laundry over clean laundry, and the insects are able to survive at least 4.5 months without taking a blood meal [7, 9].

Bed bugs have not been proven to be significant vectors of human disease, however a few recent reports explore their vector potential [1, 2]. Additionally, there has been little investigation into the adverse health effects associated with bed bugs outside of cimicosis—the bed bug feeding rash that occurs in most people after being fed on by bed bugs—and the anxiety that typically accompanies cohabitation with these insects [1, 2, 10–13].

Risk factors for obtaining a bed bug infestation have been purported to include travel, obtaining used clothes and furniture, and spending time in homeless shelters and hostel [1, 2, 14–16]. The objectives of our study were to prospectively survey ED patients to understand the prevalence of infestation, knowledge about *C. lectularius*, and the epidemiological factors associated with bed bug infestations.

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Materials and Methods

The study was approved by the University Hospitals Institutional Review Board (IRB). The study took place between June and October 2017 at University Hospitals Cleveland Medical Center, an urban tertiary care academic emergency department (ED) in downtown Cleveland, OH. After ED patients were evaluated by a health-care provider, study investigators surveyed a convenience sample of 706 patients older than 18 years of age who had no psychosis, homicidal ideation, altered mental status, or critical illness. Patients in distress or who could otherwise not accurately or safely participate in the survey were excluded. We estimate that we surveyed about 2–3% of all patients seen in our ED during the study period. The data were analyzed by reported home bed bug infestation, age, education, whether they were a current student, and income. Subjects reporting “unsure” or had “no answer” were not included in the final data analysis. For continuous variables the mean and standard deviation (SD) were reported and analyzed using the independent *t* test or analysis of variance (ANOVA). Categorical variables were summarized by frequency or percentage and analyzed using Chi square. An alpha of 0.05 was set for statistical significance.

Results

Thirty-seven percent (253/680) of subjects reported previously having been fed on by a bed bug with the average age of subjects with bed bugs (52 years \pm 14) being significantly higher than those without bed bugs (41 years \pm 18) ($p < 0.02$) [17].

The mean level of concern about getting bed bugs among subjects knowing someone living outside their home who has had bed bugs within the past 5 years was 3.6 ± 1.7 compared to 3.04 ± 1.8 for subjects that don't know anyone that has had bed bugs in the last 5 years ($p < 0.001$), (with 1 being no concern and 5 being very concerned). The concern about getting a future bed bug infestation was greater for those with a past history of a bed bug infestation 3.9 ± 1.6 compared to 3.2 ± 1.8 in those persons reporting never having had bed bugs ($p < 0.001$), (1 being no concern and 5 being very concerned).

Table 1 shows that those with a current bed bug infestation are more likely ($p < 0.05$) to know someone else that currently has bed bugs, report previously been fed up on a bed bug, believe that bed bugs can jump, have more persons between the ages of 19–64 living at home, and live in a group home than subjects without a home

bed bug infestation. There were no significant differences ($p > 0.05$) between those with and without home bed bug infestations for the following: frequency of persons living staying overnight at other people's houses, feeling comfortable visiting someone in their home knowing they had bed bugs, knowing someone else that has had bed bugs in the last 5 years, number of nights spent in a hotel room in the last 6 months, being homeless within the last year, the number of persons at home under the age of 18 years of age, earning more money now compared to the previous year, location where the laundry is done, knowing that bed bugs feed on human blood, obtaining used clothing or furniture in the last 6 months, moved into a new house in the last 6 years, level of education, believing that bed bugs lay eggs under the skin, number of bedrooms in the house, number of people living in the house over the age of 65 years, feel more withdrawn from family and friends now more than a year ago, total household income, having overnight visitors at the house, being a current student, and being able to correctly identify *C. lectularius* (Table 1).

All persons reporting a bed bug infestation had an Associate's degree or less education. There were significant differences ($p < 0.05$) in survey responses for those with less than a Bachelor's degree education compared to those with a Bachelor's degree or more education for the following: believing that bed bugs feed on human blood, having previously been fed upon by a bed bug, level of concern about getting bed bugs in the future, believing bed bugs transmit infectious diseases to humans, having had a past bed bug infestation, and the use of over-the-counter bed bug products for those with a past bed bug infestation (Table 2). There were no significant differences ($p > 0.05$) for the following: knowing anyone other than themselves and people that live with them that currently has bed bugs at home, knowing anyone excluding themselves that has had bed bugs in the past 5 years, currently reporting bed bugs at home, using a pest management professional for a past bed bug infestation, and believing that bed bugs can jump (Table 2).

Subjects between 18 and 59 years of age were significantly more likely to be able to correctly identify *C. lectularius* in a picture of different insects (64% vs. 35%) and report having been previously bitten by a bed bug (39% vs. 29%) compared to those 60–89 years of age, respectfully ($p < 0.001$ and $p = 0.04$) (Table 3). Age was not significantly associated ($p > 0.05$) for believing that bed bugs can jump, believing bed bugs lay eggs under skin, believing bed bugs transmit infectious diseases to humans, concern about getting bed bugs, or reporting that bed bugs feed on human blood.

Table 4 shows the significant differences ($p < 0.05$) between current students and non-students for knowing that bed bugs feed on human blood (93% vs. 98%) and for thinking that bed bugs lay eggs under human skin (36% vs. 50%),

Table 1 Patients with and without home bed bug infestations

	With bed bugs (N = 14)	Without bed bugs (N = 683)	RR (95% CI)	p value
Know anyone, excluding yourself and anybody that lives with you, that currently has bed bugs				
Yes	7 (54%)	98 (14%)	1.85 (1.03–3.34)	< .001
No	6 (46%)	580 (86%)	Ref	
Living situation				
House	9 (64%)	432 (63%)		< .001
Condo	0 (0%)	12 (2%)		
Apartment	3 (21%)	217 (32%)		
Nursing home	0 (0%)	1 (0.02%)		
Assisted living	0 (0%)	5 (0.7%)		
College dormitory	0 (0%)	5 (0.7%)		
Homeless shelter	0 (0%)	5 (0.7%)		
Group home	2 (14%)	5 (0.7%)		
Been bitten by a bed bug				
Yes	11 (79%)	239 (36%)	2.97 (1.09–8.12)	0.001
No	3 (21%)	419 (64%)	Ref	
Believe bed bugs can jump				
Yes	7 (50%)	443 (80%)	0.41 (0.23–0.70)	0.007
No	7 (50%)	113 (20%)	Ref	
Number of people 19–64 years of age at home				
Mean (SD)	1.86 (1.6)	1.15 (1.3)		0.05
N	14	683		
Frequency of people living with you that stay overnight elsewhere				
Never	8 (57%)	309 (46%)		0.08
≤ 1–7 times/month	3 (21%)	312 (46%)		
> 7 times/month	3 (21%)	56 (8%)		
Comfortable visiting someone in their home if they had bed bugs				
Yes	2 (15%)	36 (5%)	1.12 (0.89–1.41)	0.12
No	11 (85%)	636 (95%)	Ref	
Know anyone, excluding yourself, who has had bed bugs in the past 5 years				
Yes	11 (79%)	401 (59%)	1.91 (0.70–5.23)	0.14
No	3 (21%)	278 (41%)	Ref	
Number of nights spent in a hotel in the last 6 months				
Mean (SD)	0.07 (0.3)	1.1 (3.7)		0.29
N	14	682		
Homeless in the last year				
Yes	0 (0%)	44 (6%)	0.94 (0.92–0.95)	0.32
No	14 (100%)	632 (94%)	Ref	
Number of people < 18 years of age at home				
Mean (SD)	0.64 (1.5)	1.0 (1.4)		0.33
N	14	683		
Current salary compared to last year				
More	5 (36%)	161 (24%)		0.39
Less	1 (7%)	133 (20%)		
Same	8 (57%)	365 (55%)		
Where your laundry is done				
Laundromat	3 (23%)	132 (19%)		0.41
Personal washer/dryer	6 (46%)	427 (63%)		
On-site washer/dryer shared with non-family members	4 (31%)	124 (18%)		

Table 1 (continued)

	With bed bugs (N = 14)	Without bed bugs (N = 683)	RR (95% CI)	p value
Believe bed bugs feed on human blood				
Yes	13 (93%)	629 (97%)	0.45 (0.07–3.13)	0.42
No	1 (7%)	21 (3%)	Ref	
Obtained used clothing/furniture in the past 6 months				
Yes	3 (21%)	99 (15%)	1.09 (0.83–1.43)	0.47
No	11 (79%)	579 (85%)	Ref	
Moved into a new house in the last 6 years				
Yes	10 (71%)	426 (63%)	1.30 (0.57–3.00)	0.5
No	4 (29%)	253 (37%)	Ref	
Highest education level				
No high school	4 (29%)	90 (13%)		0.56
High school	9 (69%)	461 (68%)		
Associates degree	1 (7%)	57 (8%)		
Bachelor's degree	0 (0%)	50 (7%)		
Master's degree	0 (0%)	16 (2%)		
Doctorate degree	0 (0%)	7 (1%)		
Believe bed bugs lay eggs under the skin				
Yes	4 (57%)	215 (47%)	1.24 (0.52–2.92)	0.59
No	3 (43%)	243 (53%)	Ref	
Number of bedrooms at home				
Mean (SD)	3.1 (1.1)	2.8 (1.7)		0.6
N	14	680		
Number of people > 65 years of age at home				
Mean (SD)	0.07 (0.3)	0.11 (0.4)		0.72
N	14	683		
More withdrawn from family and friends now than a year ago				
Yes	4 (29%)	168 (25%)	1.05 (0.76–1.47)	0.74
No	10 (71%)	512 (75%)	Ref	
Total household income				
<\$25,000	7 (54%)	384 (59%)		0.78
\$25,000–\$50,000	5 (38%)	171 (26%)		
\$50,000–\$75,000	1 (8%)	46 (7%)		
\$75,000–\$100,000	0 (0%)	22 (3%)		
>\$100,000	0 (0%)	26 (4%)		
Frequency of visitors staying overnight at your house				
Never	6 (43%)	341 (50%)		0.79
< 1 time/month	4 (29%)	193 (28%)		
≥ 2 times/month	4 (29%)	146 (21%)		
Current student				
Yes	2 (14%)	110 (16%)	0.98 (0.79–1.21)	0.85
No	12 (86%)	571 (84%)	Ref	
Correctly identified <i>Cimex lectularius</i> in a picture of different insects				
Yes	8 (62%)	369 (59%)	1.06 (0.53–2.13)	0.87
No	5 (39%)	255 (41%)	Ref	
Moved into a new house in the last 6 months				
Yes	3 (21%)	143 (21%)	1.01 (0.76–1.33)	0.97
No	11 (79%)	539 (79%)	Ref	

Table 2 Survey responses according to subjects' highest reported educational level

	Less than bachelor's degree (N = 608)	Bachelor's degree or more education (N = 74)	RR (95% CI)	p value
Believe bed bugs feed on human blood				
Yes	590 (98%)	56 (84%)	0.11 (0.05–0.25)	< .001
No	11 (2%)	11 (16%)	Ref	
Been bitten by a bed bug				
Yes	245 (40%)	7 (10%)	0.66 (0.60–0.73)	< .001
No	360 (60%)	65 (90%)	Ref	
Concern about getting bed bugs (1 = no concern and 5 = very concerned)				
Mean (SD)	3.50 (1.8)	2.43 (1.7)		< .001
N	608	74		
Believe bed bugs transmit infectious diseases to humans				
Yes	367 (82%)	34 (63%)	0.48 (0.32–0.72)	< .001
No	77 (18%)	20 (37%)	Ref	
Had a past bed bug infestation				
Yes	147 (24%)	8 (11%)	0.85 (0.78–0.94)	0.01
No	455 (76%)	62 (88%)	Ref	
Had a past bed bug infestation and used over-the-counter bed bug products				
Yes	101 (69%)	2 (25%)	0.42 (0.26–0.67)	0.01
No	46 (31%)	6 (75%)	Ref	
Know anyone, excluding yourself and anybody that lives with you, that currently has bed bugs				
Yes	99 (16%)	7 (9%)	0.93 (0.86–1.0)	0.16
No	523 (84%)	68 (91%)	Ref	
Currently has bed bugs at home				
Yes	14 (2%)	0 (0%)	0.98 (0.97–0.99)	0.20
No	608 (98%)	73 (100%)	Ref	
Know anyone, excluding yourself, who has had bed bugs in the past 5 years				
Yes	377 (60%)	38 (51%)	0.82 (0.63–1.05)	0.14
No	248 (40%)	36 (49%)	Ref	
Believe bed bugs lay eggs under the skin				
Yes	199 (48%)	21 (41%)	0.89 (0.69–1.14)	0.37
No	217 (52%)	30 (59%)	Ref	
Used a pest management professional for past bed bug infestation				
Yes	96 (64%)	4 (44%)	0.66 (0.35–1.22)	0.25
No	55 (36%)	5 (56%)	Ref	
Believe bed bugs can jump				
Yes	404 (79%)	48 (80%)	1.07 (0.63–1.82)	0.80
No	110 (21%)	12 (20%)	Ref	

respectfully. There were no significant differences ($p > 0.05$) between students and non-students and believing that bed bugs transmit infectious diseases to humans, believing that bed bugs can jump, or the ability to correctly identify *C. lectularius* in a picture containing different insects.

Subjects living in an apartment were significantly more likely ($p = 0.004$) to report having been fed upon by a bed bug (45%; 95/211) compared to those living in a house (33%; 143/427). There were no significant differences between those who lived in an apartment compared to a house for: knowing someone with bed bugs 17% (37/219) versus 14% (63/438) ($p = 0.4$), having a current bed bug infestation 1.4%

(3/220) versus 2% (9/442) ($p = 0.54$), or concern for getting bed bugs (scale of 1–5 with 1 being no concern and 5 being very concerned) mean 3.4 (SD 1.8; $n = 214$) versus mean 3.4 (SD 1.8; $n = 432$), respectively.

Table 5 shows that persons with a lower annual income were more likely ($p < 0.05$) to report ever having been fed upon by a bed (Fig. 1), having had bed bugs previously, have higher concern about getting bed bugs in the future, and report neighbors that currently have bed bugs. Annual income was not associated ($p > 0.05$) with knowing anyone with bed bugs, currently having bed bugs at home, or knowing someone with bed bugs in the last 5 years.

Table 3 Survey responses according to subjects' age

	18–59 years of age (N = 580)	60–89 years of age (N = 125)	RR (95% CI)	p value
Correctly identified <i>Cimex lectularius</i> in a picture of different insects				
Yes	345 (64%)	37 (35%)	0.55 (0.46–0.66)	< .001
No	193 (36%)	69 (65%)	Ref	
Been bitten by a bed bug				
Yes	218 (39%)	35 (29%)	0.86 (0.75–0.98)	0.04
No	340 (61%)	86 (71%)	Ref	
Believe bed bugs lay eggs under the skin				
Yes	182 (46%)	40 (55%)	1.20 (0.91–1.56)	0.16
No	214 (54%)	33 (45%)	Ref	
Believe bed bugs can jump				
Yes	380 (78%)	74 (83%)	1.30 (0.80–2.13)	0.28
No	107 (22%)	15 (17%)	Ref	
Concern about getting bed bugs (1 = no concern and 5 = very concerned)				
Mean (SD)	3.41 (1.8)	3.23 (1.9)		0.33
No	82 (19%)	18 (23%)		
Believe bed bugs transmit infectious diseases to humans				
Yes	344 (81%)	59 (77%)	0.82 (0.53–1.29)	0.40
No	82 (19%)	18 (23%)	Ref	
Believe bed bugs feed on human blood				
Yes	543 (97%)	105 (96%)	0.87 (0.30–2.53)	0.80
No	18 (3%)	4 (4%)	Ref	

Discussion

Cleveland, OH has one of the highest rates of bed bug infestations in the United States [18]. UHMC hospital staff find a bed bug within the institution about every 2.2 days and on a patient in the ED approximately every 3–5 days [5, 19]. The direct annual cost to decontaminate UHMC ED rooms for bed bugs approximated \$50,000 per year [19]. A survey of ED patients that had a bed bug found on them were more likely to be sicker, older, male, be admitted to the hospital, and arrive to the ED by ambulance compared to historical controls [5, 6]. It has also been estimated that the true number of bed bug introductions into the hospital is underestimated because hospital staff predominately identify larger instars or adult insects and may be missing smaller instars [4].

The 2016 median household income for Ohio was \$52,334, yet only 7% (49/670) of our subjects reported an income of \$50,000 or more per year with only 1% (1/95) of subjects earning more than \$50,000 per year reporting bed bugs [20]. Higher income was associated a lower chance of having ever been fed upon by a bed bug or having had a bed bug infestation, less concern about getting a future bed bug infestation, and less likely to have neighbors with bed bugs. We had so few higher income subjects reporting bed bug infestations that it is difficult to compare our results with findings from household surveys that found no association between property values and infestation status in Philadelphia, PA [21]. A phone survey of individuals living in a wealthy community in Ohio reported that only 6% of subjects knew someone who had bed bugs; which was less than half the rate in our survey [22]. This discrepancy in the rates of knowing someone in Ohio who had bed bugs is likely multifactorial and could include: an evolution of the bed bug

Table 4 Survey responses according of students and non-students

	Student (N = 112)	Non-student (N = 590)	RR (95% CI)	P value
Believe bed bugs feed on human blood				
Yes	101 (93%)	545 (98%)	0.34 (0.15–0.79)	0.01
No	8 (7%)	14 (2%)	Ref	
Believe bed bugs lay eggs under the skin				
Yes	29 (36%)	193 (50%)	0.79 (0.65–0.96)	0.03
No	51 (64%)	195 (50%)	Ref	
Believe bed bugs can jump				
Yes	76 (73%)	377 (80%)	0.74 (0.51–1.06)	0.11
No	28 (27%)	93 (20%)	Ref	
Believe bed bugs transmit infectious diseases to humans				
Yes	65 (77%)	337 (81%)	0.81 (0.52–1.24)	0.34
No	20 (23%)	79 (19%)	Ref	
Correctly identified <i>Cimex lectularius</i> in a picture of different insects				
Yes	67 (63%)	314 (59%)	1.13 (0.86–1.47)	0.38
No	39 (37%)	222 (41%)	Ref	

Table 5 Survey responses based on reported annual income

	<\$25,000 (N= 395)	\$25,000–\$50,000 (N= 179)	>\$50,000 (N= 96)	X ² (df)	P value
Been bitten by a bed bug					
Yes	170 (45%)	59 (34%)	11 (12%)	34.0 (2)	< .001
No	212 (56%)	114 (66%)	80 (88%)		
Had a past bed bug infestation					
Yes	108 (29%)	29 (17%)	12 (13%)	16.0 (2)	< .001
No	267 (71%)	143 (83%)	81 (87%)		
Concern about getting bed bugs (1 = no concern and 5 = very concerned)					
Mean (SD)	3.51 (1.7)	3.38 (1.8)	2.82 (1.8)		0.002
No bed bugs at home but neighbors have bed bugs					
Yes	27 (8%)	6 (4%)	1 (1%)	7.43 (2)	0.02
No	294 (92%)	141 (96%)	82 (99%)		
Know anyone, excluding yourself and anybody that lives with you, that currently has bed bugs					
Yes	71 (18%)	22 (12%)	10 (11%)	5.24 (2)	0.07
No	320 (82%)	156 (88%)	85 (90%)		
Currently has bed bugs at home					
Yes	7 (2%)	5 (3%)	1 (1%)	1.17 (2)	0.56
No	384 (98%)	171 (97%)	94 (99%)		
Know anyone, excluding yourself, who has had bed bugs in the past 5 years					
Yes	243 (62%)	104 (58%)	55 (58%)	0.88 (2)	0.65
No	150 (38%)	74 (42%)	40 (42%)		

Fig. 1 The percentage of subjects that report having ever been fed on by a bed bug according to reported annual income

epidemic within the state over time (the Kaylor et al. survey was published in 2011), an overall increased knowledge about bed bugs, socioeconomic factors, and factors related to our specific emergency department study population [22].

A limitation of our study is that we could not confirm whether persons actually did or did not have home bed bug infestations, but a door-to-door survey in a residential census tract of Philadelphia, PA found that 11% of residents reported an active bed bug infestation and bed bugs were

confirmed in 68% of inspected homes [21]. Our study found significantly fewer people reporting an active bed bug infestation which could be related to regional differences, socioeconomic factors, and housing diversity [21]. Only 10% of individuals could correctly identify an adult bed bug in the UK, and older individuals were better able to identify the insect [23]. This contrasts with 59% (382/644) of our subjects being able to correctly identify a bed bug. In our survey, persons aged 18–59 years were significantly more

likely to be able to identify a bed bug (64%) compared to those aged 60–89 (35%) years ($p < 0.001$). Sixty-two percent (8/13) of subjects reporting a current home bed bug infestation were able to correctly identify the insect.

Bed bugs were more common in older ED patients and the insects affected about 2% of our subjects. Subjects with the least amount of education were more likely to know that bed bugs feed on human blood, report a past bed bug infestation, and believe bed bugs transmit infectious diseases to humans. We found that living in a group home increased the risk of bed bugs, but, interestingly reported homelessness, relocating to a new home, using a laundromat, sleeping in a hotel, and obtaining used clothing or furniture did not. Socioeconomic factors are related to both knowledge and experience with bed bugs.

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Compliance with Ethical Standards

Conflict of interest The authors report no conflicts of interest.

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