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## Asian Pacific Journal of Tropical Disease

journal homepage: [www.elsevier.com/locate/apjtd](http://www.elsevier.com/locate/apjtd)



Entomological research

doi: 10.1016/S2222-1808(15)61049-0

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### Human skin reactions towards bites of tropical bed bug, *Cimex hemipterus* F. (Hemiptera: Cimicidae): A preliminary case study

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#### ARTICLE INFO

##### Article history:

Received 31 Mar 2016

Received in revised form 26 Apr 2016

Accepted 30 Apr 2016

Available online 5 May 2016

##### Keywords:

*Cimex hemipterus*

Tropical bed bug

Bites

Skin reactions

Wheals

Lesions

#### ABSTRACT

**Objective:** To observe the manifestation of skin reactions and determine the time for skin reactions from bites of tropical bed bug (*Cimex hemipterus*) to disappear on different body parts.

**Methods:** Forearm, upper arm and shoulder were exposed to tropical bed bugs and the manifestations of skin reactions afterwards were observed up to 144 h.

**Results:** Itches, wheals and lesions were recorded for the three body parts. Itches were felt for about 15 min for all body parts. The wheals were recorded up to an hour before it flattened, and lesions manifested right after that and lasted for several days. One individual of bed bug took the least time for the skin reaction to disappear while shoulder recorded the longest time for the skin reactions to disappear completely.

**Conclusions:** Different body parts may produce different skin reactions and the time required for the skin reactions to disappear completely was also varied.

## 1. Introduction

Bed bugs are known to feed exclusively on blood where each of their immature life stage must take a blood meal so that they can molt successfully into the next life stage. In addition, the adults of this insect, males and females, are also required to feed on blood regularly to produce offspring via traumatic insemination[1,2]. Bed bugs feed approximately every 7–8 days and these feeding intervals depend on several factors such as environmental temperature and humidity, digestion rate as well as the availability of blood meal[1–4]. Bed bugs in both nymphal and adult stages have modified needle-like mouth parts that facilitate penetration of the human skin during feeding and excrete anticoagulant salivary proteins that numb the penetrated area as well as preventing the clotting of blood which is subsequently sucked up[4,5].

The need for blood feeding by this insect led to various skin

reactions caused by the bites, including psychological effects and some impacts on mental health[6–9]. The effects of a bed bug feeding on human include discomfort, psychological distress, secondary infection and pathogen transmission, allergic responses and skin reactions[1,9,10]. Clinical manifestations of bed bug bites are mainly cutaneous reactions such as rashes, bullous eruptions, itches, wheals and lesions[7,8,11]. People would generally develop pruritis (extremely itchy sensation), wheals and lesions after they have been bitten by the bed bugs. The objectives of this study were to observe the development of skin reactions towards tropical bed bug [*Cimex hemipterus* (*C. hemipterus*)] bites on the forearm, upper arm and shoulder and record the time taken for the skin reactions to disappear.

## 2. Materials and methods

### 2.1. Tropical bed bugs and feeding

Adults of *C. hemipterus* were randomly selected from colonies reared at the Household and Structural Urban Entomology Laboratory, Universiti Sains Malaysia and separated into males and females before being transferred into sample vials. Sample vials were then covered with a fine net cloth and a rubber band to hold it in place. After the net cloth was secured, sample vials were placed on the forearm (Figure 1), upper arm and shoulder for 10 min.

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The study protocol was performed according to the Helsinki declaration and approved by Universiti Sains Malaysia Research Ethics Committee (Human). Informed written consent was obtained from Mr. Abd Hafis Abd Rahim.

Foundation Project: Supported by Universiti Sains Malaysia (Short Term Grant: 304/PBIOLOGI/6313030).

The journal implements double-blind peer review practiced by specially invited international editorial board members.

There were three different numbers of individuals (one, three and five individuals) for each body part, with three replicates for each number of individuals.



**Figure 1.** Sample vials containing adult bed bugs were placed on the forearm.

## 2.2. Manifestations of skin reactions

The manifestations of skin reactions were observed at 0 min, 5 min, 10 min, 15 min, 30 min, 45 min, and 60 min for the first hour after feeding. The next observations were made after 2, 3, 4, 5, 6, 8, 10, 12, 16, 20, 24, 36, 48, 72, 96, 120 and 144 h after feeding. The areas where the bed bugs were fed were observed and scrutinized thrice to see the manifestations of the skin reactions. Three types of skin reactions, itch, wheal and lesion, were recorded. Itch is a skin condition accompanied by the desire to scratch the area of the skin to relieve discomfort. Itches were recorded during the observations if the skin reactions were felt. A wheal is an area of the skin that is temporarily raised while a lesion is superficial reddening of the skin. The size of the wheal and lesion was not measured using the metric system. Observations only recorded whether the wheal or lesion still exist or have disappeared from the body parts. Photos of skin reactions were taken during observations.

## 2.3. Statistical analysis

Data of the manifestation of skin reactions were subjected to analysis using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Normality test showed that the data were not normally distributed. Thus, the data were transformed and analyzed using univariate ANOVA with permutation to determine the significant differences between the time taken for the skin reactions to disappear based on the body parts, the number of individuals and gender.

## 3. Results

The manifestation of the skin reactions was summarized in Table 1. Overall, the itch or the intense sensation to scratch the bite area was manifested or more likely to be felt right after sample vials were removed from the skin. This sensation would last for around 13 min for the forearm and 15 min for the upper arm and shoulder. The wheals appeared around 5 min after the bed bug bites and lasted for about an hour for all the tested body parts. However, the shape of the

wheals was varied (Figures 2–4). One individual might produce two or three wheals and three individuals might produce three wheals or a big one. In addition, an area where five individuals were fed usually produced one big wheal with no distinctive individual bite marks.

**Table 1**

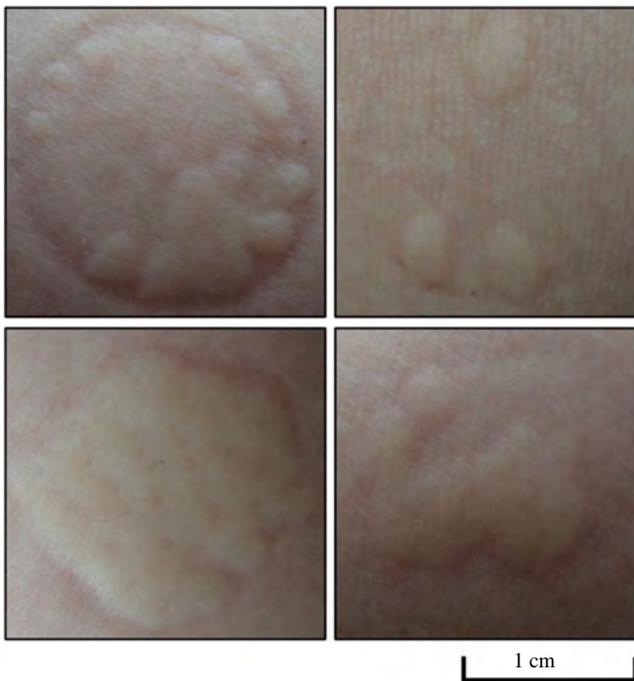
The manifestation of skin reactions on the forearm, upper arm and shoulder.

Body part	Number of individuals	Gender	Skin manifestation (mean)		
			Itch (min)	Wheal (min)	Lesion (h)
Forearm	1	Male	13	60	22.00
		Female	13	60	22.00
	3	Male	13	60	53.33
		Female	13	60	54.67
	5	Male	13	60	56.00
		Female	13	60	60.00
Upper arm	1	Male	15	60	33.00
		Female	15	60	33.00
	3	Male	15	60	43.33
		Female	15	60	56.67
	5	Male	15	60	65.33
		Female	15	60	80.00
Shoulder	1	Male	15	60	58.67
		Female	15	60	58.67
	3	Male	15	60	84.00
		Female	15	60	58.67
	5	Male	15	60	84.00
		Female	15	60	84.00

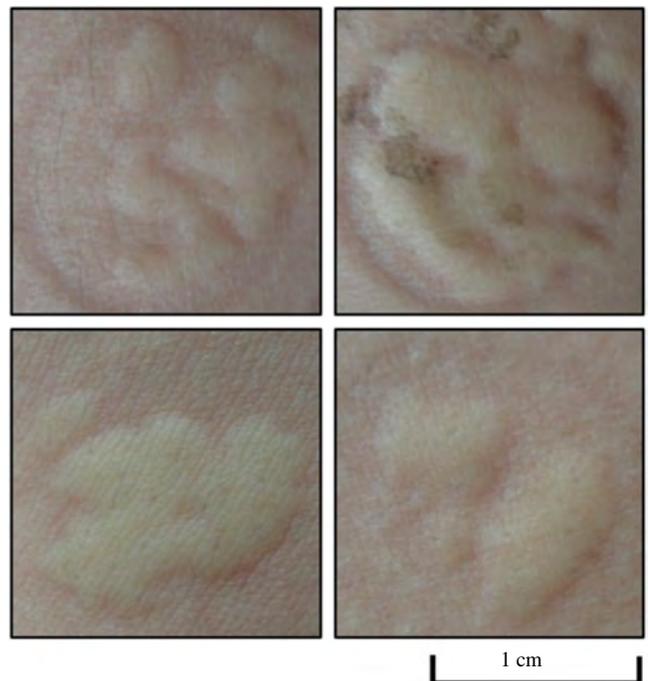


**Figure 2.** Various manifestations of wheals on the forearm.

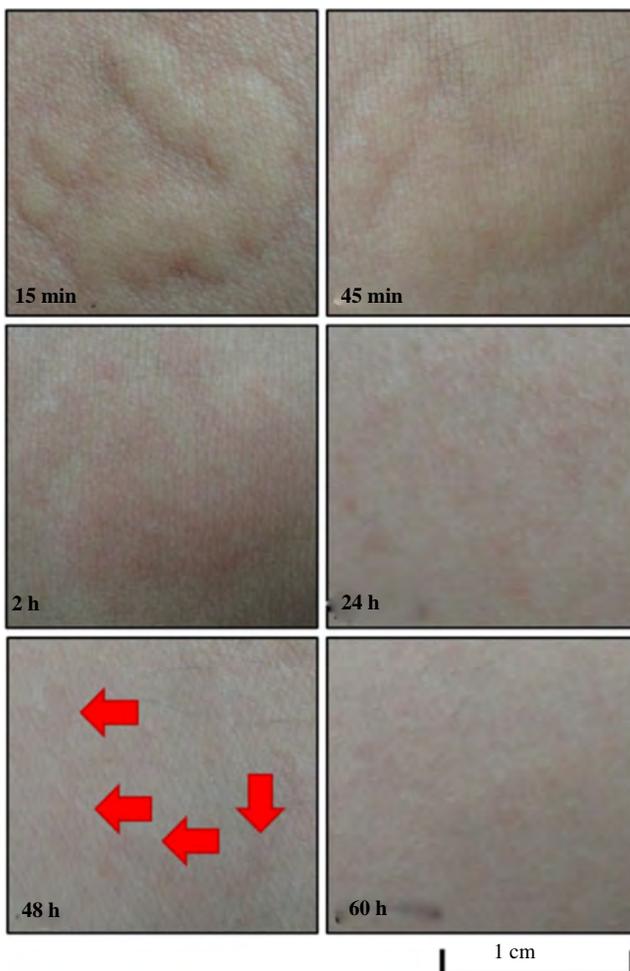
Lesions started to appear once the wheals flattened and the reddening of the skin became apparent. The lesions took the longest time to disappear and lasted several days (Figures 5–7). Five individuals (male and female) and three male individuals that fed on the shoulder recorded the longest time (84 h) for the lesions or redness to disappear completely. On the contrary, one individual, male or female, usually took the least time for the bite marks to disappear with one individual fed on the forearm recorded the shortest time (22 h) for the lesions to disappear entirely.



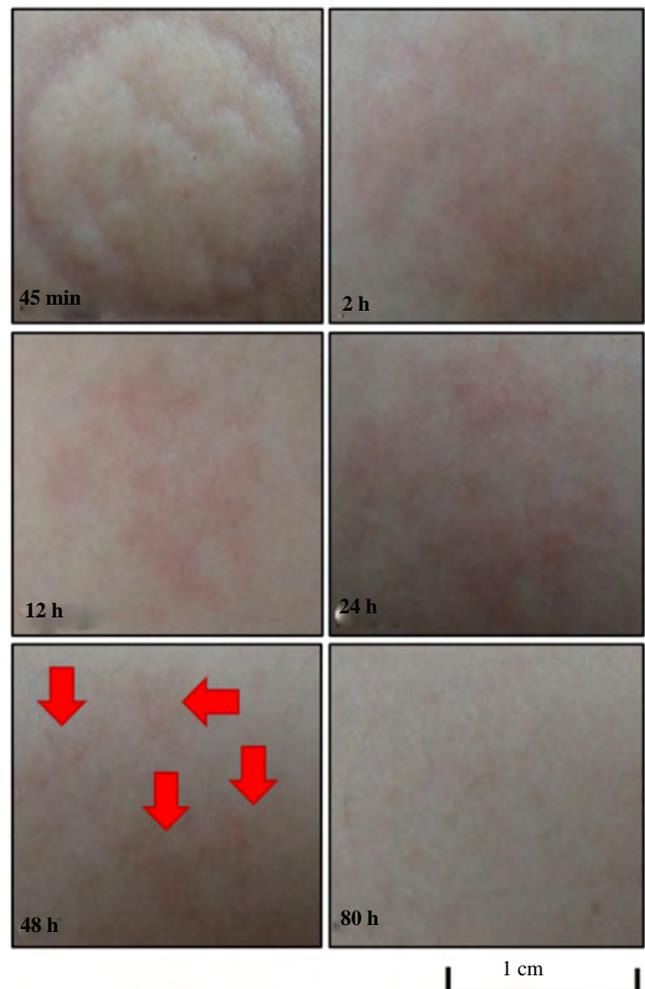
**Figure 3.** Various manifestations of wheals on the upper arm.



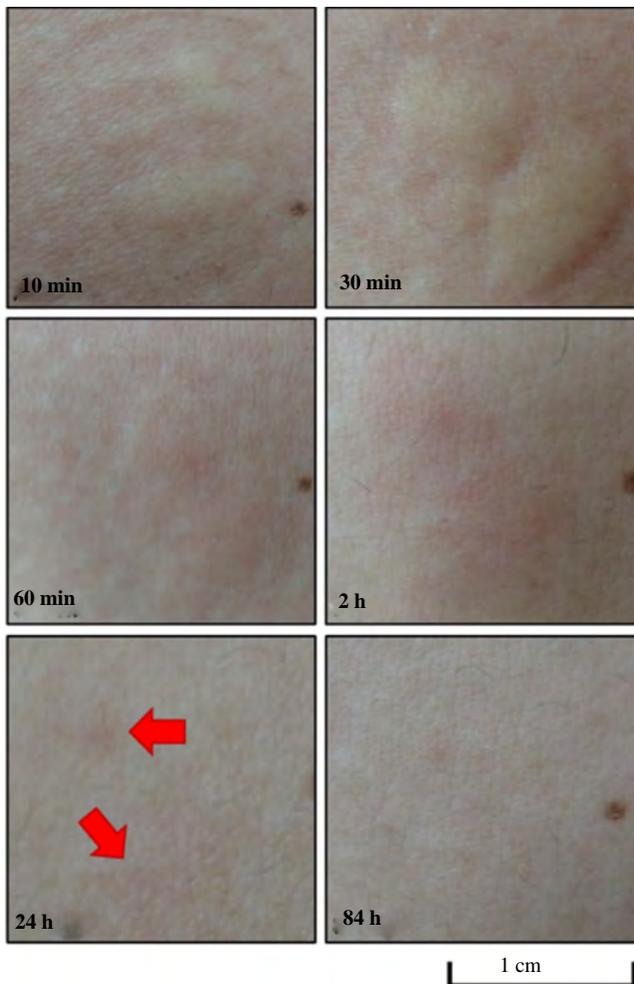
**Figure 4.** Various manifestations of wheals on the shoulder.



**Figure 5.** Manifestation of skin reactions on the forearm. Skin reactions started with itches and wheals. Once the wheals flattened, lesions can be seen and last for several days. Red arrows show that the lesions start to disappear, but still can be seen slightly.

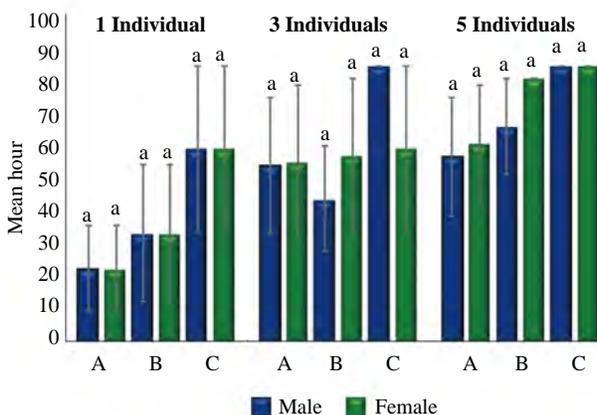


**Figure 6.** Manifestation of skin reactions on the upper arm. Skin reactions started with itches and wheals. Once the wheals flattened, lesions can be seen and last for several days. Red arrows show that the lesions start to disappear, but still can be seen slightly.



**Figure 7.** Manifestation of skin reactions on the shoulder. Skin reactions started with itches and wheals. Once the wheals flattened, lesions can be seen and last for several days. Red arrows show that the lesions start to disappear, but still can be seen slightly.

The statistical univariate analysis found that there was no significant difference between the time taken for the skin reactions on the forearm, upper arm and shoulder to disappear entirely (Figure 8). There was also no significant difference between the numbers of the individual. Furthermore, the statistical analysis found that there was no significant difference between males and females for each number of individuals as well as body parts.



**Figure 8.** Time taken for skin reactions to disappear. Bars with the same letter were not significantly different (ANOVA,  $P > 0.05$ ). A: Forearm; B: Upper arm; C: Shoulder.

#### 4. Discussion

Tropical bed bugs are one of the two ectoparasite species from the family of Cimicidae that feed solely on blood[1-4]. All the immature stages and both male and female of the adults require blood for nutrition, growth as well as reproduction, and it usually takes about 10 min to complete each feeding session[1,2,12]. Bed bugs have developed a modified mouth part located on the ventral side of the head that consist of a triangular labrum, a 3-segmented labium, and a pair of mandible and maxillary needle-like stylets. The mandibular stylets are inserted into the skin of the host and the maxillary stylets enter the wound[4,13]. During feeding, the saliva which contains various protein fractions that have anticoagulant properties runs down into the puncture and prevents the clotting of blood which is subsequently sucked up[3,4,7].

The need for blood feeding requires the piercing of the skin and sucking up of the blood from various hosts including human. Bed bugs are nocturnal insects, thus blood feeding normally occurs at night when people are sleeping[1-3,14]. Bed bugs most frequently bite on any area of the skin that is exposed during sleeping as clothing can prevent bed bug bites[7]. The body parts that are often exposed during sleep include the face, neck, arms and legs as well as abdomen for most men. This study chose three of those parts as the parts could be accessed easily in the laboratory for observations and photographed. The skin of human varies in thickness in different parts of the body and usually thicker on the posterior than anterior aspects of the body. The skin provides protection from mechanical injury, acts as a barrier against harmful agents such as fumes and blood-sucking insects, and provides information about the external environment[15].

Most people started to notice that they had been bitten by blood-sucking insects when a pruritic, red wheal started to appear on the biting sites. This often occurs after a few feedings by a particular blood-sucking insect species such as bed bugs, mosquitoes, and some species of flies and fleas[9]. Even though bed bugs' bites are usually never felt, biologically active proteins, non-proteinaceous molecules and enzymes secreted together with their saliva may cause progressive, allergenic, visible symptomatic skin reactions to the repeated bites[5,7,16-18]. After affecting by the bed bug bites, the main skin reactions manifested on live animal and human hosts have led to the development of an artificial feeding system to reduce the dependence on the live host, human or animals by using alternative blood sources such as expired donor blood[19,20].

This study explored the skin reactions that would appear on three parts of human bodies, the forearm, upper arm, and shoulder, when a various number of individuals fed on that particular body part. We also investigated the effect of male and female bites on those body parts. Although the statistical analysis by SPSS software showed no significant differences between those factors

statistically, there were still some differences observed between the time taken for the skin reactions to disappear when one, three and five individuals fed on different body parts. Harlan wrote that immediate reactions may appear from 1 to 24 h after a bite and may last 1–2 days while delayed reactions usually appeared 1–3 days or more after a bite and may last up to 2–5 days[3]. In this study, the itch or the desire to scratch the bite area disappeared after about 15 min for all body parts. However, the lesions that manifested from the bites of 5 individuals, male and female, on the shoulder lasted for 84 h (about 3 days). The same result occurred when 3 male bed bugs fed on the shoulder.

Five females took a longer period for the skin reactions to disappear completely as compared to five males that fed on the upper arm. On the other hand, a longer time is needed for the skin reactions to disappear when 3 males of tropical bed bugs fed on the shoulder as compared to 3 females on the same body part. Most of the studies regarding bed bug bites were associated with *Cimex lectularius* (*C. lectularius*) and the reports usually did not state the source of the bite, whether the skin reactions caused by males or females, as well as which life stage was used, instar or adult[1,7,21]. Goddard *et al.* observed the development of cutaneous lesions caused by 4 adult bed bugs on the forearm of both right and left hands[12]. They reported that the bite lesions on both arms resolved after 10 days, but faint erythema remained visible on the bite area. On the contrary, lesions manifested on the forearm from this study resolved entirely in less than 3 days (about 60 h).

All body parts tested did not produce delayed reactions since no skin reactions were manifested after all the immediate reactions disappeared completely. Reinhardt *et al.* reported that one group of volunteers produced symptoms 7–11 days after the first bed bug bites and 2–3 days later for the second bites. In contrast, the other group of volunteers did not show any skin reactions within 2–20 weeks of the first bites, but manifested skin reactions within 6–11 days of the second bed bug bites. Reinhardt *et al.* also reported that only one person out of 24 volunteers showed no skin reactions towards the bed bug bites even after being subjected to three successive experimental bites[22]. A study at an infested camp of internally displaced persons in Freetown, Sierra Leone found that out of 221 individuals, 86% of them had wheals from the bites. However, they did not state which species caused the skin reactions as the place was infested with two species of bed bugs, *C. hemipterus* and *C. lectularius*, and no attempt was made to differentiate the relative skin manifestations from the bites of the two species[23]. As of 2012, the differences in clinical reactions from the bites of the two species of bed bugs associated with humans have never been investigated[7].

The severity of the skin reactions manifested from the bed bug bites varies between individuals. The manifestations may start out as small indistinct red macular lesions less than 5 mm in diameter,

which may later progress into large circular or ovoid wheals usually described as popular urticaria and may be as big as 2–6 cm in diameter. These lesions tend to be intensely itchy. Although the wheals have been reported to be up to 20 cm in diameter, it is possible that such reactions could have resulted from multiple bites or trauma on the bites through scratching, thereby increasing the size of the lesions[1,7,21]. In this study, the skin reaction started out as wheals where the skin of the bite area became swollen, associated with itchy sensation, but soon disappeared or flattened after about an hour. Only then would the lesions or reddening of the skin start to appear and last for several days. The wheals and lesions were not very big for only five individuals of bed bugs were used at the most.

Apart from the skin reactions, bed bug bites and infestations have caused various psychological effects on people. Mental health impacts may include stress, anxiety, fatigue, nightmares, hypervigilance, avoidance behavior, personal dysfunction and psychosocial functioning[1,7,8,12,24,25]. Goddard and deShazo reported that some of these psychological effects developed as people tried to avoid places, people and activities that might transmit the bed bugs. They also reported that 5 posting from the Internet detailed suicide thoughts or attempts[25]. In another case, a woman with previous psychiatric morbidity jumped to her death following repeated bed bug infestations in her apartment[26]. The case reported that the bed bug infestations were the likely trigger for the onset of a negative psychological state that ultimately led to the suicide.

Since bed bugs are obligatory blood feeder, there were concerns whether they could transmit any pathogens or diseases. The transmission of these harmful agents is possible through salivary gland and their feces which may contain the living pathogens thus releasing those noxious agents into the human environment[21,27]. However, there are no definitive reports of pathogens transmitted by Cimicidae to human so far. There were several studies that showed the possibility of their future roles in the field of vector-borne diseases and even recent reports attributed that nearly 45 microbes are transmissible by *C. lectularius* but without enough evidences of diseases arising from that transmission[11,21,28-30].

Skin reactions caused by bed bug bites may occur variedly for different parts of the human body. Skin reactions from bed bug bites on the shoulder took the longest time to disappear and five individuals of bed bugs produced skin reactions that took a longer time to disappear as compared to one and three individuals of bed bugs. Further study could investigate the manifestations of skin reactions on the other body parts such as the face, neck, back and leg. In addition, another study could investigate the effect of bed bug bites between groups of people which will give more insight on sensitivity as well.

## Conflict of interest statement

We declare that we have no conflict of interest.

## Acknowledgments

The authors would like to thank Universiti Sains Malaysia for funding the research (Short Term Grant: 304/PBIOLOGI/6313030).

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