Risk Factors Associated with Bedbug (Cimex spp.) Infestations Among Hong Kong Households: A Cross-Sectional Study

Hin Chung Eddy Fung (edfung98@gmail.com)
The Chinese University of Hong Kong The Jockey Club School of Public Health and Primary Care
https://orcid.org/0000-0002-2410-4037

Hung Wong
The Chinese University of Hong Kong Department of Social Work

Siu Wai Chiu
The Chinese University of Hong Kong School of Life Sciences

Jerome Ho Lam Hui
The Chinese University of Hong Kong School of Life Sciences

Hon Ming Lam
The Chinese University of Hong Kong School of Life Sciences

Roger Yat-nork Chung
The Chinese University of Hong Kong The Jockey Club School of Public Health and Primary Care

Samuel Yeung-shan Wong
The Chinese University of Hong Kong The Jockey Club School of Public Health and Primary Care

Siu Ming Chan
The Chinese University of Hong Kong Department of Social Work

---

Research Article

Keywords: Bedbug, Cimex spp., Infestation, health disparity, risk factors, Hong Kong

Posted Date: September 8th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-80113/v2

Abstract

To investigate the risk factors associated with bedbug infestations among Hong Kong households, self-reported questionnaires in Chinese were distributed online between June 2019 to July 2020. The questionnaire collected data on participants' sociodemographics, history of bedbug infestation, and housing situation. Among the 663 participants who completed the questionnaire, 422 (63.7%) have experienced bedbug infestations in the past year, they were concentrated around the Kowloon region. Weighted bivariate and multivariate binary logistic regression were performed to identify the statistically significant (p-value <0.05) factors associated with bedbug infestations. Bivariate analysis shows a positive correlation between the number of reported dilapidated housing features and bedbug infestation. For multivariate analysis, those aged 45-64 (OR=2.53, 95% CI 1.30-4.91), have primary education or below (OR=9.43, 95% CI 3.12-28.44), and monthly household income ≤HKD30,000 (OR=1.69, 95% CI 1.15-2.5) were more likely to have bedbug infestation compared to their respective reference groups, i.e., ≥65, tertiary education, and >HKD30,000; housing risk factors identified are living in subdivided flats (OR=16.53, 95% CI 1.01-269.72), crowded household (OR=1.55, 95% CI 1.06-2.28), having second-hand furniture (OR=2.97, 95% CI 1.16-7.58), housing cleanliness issues (OR=2.66, 95% CI 1.13-6.25), and presence of bedbugs in neighbouring residential units (OR=3.32, 95% CI 1.57-7.04) or on the streets (OR=1.9, 95% CI 1.12-3.23). This study has identified lower income, lower education level, crowded household, living in subdivided flats, and certain dilapidated housing features to be risk factors of bedbug infestations; efforts and policies should prioritise vulnerable groups and focus on addressing the housing risk factors identified in this study.

Background

Bedbugs (*Cimex* spp.) are nocturnal ectoparasites that feed on human blood (Cannet et al., 2015). One inseminated adult female bedbug can start an infestation alone by laying 0.64 eggs per day on average, with the bedbug population doubling in size approximately every 13 days (Polanco et al., 2011). The United States Environmental Protection Agency (US EPA) has deemed bedbugs to be a "pest of significant public health importance" (USEPA, 2010); bedbug infestations disproportionately affect vulnerable households often with multiple disadvantages (Sutherland et al., 2020; Cooper et al., 2016; Eddy and Jones, 2011; Harlan et al., 2007; Wang et al., 2018). The global bedbug resurgence since the 1990s has been attributed to several factors including human population growth and urbanization (Davies et al., 2012; Wang and Wen, 2011; Zorrilla-Vaca et al., 2015). These factors strain housing systems leading to more deprived housing with dilapidated housing features that provide favourable conditions for the spread of bedbug infestation such as cracks in walls, peeling wallpaper, and crowded housing (Eddy and Jones, 2011; Godfrey and Julien, 2005; Harlan et al., 2007). The effect of different building types on the risk of bedbug infestation is worth further investigation since certain building characteristics may pose higher risks (Ralph et al., 2013); the identification of bedbug infestation risk factors can inform initiatives and policies to tackle household vulnerabilities for bedbug infestations and the global bedbug resurgence.

Bedbug infestations occur when their population grows out of control causing adverse health effects and financial burden to the building occupants (Davies et al., 2012; Harlan et al., 2007; USEPA, 2010; Zorrilla-Vaca et al., 2015). Bedbug bites may occur in a linear pattern on exposed skin while the host is asleep or still, these usually result in multiple itchy sores where bites occur (Doggett and Russell, 2009; Parola and Izri, 2020; Thomas et al., 2004; Zorrilla-Vaca et al., 2015). In severe cases, the bites may result in bullous eruptions (deShazo et al., 2012) and excessive blood lost to blood meals may result in anaemia (Doggett and Russell, 2009; Zorrilla-Vaca et al., 2015). Bedbug infestations may result in a broad range of psychosocial disorders including anxiety, depression, and insomnia (Ashcroft et al., 2015; Parola and Izri, 2020).

Bedbug infestations pose a significant economic burden to households and businesses (Harlan et al., 2007; Scarpino and Althouse, 2019). Based on the authors' calculations, hiring a professional exterminator in Hong Kong per household infestation typically ranges from HKD3000 to 30,000 (around USD390 to 3,900) depending on the infestation severity, treatment types, living floor area, and other factors. For reference, the 2019 median monthly household income for all households in Hong Kong is HKD28,700 (around USD3,700) (Census and Statistics Department HKSAR, 2020). For businesses or facilities such as hotels or hospitals, the cost per infestation may be upwards of HKD200,000 (around USD26,000). Low-income households may not afford to hire exterminators or replace infested belongings.

The housing situation in Hong Kong offers a unique set of environmental factors that are hypothesized to facilitate the local and international spread of bedbugs; these include crowded living environments, presence of dilapidated housing, and vastly different accommodations (Ma et al., 2018; Jayantha and Hui, 2012; Wong and Chan, 2019). Hong Kong is one of the most densely populated cities in the world (Chan, 1999; Hui and Yu, 2013), exacerbated by rising housing prices and rent, worsening housing conditions, and the financialisaton of housing (Aalbers, 2017; Boyer, 2000; Fernandez and Aalbers, 2016; Smart and Lee, 2003). According to a survey conducted by Demographia (2019), the houses in Hong Kong were the most unaffordable among 293 metropolitan housing markets in the world. The shortage of housing and escalating housing prices and rent have forced families to live in tiny flats or rooms with poor housing environment. The median living area per capita in Hong Kong is 161.5 ft^2 or around 15.0 m^2 (Census and Statistics Department HKSAR, 2018). Although the Hong Kong government fully recognize the housing issues, housing problems still have not been solved.

Subdivided flats are a unique housing type in Hong Kong that are formed from the splitting of a residential unit into two or more subdivisions; these subdivisions are crowded, and have many dilapidated features such as cracks in partitions or peeling wallpaper (Census and Statistics Department HKSAR, 2018; Yau and Ho, 2017). In 2016, households living in subdivided flats have median living floor area per capita of 56.5 ft^2 and median monthly household income of HKD13,500 (around USD1,700), both are lower than their respective medians for all domestic households (Census and Statistics Department HKSAR, 2018). The formation of subdivided flats is driven by the constraints on developable land and the rising demand for housing from the influx of economic migrants and a growing and aging

population. The marginalised residents of subdivided flats often possess many health-related risk factors and socioeconomic disadvantages from having one or a mixture of low income, low education level, being elderly, migrant status, or rental inflation that outpace their salary increase (Li, 2001; Wong and Chan, 2019; Yau and Ho, 2017). Therefore, the building and occupant characteristics of subdivided flats are likely risk factors for the spread of bedbug infestations in Hong Kong (Cheung, 2017; Ting, 2019). Furthermore, reports suggests that bedbug infestations in subdivided flats are contributing to a wider social issue of their occupants sleeping at 24-hour fast food restaurant to avoid bedbug bites (NowTv, 2019; Ting, 2019).

Bedbug infestations are largely neglected in Hong Kong despite being a public health threat due to 1) the perception that bedbugs pose an insignificant health concern compared to other pests such as mosquitoes; 2) those affected by bedbugs being unlikely to report or seek help for several reasons such as shame, and the lack of means or know-how; and 3) the perception that bedbug infestations are a personal hygiene instead of a public health issue, assigning blame onto individuals and their households rather than addressing social disparities (Cheung, 2017; Ting, 2019).

Although dilapidated housing features may manifest similarly in different countries, the unique features of Hong Kong's housing situation and the effect of the local context on socioeconomic disadvantages may affect Hong Kong's bedbug issue differently. Studies have been done previously in the US that identified lower income (Sutherland et al., 2020; Gounder et al., 2014; Ralph et al., 2013; Sheele et al., 2019), lower education level (Sheele et al., 2019), and crowded or high occupancy households (Sutherland et al., 2020; Gounder et al., 2014; Ralph et al., 2013) to be risk factors for bedbug infestation. However, no formal study has been done to investigate risk factors for bedbug infestation in Hong Kong. To provide insight into the bedbug situation in Hong Kong and inform initiatives and policies against bedbug infestations and the surrounding issues, this study aims to identify the risk factors associated with bedbug infestations among Hong Kong households.

Methods

Study site

This study used a population-based cross-sectional study design and was conducted in the Hong Kong Special Administrative Region (HKSAR), China. As shown in Figure 1, Hong Kong is divided into 3 regions which are further divided into 18 districts (Rating and Valuation Department HKSAR, 2013).

Data collection and sampling method

Data collection occurred between June 2019 to July 2020. Data was collected using online self-reported questionnaires in Chinese which collected data on participants' sociodemographics, history of bedbug infestation, and housing situation. Appendix 1 shows the translated English version of the questionnaire used. Self-reported questionnaires have been used in previous studies to investigate the risk factors for

bedbug infestations (Ralph et al., 2013). Participants were eligible to participate if they lived in Hong Kong and were aged 18 or above. The questionnaire was piloted by 2 pilot testers who met the eligibility criteria and adjusted based on their comments. The questionnaire was created by using Google Forms, and its electronic link was broadcast on discussion forums and social media pages of different districts in Hong Kong. Volunteer sampling was used to recruit participants. A total of 696 participants completed the questionnaire; this is beyond the minimum sample size of 617 which was determined by an a priori power analyses using z tests for logistic regression in G*Power 3.1 (Faul et al., 2009).

Measurements

For the first question in the questionnaire, “In the past year, how often did you see bedbugs in your place of residence?”, responses ranged from “never” to “very often” on a five-point Likert scale. This variable was transformed into a dichotomous dependent variable, “bedbug infestation”, with “never” being “no” and all other responses being “yes”. A picture of a bedbug was provided to remind participants of its appearance and minimize its erroneous recognition.

Crowded household was measured using a pseudo-quantitative method. Participants were asked whether they felt that their residence lacked space or is crowded (given the variable name “feeling crowded”), their living floor area (ft^2), and household size. Data from these variables were used to compute the dichotomous variable “crowded household” defined as those who felt that their residence lacked space or is crowded, or those with living floor area per capita $\leq$120 ft^2/person. The cut-off of $\leq$120 ft^2/person was chosen since less than 25% of the sample met the criteria. Living floor area per capita was computed by taking the upper bounds of each interval responses for living floor area and dividing that by the household size. For living floor area of >900 ft^2, the upper bound was taken as 1200 ft^2, and household size $\geq$5 was taken as 5.

Participants selected their housing type and dilapidated housing features from lists created based on the literature. Participants’ sex, age, education level, monthly household income (HKD), and district were also collected. All variables were collected as categorical variables.

Participants had the option to leave their contact information if they were willing to participate in future bedbug related research. Seven participants were contacted, and the researchers visited their residence to make observations and take photographs of their housing situation within the study period.

Statistical analysis

A choropleth map of self-reported bedbug infestation cases by district was made. Data analysis was performed using IBM SPSS 24. Weighting by age and sex was applied to the analysis using census data for the end of 2019.

Bivariate logistic regression using chi-square test for categorical variables was used to identify variables associated with bedbug infestation. All variables were considered for inclusion in the multivariate logistic regression to investigate their effects on the odds of bedbug infestation, except for “number of dilapidated housing features” since the analysis was interested in the association between the existence of certain dilapidated features and bedbug infestation, and to avoid multicollinearity. Covariates were entered using the forward conditional method if $p<0.05$ and retained if $p<0.1$. Effect estimates for the covariates in the bivariate and multivariate analysis are presented as odds ratio (OR) with their corresponding 95% confidence interval (CI). Statistical significance was considered if $p<0.05$.

Hosmer-Lemeshow goodness-of-fit test and multicollinearity diagnostics were performed on the final model of the multivariate regression. The model does not violate the goodness-of-fit assumption if $p>0.05$. Multicollinearity was considered if the covariates had variance inflation factors (VIF)$\geq$10, or their absolute value of the Pearson correlation coefficient $|r|\geq 0.7$ (Dormann et al., 2013).

Results

The questionnaire received a total of 696 participants; they were all included in the analysis. The sample size included in the multivariate regression after listwise deletion of missing variables is 663 (95.3%), which is beyond the minimum required sample size of 617. Seven participants underwent follow-up visits; Fig. 6 shows selected photographs taken at their place of residence.

Table 1
Frequency of self-reported bedbug infestation among participants

In the past year, how often did you see bedbugs in your place of residence? (N = 663)	**Weighted frequency (%)**	**95% CI**
Very often	100 (15.1)	12.3–17.8
Often	93 (14.1)	11.4–16.7
Sometimes	92 (13.9)	11.3–16.6
Rarely	137 (20.6)	17.6–23.7
Never	241 (36.3)	32.6–39.9

In Table 1, responses for the first question in the questionnaire, “In the past year, how often did you see bedbugs in your place of residence?”, were transformed into the variable “bedbug infestation” with “never” being “no” and all other responses being “yes”, 422 (63.7%) participants have experienced bedbug infestation in the past year.

Choropleth map

Figure 1 shows the number of self-reported bedbug infestation cases in Hong Kong by district between June 2019 to July 2020. Kwai Tsing (61), Kwun Tong (48), Sham Shui Po (46), Kowloon City (42) and Shatin (41) districts had the highest number of reported bedbug infestations. The distribution of self-reported bedbug infestations was concentrated around the Kowloon region. Due to the small number of responses in some districts, the 18 districts were regrouped into 3 regions (Hong Kong Island, Kowloon, and New Territories) for analysis in bivariate and multivariate regression.

Bivariate analysis

Table 2
Bivariate analysis between bedbug infestation and participant characteristics

	Weighted bedbug infestation (%)	OR (95% CI)[a]	p-value[a]
Sex (N = 662)			
Female (ref.)	228 (63.3)	1.04 (0.76–1.44)	0.788
Male	194 (64.2)		
Age (N = 663)			0.006
0–24	72 (52.2)	0.4 (0.24–0.68)	< 0.001
25–44	126 (64.3)	0.66 (0.4–1.09)	0.101
45–64	137 (65.2)	0.68 (0.41–1.11)	0.124
≥65 (ref.)	87 (73.1)		
Education level (N = 664)			< 0.001
Primary education or below	63 (92.6)	10.56 (4.11–27.11)	< 0.001
Secondary education	152 (69.7)	1.87 (1.32–2.67)	< 0.001
Tertiary education (ref.)	208 (55)		
Monthly household income (N = 664)			< 0.001
< HKD10,000	74 (74.7)	3.13 (1.56–6.27)	0.001
HKD10,000–30,000	188 (73.7)	2.99 (1.65–5.43)	< 0.001
HKD30,001–50,000	82 (52.9)	1.2 (0.65–2.21)	0.566
HKD50,001–80,000	52 (52.5)	1.18 (0.61–2.27)	0.629
> HKD80,000	27 (48.2)		
Monthly household income ≤ HKD30,000 (No = ref.) (N = 663)	261 (73.9)	2.63 (1.9–3.64)	< 0.001

[a]N=663 for all bivariate logistic regression models.

	Weighted bedbug infestation (%)	OR (95% CI)[a]	p-value[a]
Region (New Territories region = ref.)			0.013
Hong Kong Island region (N = 662)	33 (70.2)	1.62 (0.84–3.11)	0.149
Kowloon region (N = 663)	179 (69.6)	1.62 (1.16–2.28)	0.005
New Territories region (N = 662)	210 (58.7)		
Crowded household (N = 663)	177 (72)	1.81 (1.29–2.55)	< 0.001
Feeling crowded (N = 662)	142 (72.1)	1.69 (1.18–2.43)	0.004
Living floor area per capita ≤ 120 ft^2/person (No = ref.) (N = 663)	89 (72.4)	1.64 (1.07–2.54)	0.024
Living floor area (ft^2) (N = 660)			0.001
≤300	118 (75.2)	2.63 (1.33–5.21)	0.005
301–600	209 (63.7)	1.53 (0.82–2.86)	0.177
601–900	70 (53.8)	1.02 (0.52–2.01)	0.947
>900	24 (53.3)		
Household size (N = 663)			< 0.001
1	59 (84.3)	2.15 (0.98–4.71)	0.057
2	83 (62.4)	0.66 (0.38–1.17)	0.155
3	106 (62.4)	0.66 (0.38–1.14)	0.134
4	106 (54.4)	0.47 (0.28–0.8)	0.005
≥5	68 (71.6)		
Housing type (No = ref.)			

[a]N=663 for all bivariate logistic regression models.

	Weighted bedbug infestation (%)	OR (95% CI)[a]	p-value[a]
Public rental housing (N = 664)	205 (71.4)	1.82 (1.31–2.53)	< 0.001
Home ownership scheme (N = 663)	45 (51.7)	0.56 (0.35–0.88)	0.011
Private housing (whole unit) (N = 662)	129 (56.3)	0.62 (0.44–0.86)	0.004
Subdivided flats (N = 664)	25 (96.2)	29.11 (1.83-461.92)	0.017
Village house (N = 662)	17 (56.7)	0.73 (0.35–1.51)	0.391
Non-profit-making organisation houses (N = 663)	1 (50)	1.11 (0.05–25.26)	0.946
Dorm room (government, worker, disciplined services) (N = 663)	1 (50)	0.39 (0.02–7.2)	0.525
Wooden house (N = 663)	0 (0)		1
Number of dilapidated housing features (N = 664)		1.28 (1.18–1.39)	< 0.001
0	80 (51.9)		
1	68 (50)		
2	79 (69.9)		
3	52 (62.7)		
4	46 (80.7)		
5	38 (77.6)		
6	19 (70.4)		
≥7	41 (91.1)		
Dilapidated housing features (No = ref.)			
Lack privacy (within the house and between neighbours) (N = 662)	78 (69.6)	1.37 (0.89–2.13)	0.155
Insufficient sunlight during the day (N = 663)	79 (75.2)	1.9 (1.19–3.06)	0.008
Light pollution at night (N = 663)	28 (73.7)	1.6 (0.76–3.34)	0.213

[a]N=663 for all bivariate logistic regression models.

	Weighted bedbug infestation (%)	OR (95% CI)[a]	p-value[a]
Too hot in summer or too cold in winter (N = 664)	124 (69.7)	1.43 (0.99–2.07)	0.055
No air conditioner, fan, or heater (N = 663)	11 (91.7)	6.28 (0.83–47.61)	0.075
High humidity or leaking/dripping water (N = 663)	139 (70.9)	1.59 (1.11–2.28)	0.012
Old or dirty walls, furniture, or belongings (besides having bedbugs) (N = 663)	125 (73.5)	1.84 (1.25–2.7)	0.002
Second-hand furniture (N = 663)	39 (86.7)	3.99 (1.67–9.54)	0.002
Wallpaper or ceiling paint peeling, or rebar showing through walls (N = 664)	90 (76.3)	2.09 (1.32–3.31)	0.002
Poor ventilation (N = 662)	64 (68.8)	1.3 (0.81–2.07)	0.275
Strange odour (N = 663)	65 (74.7)	1.79 (1.07–2.99)	0.026
Rodent infestation (N = 663)	44 (83)	2.87 (1.39–5.92)	0.004
Noisy or have noise problems (N = 663)	72 (72.7)	1.66 (1.03–2.66)	0.037
Stranger or new resident moved in (N = 664)	31 (66)	1.13 (0.6–2.13)	0.695
Housing cleanliness issues (besides having bedbugs) (N = 662)	50 (87.7)	4.26 (1.93–9.4)	< 0.001
Residential unit originally had bedbugs (N = 664)	19 (86.4)	3.65 (1.06–12.53)	0.04
Presence of bedbugs in neighbouring residential units (N = 663)	75 (89.3)	5.29 (2.63–10.64)	< 0.001
Presence of bedbugs on the streets (N = 663)	98 (80.3)	2.77 (1.72–4.48)	< 0.001

[a]N=663 for all bivariate logistic regression models.

Table 2 shows that the sociodemographic variables significantly associated with bedbug infestation were age, education level, monthly household income, and region ($p < 0.05$). Sex was not significantly associated with bedbug infestation. Those in the age group 0–24 were less likely to have bedbug

infestation while those with lower education level and lower monthly household income were more likely to have bedbug infestation. Only those in income groups < HKD10,000 ($p = 0.001$) and HKD10,000–30,000 ($p < 0.001$) were more likely to have bedbug infestation compared to the reference category, >HKD80,000. Thus, monthly household income was recoded into a dichotomous variable “monthly household income ≤ HKD30,000” ($p < 0.001$) and included in the multivariate regression. Compared to living in the New Territories region, living in the Hong Kong Island region was not significantly different, but living in the Kowloon region ($p = 0.005$) was more likely to have bedbug infestation.

Crowded household ($p < 0.001$) and the variables that were used to derive it i.e. feeling crowded ($p = 0.004$), living floor area per capita ≤ 120 ft^2/person ($p = 0.024$), living floor area ($p = 0.001$), and household size ($p < 0.001$) were significantly associated with bedbug infestation. There was a negative correlation between living floor area and percentage of bedbug infestation (Fig. 2). Those living in ≤ 300 ft^2 ($p = 0.005$) were more likely to have bedbug infestation than the reference category, > 900 ft^2. However, the relationship between household size and percentage of bedbug infestation appears to peak at the extremes (Fig. 3). When dividing the upper bounds of the intervals for living floor area by that of household size to compute living floor area per capita, the negative correlation with percentage of bedbug infestation was retained (Fig. 4).

The housing types significantly associated with bedbug infestation were public rental housing ($p < 0.001$), home ownership scheme ($p = 0.011$), private housing (whole unit) ($p = 0.004$), and subdivided flats ($p = 0.017$). Those living in public rental housing and subdivided flats were more likely to have bedbug infestation, whereas those living in home ownership scheme and private housing (whole unit) were less likely.

Participants who reported more dilapidated housing features were significantly more likely to report bedbug infestation ($p < 0.001$) (Fig. 5). The dilapidated housing features that increased the likelihood of bedbug infestation were insufficient sunlight during the day ($p = 0.008$) (Fig. 6a); high humidity or leaking/dripping water ($p = 0.012$) (Fig. 6b); old or dirty walls, furniture, or belongings ($p = 0.002$) (Fig. 6c); second-hand furniture ($p = 0.002$); wallpaper or ceiling paint peeling, or rebar showing through walls ($p = 0.002$) (Figs. 6b and 6d); strange odour ($p = 0.026$); rodent infestation ($p = 0.004$); noisy or have noise problems ($p = 0.037$); housing cleanliness issues (besides having bedbugs) ($p < 0.001$) (Fig. 6e); residential unit originally had bedbugs ($p = 0.04$); presence of bedbugs in neighbouring residential units ($p < 0.001$); and presence of bedbugs on the streets ($p < 0.001$).

Multivariate analysis

Table 3
Final model predicting bedbug infestation

Final model (N = 663)	OR (95% CI)	p-value
Age (≥ 65 = ref.)		0.007
0–24	1.26 (0.63–2.5)	0.517
25–44	1.92 (0.98–3.75)	0.056
45–64	2.53 (1.3–4.91)	0.006
Education level (Tertiary education = ref.)		< 0.001
Primary education or below	9.43 (3.12–28.44)	< 0.001
Secondary education	1.49 (1-2.22)	0.051
Monthly household income ≤ HKD30,000	1.69 (1.15–2.5)	0.008
Crowded household	1.55 (1.06–2.28)	0.024
Subdivided flats	16.53 (1.01-269.72)	0.049
Second-hand furniture	2.97 (1.16–7.58)	0.023
Housing cleanliness issues (besides having bedbugs)	2.66 (1.13–6.25)	0.024
Presence of bedbugs in neighbouring residential units	3.32 (1.57–7.04)	0.002
Presence of bedbugs on the streets	1.9 (1.12–3.23)	0.018
Constant	0.35 (0–0)	0.002

Table 3 shows the final model. Sociodemographic factors entered into the final model were age (p = 0.007), education level (p < 0.001), and monthly household income ≤ HKD30,000 (OR = 1.69, 95% CI 1.15–2.5, p = 0.008). Compared to those aged ≥ 65, the younger age groups 0–24 and 25–44 did not have significantly different ORs, but those aged 45–64 (OR = 2.53, 95% CI 1.30–4.91, p = 0.006) were more likely to have bedbug infestations. Those with primary education or below (OR = 9.43, 95% CI 3.12–28.44, p < 0.001) were more likely to have bedbug infestations compared to tertiary education.

Housing factors entered into the final model were crowded household (OR = 1.55, 95% CI 1.06–2.28, p = 0.024); subdivided flats (OR = 16.53, 95% CI 1.01-269.72, p = 0.049), second-hand furniture (OR = 2.97, 95% CI 1.16–7.58, p = 0.023); housing cleanliness issues (besides having bedbugs) (OR = 2.66, 95% CI 1.13–6.25, p = 0.024); presence of bedbugs in neighbouring residential units (OR = 3.32, 95% CI 1.57–7.04, p = 0.002); and presence of bedbugs on the streets (OR = 1.9, 95% CI 1.12–3.23, p = 0.018). They were independent housing risk factors for bedbug infestations.

The final model was able to correctly predict 70.6% of bedbug infestations. The omnibus test of model coefficient for the final model was significant (p < 0.001); it was better at predicting bedbug infestations compared to the null model. The Cox and Snell, and Nagelkerke R square of the final model was 0.178

and 0.244 respectively. The Hosmer-Lemeshow test was not significant ($p = 0.597$); the goodness-of-fit assumption was not violated. Appendix 2 shows that the results for multicollinearity diagnostics of the final model were below the thresholds, VIF < 3 and $|r|<0.7$, there is no evidence of multicollinearity.

Discussion

This is the first empirical study to investigate the bedbug issue and its associated housing risk factors in Hong Kong. This study has identified crowded household to be an important risk factor for bedbug infestation, similar studies support this conclusion (Sutherland et al., 2020). However, this is different from the results in Gounder et al. (2014) which suggested crowded household to be a protective factor and household size to be a more important risk factor than crowdedness. The disagreement may be due to differences in study design and methodology; specifically, Gounder et al. (2014) defined crowded housing as having ≥ 2 occupants for every living room and bedroom, and Sutherland et al. (2020) defined it as having > 1.5 occupants per room. Moreover, Hong Kong's highly dense housing environment is different from Western countries. The crowdedness of the living situation may facilitate the propagation of bedbug infestations as human hosts become accessible by living in close proximity (Harlan et al., 2007).

The results of this study indicate that living in subdivided flats, which are formed from the splitting of a residential unit into two or more subdivisions and often neighbouring several others, is a risk factor for bedbug infestation. Other studies have found similar results, living in poor neighbourhoods and buildings with many adjacent housing units facilitate the spread of bedbugs via egress points such as electrical conduits or cracks in walls (Davies et al., 2012; Harlan et al., 2007; Ralph et al., 2013). Furthermore, subdivided flats are often occupied by people of low socioeconomic status which has been identified as a risk factor in previous studies (Gounder et al., 2014; Sheele et al., 2019; Sutherland et al., 2020). The relationship between subdivided flats and bedbug infestations is further supported by the findings of this study showing that the number of self-reported bedbug cases are concentrated in the Kowloon region where over 50% of subdivided flats are located (Census and Statistics Department HKSAR, 2018). The combination of the building characteristics of subdivided flats and the sociodemographic characteristics of their occupants makes them especially vulnerable to bedbug infestations.

This study finds that participants who report more dilapidated housing features are more likely to report bedbug infestations. Particularly, having second-hand furniture, housing cleaning issues (besides having bedbugs), presence of bedbugs in neighbouring residential units, and presence of bedbugs on the streets are independently associated with bedbug infestations. Second-hand furniture has been suggested as a risk factor in other studies as they may harbour bedbugs from the previous owner (Davies et al., 2012; Gounder et al., 2014; Harlan et al., 2007; Ralph et al., 2013; Wang et al., 2010). Housing cleanliness issues may allow bedbugs to hide and be difficult to detect and eradicate which agrees with previous literature (Davies et al., 2012; Harlan et al., 2007; Zorrilla-Vaca et al., 2015). Having bedbugs in neighbouring residential units and on the streets may indicate the spreading of bedbugs in a community setting via hitchhiking or egress points such as cracks in walls or electrical conduits. Sheele et al. (2019) found that

knowing someone with bedbugs is also a risk factor for bedbug infestation. This complicates bedbug management as bedbugs may return from the wider community, even if adjacent units are treated for bedbugs. Addressing bedbugs may require the collective efforts of the wider community, not simply among neighbouring residential units or individual households.

With regards to the participants' sociodemographics, having higher education level is a protective factor against bedbug infestation, it may reflect knowledge on bedbug infestation management or the ability to access related assistance or information. A previous study by Sheele et al. (2019) also found that those with higher education level were less likely to have bedbug infestations. Older adults (45–64) are at greater risk since they may be more active, thus are more likely to be in contact with infested places or persons, facilitating the spread of bedbugs (Ralph et al., 2013; Sheele et al., 2019). This study finds that the elderly (≥ 65) have the greatest proportion of bedbug infestation; they may be more likely to suffer from disabilities and financial difficulties resulting in their inability to maintain household cleanliness and not afford bedbug management services (Gounder et al., 2014; Li, 2001). Having monthly household income ≤ HKD30,000 is a risk factor for bedbug infestation. In comparison, the 2019 median monthly household income of all economically active households in Hong Kong is HKD35,500 (Census and Statistics Department HKSAR, 2020), and the typical cost for hiring exterminators ranges from HKD3,000 to HKD30,000. Low-income households may not afford to hire bedbug exterminators or replace infested furniture and personal belongings. Committing to these costs may result in perpetual poverty as bedbugs may return, requiring multiple expensive treatments (Harlan et al., 2007). Furthermore, low-income households are more likely to participate in risky behaviours such as trading second-hand furniture or using communal laundries which may (re-)introduce bedbugs into their homes from the community (Gounder et al., 2014; Harlan et al., 2007; Ralph et al., 2013).

Limitations

Although weighting by age and sex was applied to the analysis, the sample may be non-representative of the Hong Kong population as the sampling method used was volunteer sampling using online self-reported questionnaires. Attempts were made to weight by district and housing type, or region and housing type; however, it was not possible to calculate the sample weights this way as the sample size was too small and some categories had zero frequencies. Online data collection meant that responses from disadvantaged or marginalised groups with limited internet access such as primary education or below, elderly (≥ 65 year olds), and occupants of subdivided flats may have been barred from participating, resulting in the reduced representativeness of these groups and their larger confidence intervals (Mascha and Vetter, 2018).

Online data collection made it difficult to comprehensively evaluate the participants' housing situation. The presence of certain housing factors depended on the participant's subjective view of their existence, for example the same housing unit may be considered to have housing cleanliness issues by one participant but acceptable to another. Participants selected dilapidated housing features from a list, although an "others (please specify)" option was available, protective factors were not investigated.

Furthermore, there was no way to confirm the existence of bedbug infestations or any of the participants responses, except for seven participants who underwent follow-up visits.

Although steps were taken to minimize the erroneous recognition of bedbugs by providing a picture on the questionnaire to remind them of its appearance, bedbug sightings by older participants may be inaccurately reported since previous studies have found that the elderly (> 60 year olds) are more likely to wrongly identify bedbugs from a picture compared to younger people in questionnaires (Sheele et al., 2019). Furthermore, participants may be predominantly reporting adult bedbug sightings and failing to identify smaller bedbugs in earlier instars, resulting in under-reporting (Sheele et al., 2017). A previous study by Wang et al. (2016) came across similar issues of under reporting where a high (49%) percentage of residents were unaware of the presence of bedbugs.

Social desirability may skew the responses towards lower reported bedbug infestations and housing risk factors since having them are associated with negative stereotypes such as being poor, uneducated, and unhygienic (Ashcroft et al., 2015; Cheung, 2017). However, people who do not have bedbugs may not report their situation since they may find the voluntary online questionnaire irrelevant to them, and vice versa for those who have bedbugs, resulting in an arbitrarily higher percentage of reported bedbug infestations; the results of this study may be biased towards those who have had bedbug infestations.

The cross-sectional study design was unable to establish the temporal sequence of events between bedbug infestations and the variables being investigated. Sociodemographic and housing factors are likely to have existed before the occurrence of the bedbug infestation. However, having bedbug infestations may result in some of these factors arising. For example, the signs of bedbugs (their faeces, carcass, and exuviae on walls or furniture) may be interpreted as having housing cleanliness issues.

Crowded and dilapidated housing features are likely to be manifested similarly in other settings. However, the generalisability of the results from this study may be limited by certain unique features of Hong Kong's housing situation such as housing related policies, housing types, and their specific building features, coupled with the effect of the immediate sociocultural, economical, and legal setting on the local manifestation of socioeconomic disadvantages. For example, what may be considered spacious housing in Hong Kong may be considered as cramped elsewhere.

Policy recommendations

There needs to be a shift in viewing bedbug infestations as a personal hygiene to a public health issue. Efforts and policies should be focused on alleviating crowded and dilapidated housing and providing adequate standards of living. This will directly address the global bedbug resurgence by removing its environmental facilitators and reverberate improvements to other aspects of life related to housing such as employment, education, and health. Efforts and policies should also prioritize vulnerable groups such as the elderly, low education level, low-income groups, and occupants of at-risk housing types such as subdivided flats.

Faced with the global threat of bedbug resurgence, simultaneous top-down and bottom-up approaches are required. Examples of top-down approaches are anti-poverty policies, increasing the supply and shortening the waiting time of public housing, and relief and cleaning services for those in deprived housing (Li, 2001; WHO, 2018; Wong and Chan, 2019; Yau and Ho, 2017). Bottom-up approaches focus on empowering and building resilience of the public to address bedbugs themselves, especially vulnerable groups at risk or already suffering from bedbugs. Educating low-income households to identify the early signs of bedbug infestations and to self-manage using integrated pest management (IPM) or affordable non-chemical control methods when infestation rates are still low prevents infestations from exacerbating and spreading, thus mitigates the expensive costs of hiring exterminators or replacing furniture and personal belongings (Alizadeh et al., 2020; Bennett et al., 2016; Cooper et al., 2016; Romero et al., 2017; Wang et al., 2018; Wang et al., 2012).

Conclusion

This study provides empirical evidence for crowded household, subdivided flats, and certain dilapidated housing features namely having second-hand furniture, housing cleanliness issues, and presence of bedbugs in neighbouring residential units or on the streets to be risk factors for bedbug infestations. Complex interaction between the housing features and sociodemographic vulnerabilities makes some housing types, such as subdivided flats, and their occupants at greater risk of bedbug infestation, disproportionately affecting vulnerable households often with multiple disadvantages. These sociodemographic vulnerabilities, including lower education and income, may act as barriers to bedbug infestation control through the inability to access information for managing bedbug infestations or afford pest control services – committing to these costs may result in perpetual poverty as bedbug extermination may require multiple treatments. Furthermore, low-income households are more likely to participate in risky behaviours such as trading second-hand furniture or using communal laundries which complicates the control of bedbug infestations as it may (re-)introduce bedbugs into their homes from the community. The housing features and sociodemographic characteristics of their occupants may differently affect the spread of bedbugs in the community and require supportive housing policies and the collective efforts of the wider community even if adjacent neighbouring units are treated for bedbugs. To better control the often-neglected issue of bedbug infestations, there needs to be a shift from viewing bedbug infestations as a personal hygiene to a public health issue. Efforts and policies should focus on addressing the housing risk factors identified in this study and prioritise vulnerable groups including the elderly, low education level, low-income groups, and occupants of subdivided flats.

Abbreviations

CI	Confidence interval
CUHK	The Chinese University of Hong Kong
HKD	Hong Kong Dollar
HKSAR	Hong Kong Special Administrative Region
IBM	International Business Machines Corporation
OR	Odds ratio
ref.	Reference category
SBREC	Survey and Behavioural Research Ethics Committee
SPSS 24	Statistical Product and Service Solutions version 24
USD	United States Dollar
US EPA	United States Environmental Protection Agency
VIF	Variance Inflation Factors
|r|	Absolute value of the Pearson correlation coefficient

Declarations

Funding

This study has received no funding.

Competing interests

The authors declare that they have no competing interests.

Ethics approval

This research has been approved by the Survey and Behavioural Research Ethics Committee (SBREC), of CUHK [Reference No. SBRE-19-778].

Consent to participate

Written informed consent was obtained from all participants in digital form. After accessing the link to the online survey, participants were shown a statement of consent which explains the purpose of the study, type of questions to be asked, eligibility criteria, data security, participant rights, and risks involved.

The questions to the online questionnaire were only shown after participants voluntarily select “Agree” then “next”.

Consent for publication

Not applicable

Availability of data and materials

Appendix 3 contains the deidentified dataset of participants’ responses used in data analysis for this research. In “Sheet 1”, the first row is the variable name and corresponds to the variables presented in the results section. The spaces in the variable names have been replaced with an underscore. Each column corresponds to a variable. Each subsequent row from the first represents a participant. Missing variables are entered as “999”. The column labelled “case_weight_age_sex” contains the case weightings by age and sex. “Sheet 2” shows the coding scheme for each variable.

Code availability

Not applicable

Authors’ contributions

Eddy Hin Chung Fung performed data collection, data analysis, and manuscript writing. Hung Wong conceptualized and coordinated the research. Siu Wai Chiu, Jerome Ho Lam Hui, Hon Ming Lam, and Siu Ming Chan provided scientific knowledge. Roger Yat-nork Chung and Samuel Yeung-shan Wong provided public health knowledge about bedbugs and research design on data collection and data analysis. All authors read, edited, and approved the final manuscript.

Acknowledgements

This study is part of a larger project entitled “Providing low-income residents with safe, effective, affordable and sustainable solutions in tackling bed bug problems” conducted by the Chinese University of Hong Kong (CUHK) Anti-Bedbug Research Action Group, composed of professors and students formed in January 2019. The authors extend their sincerest gratitude to the group of student volunteers from this group for their efforts in data collection.

References

Aalbers, M. B. (2017). The Variegated Financialization of Housing (Conference Paper). *International Journal of Urban and Regional Research*, 41(4), 542-554. doi:10.1111/1468-2427.12522.

Alizadeh, I., Jahanifard, E., Sharififard, M., & Azemi, M. E. (2020). Effects of Resident Education and Self-Implementation of Integrated Pest Management Strategy for Eliminating Bed Bug Infestation in Ahvaz City, Southwestern Iran. *J Arthropod Borne Dis*, 14(1), 68-77. doi:10.18502/jad.v14i1.2705.

Ashcroft, R., Seko, Y., Chan, L. F., Dere, J., Kim, J., & McKenzie, K. (2015). The mental health impact of bed bug infestations: a scoping review. *Int J Public Health*, 60(7), 827-837. doi:10.1007/s00038-015-0713-8.

Bennett, G. W., Gondhalekar, A. D., Wang, C., Buczkowski, G., & Gibb, T. J. (2016). Using research and education to implement practical bed bug control programs in multifamily housing. *Pest Manag Sci*, 72(1), 8-14. doi:10.1002/ps.4084.

Boyer, R. (2000). The political in the era of globalization and finance: Focus on some regulation school research. *International Journal of Urban and Regional Research*, 24(2), 274-322. doi:10.1111/1468-2427.00250.

Cannet, A., Akhoundi, M., Berenger, J. M., Michel, G., Marty, P., & Delaunay, P. (2015). A review of data on laboratory colonies of bed bugs (Cimicidae), an insect of emerging medical relevance. *Parasite*, 22, 21. doi:10.1051/parasite/2015021.

Census and Statistics Department HKSAR (2018). Hong Kong 2016 Population By-census - Thematic Report : Persons Living in Subdivided Units. https://www.bycensus2016.gov.hk/data/16BC_SDU_report.pdf. Accessed 21 Jan 2020.

Census and Statistics Department HKSAR (2020). Population and Household Statistics Analysed by District Council District 2019. https://www.statistics.gov.hk/pub/B11303012019AN19B0100.pdf. Accessed 21 Mar 2020.

Chan, Y. K. (1999). Density, crowding, and factors intervening in their relationship: Evidence from a hyper-dense metropolis. *Social Indicators Research*, 48(1), 103-124. doi:10.1023/A:1006944807696.

Cheung, R. (2017, 14 Jun). Is Hong Kong on the verge of a major bed bug epidemic? We talk to the experts and get some tips. *South China Morning Post*. Retrieved from https://www.scmp.com/lifestyle/health/article/2098227/hong-kong-verge-major-bed-bug-epidemic-we-talk-experts-and-get-some

Cooper, R. A., Wang, C., & Singh, N. (2016). Evaluation of a model community-wide bed bug management program in affordable housing. *Pest Manag Sci*, 72(1), 45-56. doi:10.1002/ps.3982.

Davies, T. G., Field, L. M., & Williamson, M. S. (2012). The re-emergence of the bed bug as a nuisance pest: implications of resistance to the pyrethroid insecticides. *Med Vet Entomol*, 26(3), 241-254. doi:10.1111/j.1365-2915.2011.01006.x.

Demographia (2019). 16th Annual Demographia International Housing Affordability Survey. http://www.demographia.com/. Accessed 25 May 2021.

deShazo, R. D., Feldlaufer, M. F., Mihm, M. C., Jr., & Goddard, J. (2012). Bullous reactions to bedbug bites reflect cutaneous vasculitis. *Am J Med*, 125(7), 688-694. doi:10.1016/j.amjmed.2011.11.020.

Doggett, S. L., & Russell, R. (2009). Bed bugs What the GP needs to know. *Australian Family Physician*, 38(11), 880-884.

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carre, G., et al. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography*, 36(1), 27-46. doi:10.1111/j.1600-0587.2012.07348.x.

Eddy, C., & Jones, S. C. (2011). Bed bugs, public health, and social justice: Part 1, A call to action. *J Environ Health*, 73(8), 8-14. https://www.ncbi.nlm.nih.gov/pubmed/21488465.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav Res Methods*, 41(4), 1149-1160. doi:10.3758/BRM.41.4.1149.

Fernandez, R., & Aalbers, M. B. (2016). Financialization and housing: Between globalization and Varieties of Capitalism. *Competition & Change*, 20(2), 71-88. doi:10.1177/1024529415623916.

Godfrey, R., & Julien, M. (2005). Urbanisation and health. *Clin Med (Lond)*, 5(2), 137-141. doi:10.7861/clinmedicine.5-2-137.

Gounder, P., Ralph, N., Maroko, A., & Thorpe, L. (2014). Bedbug complaints among public housing residents-New York City, 2010-2011. *J Urban Health*, 91(6), 1076-1086. doi:10.1007/s11524-013-9859-y.

Harlan, H. J., Faulde, M. K., & Baumann, G. J. (2007). Bedbugs. In X. Bonnefoy, H. Kampen, & K. Sweeney (Eds.), *Public Health Significance of Urban Pests* (pp. 131-153). Europe: World Health Organization.

Hui, E. C. M., & Yu, K. H. (2013). Commuting patterns of residents within a high-density urban development: A study of Hong Kong. *Habitat International*, 39, 201-213. doi:10.1016/j.habitatint.2012.12.008.

Jayantha, W. M., & Hui, E. C. M. (2012). Housing consumption and residential crowding in Hong Kong: a long-term analysis. *Journal of Facilities Management*, 10(2), 150-172. doi:10.1108/14725961211218785.

Li, P. K. (2001). Policy implications on assistance for the "caged elderly" in Hong Kong. *J Health Soc Policy*, 12(4), 35-52. doi:10.1300/J045v12n04_03.

Ma, S. Y. T., Chan, E. H. W., & Choy, L. H. T. (2018). Evolving institutions to tackle asymmetrical information problems in the housing market: A case study on 'shrinkage' of flat sizes in Hong Kong.

Habitat International, 75, 154-160. doi:10.1016/j.habitatint.2018.03.009.

Mascha, E. J., & Vetter, T. R. (2018). Significance, Errors, Power, and Sample Size: The Blocking and Tackling of Statistics. *Anesth Analg*, 126(2), 691-698. doi:10.1213/ANE.0000000000002741.

NowTv (2019). Now Report: Bedbug Disaster. https://www.youtube.com/watch?v=fgABkTklbho. Accessed 16 July 2020.

Parola, P., & Izri, A. (2020). Bedbugs. *N Engl J Med*, 382(23), 2230-2237. doi:10.1056/NEJMcp1905840.

Polanco, A. M., Brewster, C. C., & Miller, D. M. (2011). Population Growth Potential of the Bed Bug, *Cimex lectularius* L.: A Life Table Analysis. *Insects*, 2(2), 173-185. doi:10.3390/insects2020173.

Ralph, N., Jones, H. E., & Thorpe, L. E. (2013). Self-Reported Bed Bug Infestation Among New York City Residents: Prevalence and Risk Factors. *Journal of Environmental Health*, 76(1), 38-45.

Rating and Valuation Department HKSAR (2013). Areas and Districts. https://www.rvd.gov.hk/doc/tc/hkpr13/06.pdf. Accessed 23 May 2021.

Romero, A., Sutherland, A. M., Gouge, D. H., Spafford, H., Nair, S., Lewis, V., et al. (2017). Pest Management Strategies for Bed Bugs (Hemiptera: Cimicidae) in Multiunit Housing: A Literature Review on Field Studies. *Journal of Integrated Pest Management*, 8(1), 1-10. doi:10.1093/jipm/pmx009.

Scarpino, S. V., & Althouse, B. M. (2019). Uncovering the hidden cost of bed bugs. *Proc Natl Acad Sci U S A*, 116(15), 7160-7162. doi:10.1073/pnas.1902404116.

Sheele, J. M., Barrett, E., Dash, D., & Ridge, G. E. (2017). Analysis of the life stages of *Cimex lectularius* captured within a medical centre suggests that the true numbers of bed bug introductions are under-reported. *J Hosp Infect*, 97(3), 310-312. doi:10.1016/j.jhin.2017.07.025.

Sheele, J. M., Crandall, C. J., Chang, B. F., Arko, B. L., Dunn, C. T., & Negrete, A. (2019). Risk Factors for Bed Bugs Among Urban Emergency Department Patients. *J Community Health*, 44(6), 1061-1068. doi:10.1007/s10900-019-00681-2.

Smart, A., & Lee, J. (2003). Financialization and the role of real estate in Hong Kong's regime of accumulation. *Economic Geography*, 79(2), 153-171. doi:10.1111/j.1944-8287.2003.tb00206.x.

Sutherland, C., Greenlee, A. J., & Schneider, D. (2020). Socioeconomic drivers of urban pest prevalence. *People and Nature*, 2(3), 776-783. doi:10.1002/pan3.10096.

Thomas, I., Kihiczak, G. G., & Schwartz, R. A. (2004). Bedbug bites: a review. *Int J Dermatol*, 43(6), 430-433. doi:10.1111/j.1365-4632.2004.02115.x.

Ting, V. (2019, 24 Sep). Bedbug infestations widespread in Hong Kong, study finds, with one expert warning of 'public health issue'. *South China Morning Post*. Retrieved from

https://www.scmp.com/news/hong-kong/health-environment/article/3030198/bed-bug-infestations-widespread-hong-kong-study

USEPA (2010). Joint statement on bed bug control in the United States from the U.S. Centers for Disease Control and Prevention (CDC) and the U.S. Environmental Protection Agency (EPA). U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention. http://purl.fdlp.gov/GPO/gpo21927. Accessed 16 Mar 2020.

Wang, C., Eiden, A., Singh, N., Zha, C., Wang, D., & Cooper, R. (2018). Dynamics of bed bug infestations in three low-income housing communities with various bed bug management programs. *Pest Manag Sci*, 74(6), 1302-1310. doi:10.1002/ps.4830.

Wang, C., Saltzmann, K., Bennett, G., & Gibb, T. (2012). Comparison of Three Bed Bug Management Strategies in a Low-Income Apartment Building. *Insects*, 3(2), 402-409. doi:10.3390/insects3020402.

Wang, C., Saltzmann, K., Chin, E., Bennett, G. W., & Gibb, T. (2010). Characteristics of *Cimex lectularius* (Hemiptera: Cimicidae), infestation and dispersal in a high-rise apartment building. *J Econ Entomol*, 103(1), 172-177. doi:10.1603/ec09230.

Wang, C., Singh, N., Zha, C., & Cooper, R. (2016). Bed Bugs: Prevalence in Low-Income Communities, Resident's Reactions, and Implementation of a Low-Cost Inspection Protocol. *J Med Entomol*, 53(3), 639-646. doi:10.1093/jme/tjw018.

Wang, C., & Wen, X. (2011). Bed Bug Infestations and Control Practices in China: Implications for Fighting the Global Bed Bug Resurgence. *Insects*, 2(2), 83-95. doi:10.3390/insects2020083.

WHO (2018). Household crowding. World Health Organization. https://apps.who.int/iris/rest/bitstreams/1161792/retrieve. Accessed Nov 23 2020.

Wong, H., & Chan, S. M. (2019). The impacts of housing factors on deprivation in a world city: The case of Hong Kong. *Social Policy & Administration*, 53(6), 872-888. doi:10.1111/spol.12535.

Yau, Y., & Ho, D. C. W. (2017). Exploring policy options to combat illegal microapartments in Hong Kong. *Urbani Izziv-Urban Challenge*, 28(2), 83-95. doi:10.5379/urbani-izziv-en-2017-28-02-001.

Zorrilla-Vaca, A., Silva-Medina, M. M., & Escandón-Vargas, K. (2015). Bedbugs, *Cimex* spp.: their current world resurgence and healthcare impact. *Asian Pacific Journal of Tropical Disease*, 5(5), 342-352. doi:10.1016/s2222-1808(14)60795-7.

Figures

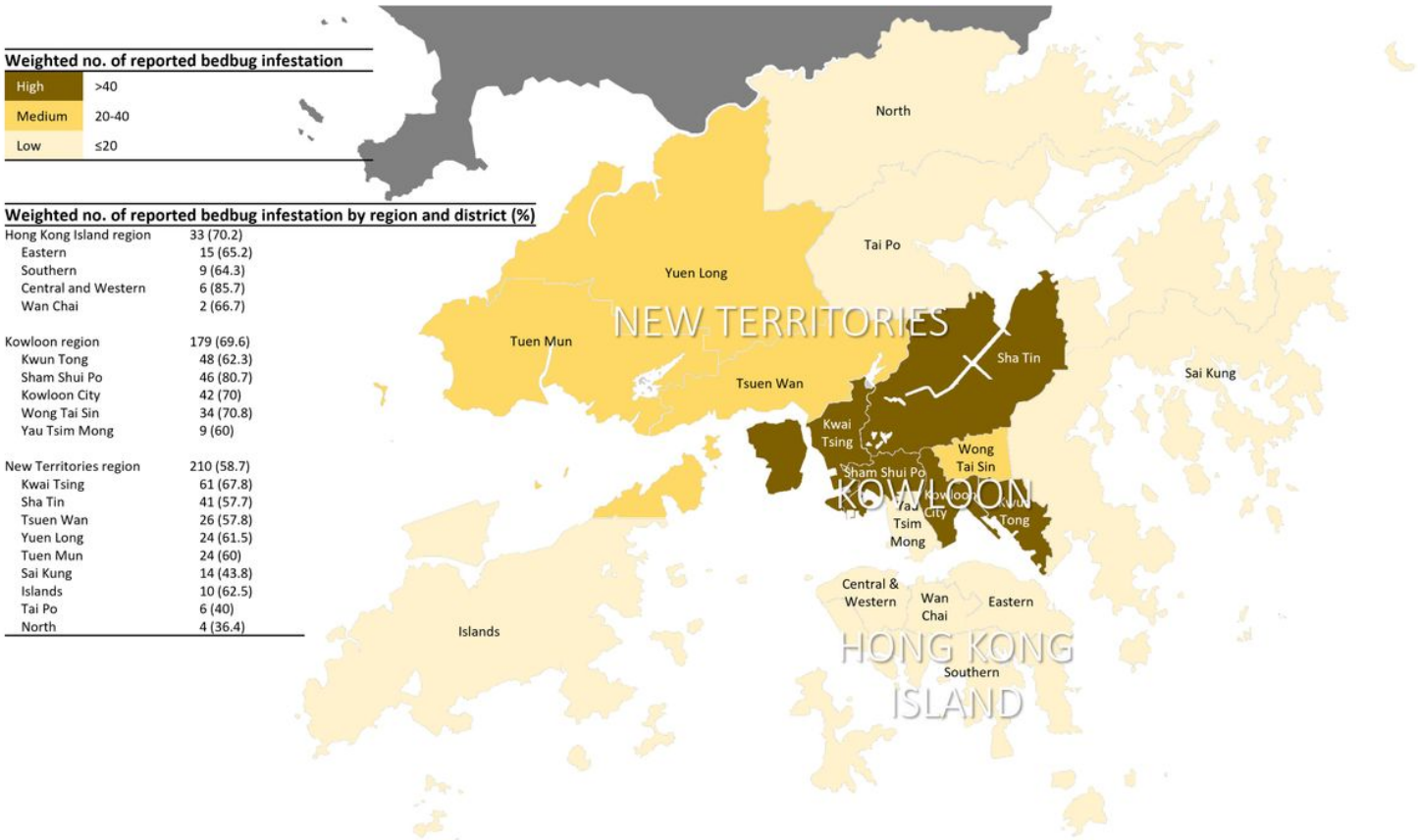

Figure 1

Distribution of bedbug cases by district (adapted from “Hong Kong 18 Districts Blank Map” by wahaha2005 and is licensed under Creative Commons Attribution-Share Alike 3.0 Unported license)

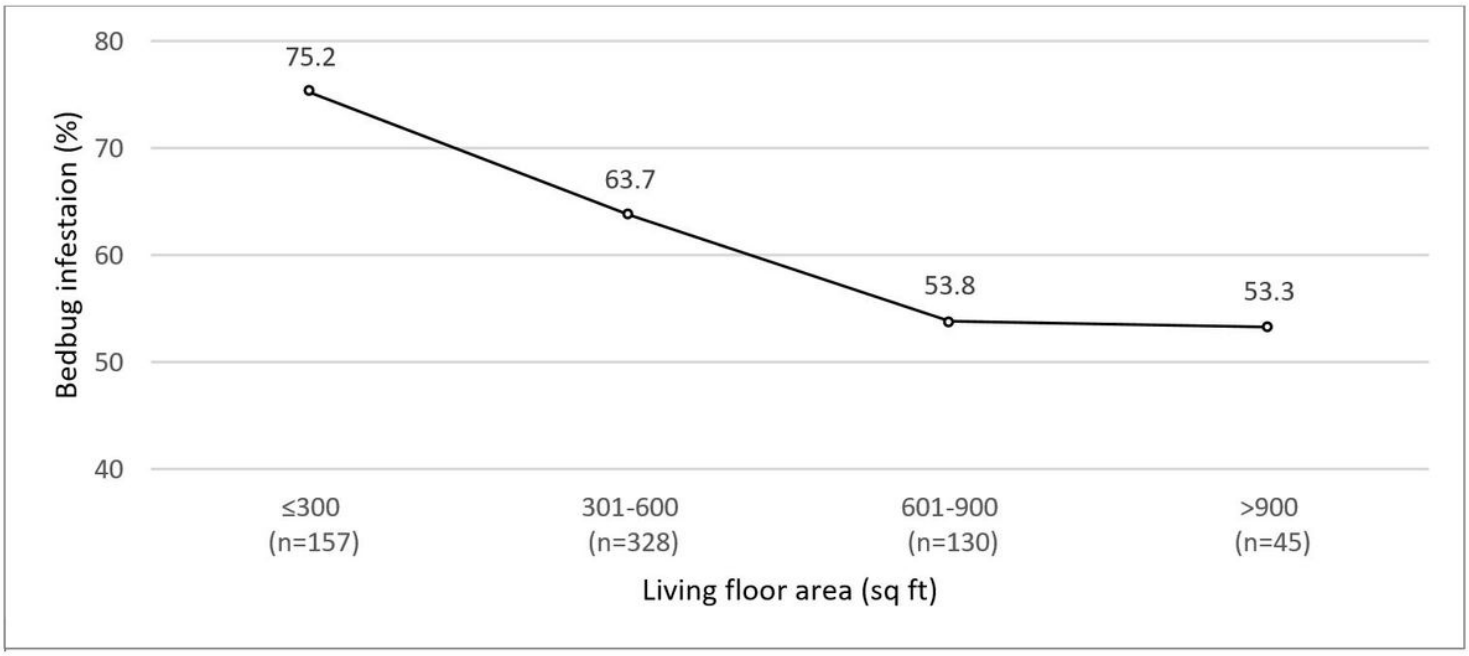

Figure 2

Association between living floor area and bedbug infestation (N=660)

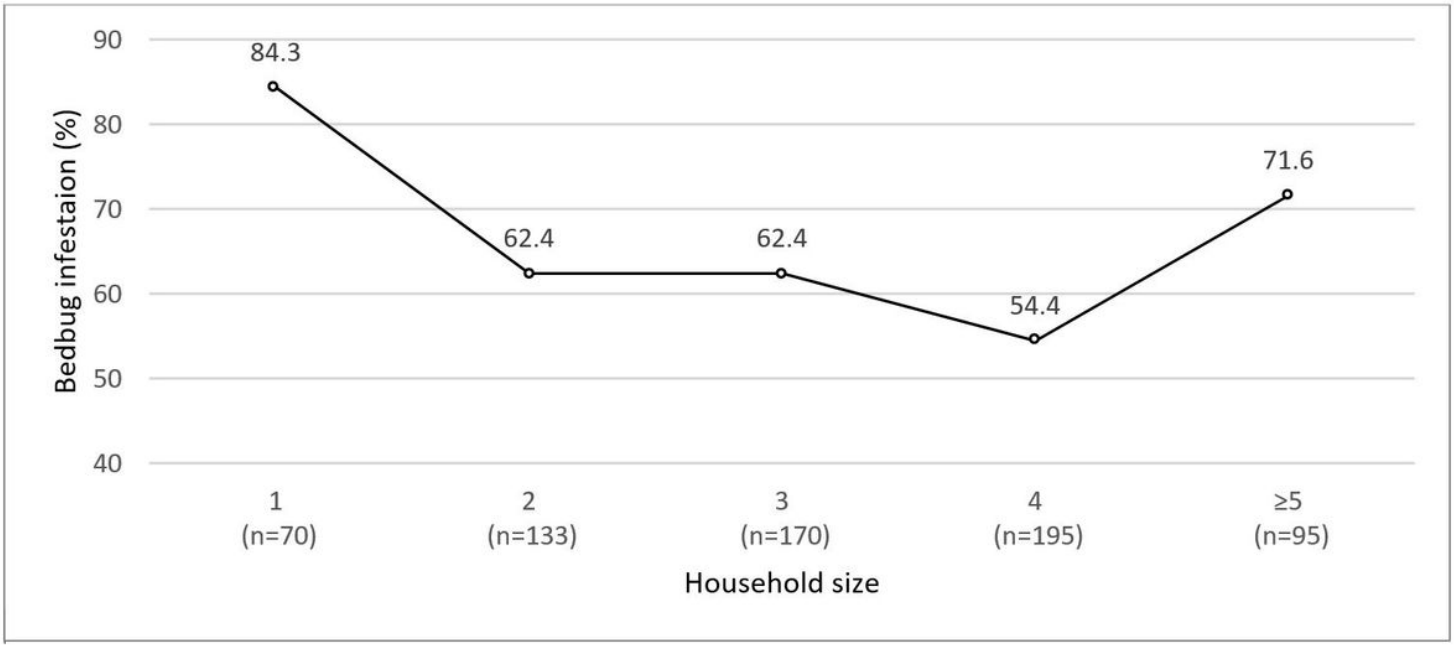

Figure 3

Association between household size and bedbug infestation (N=663)

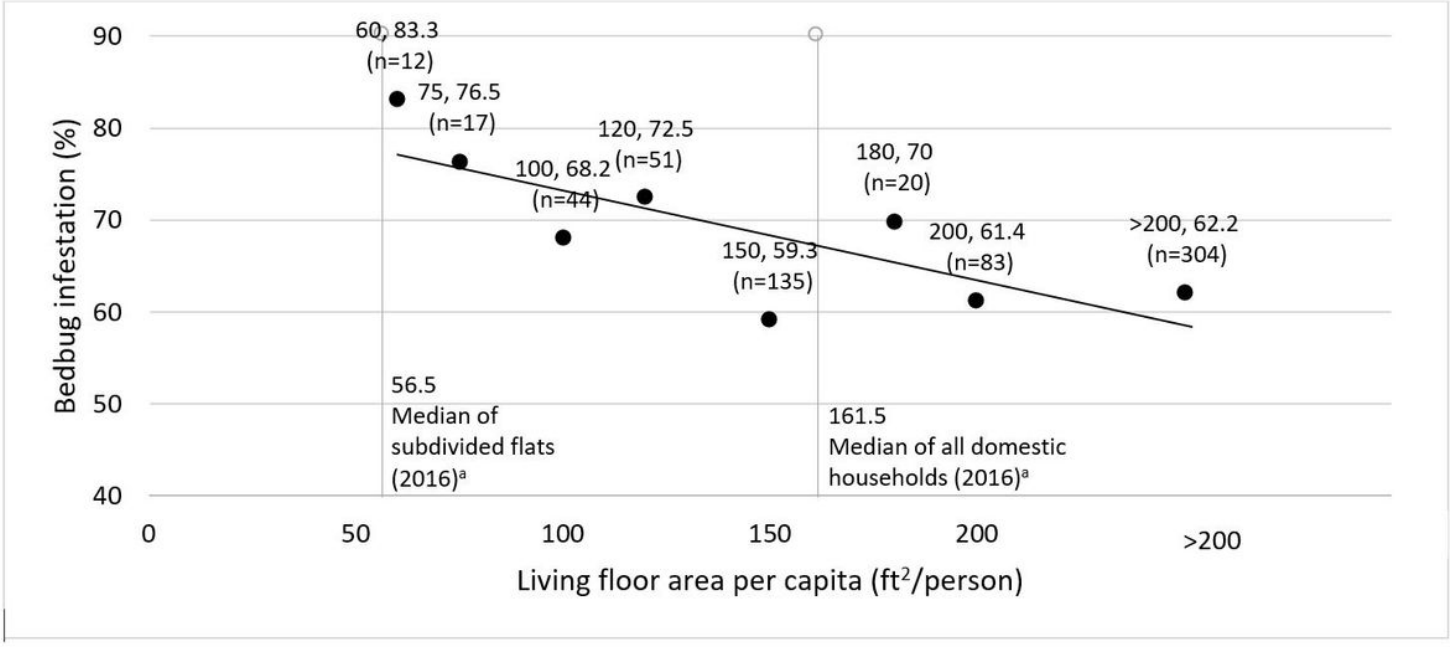

Figure 4

Association between living floor area per capita and bedbug infestation (N=666) (aMedian figures from Census and Statistics Department HKSAR 2018)

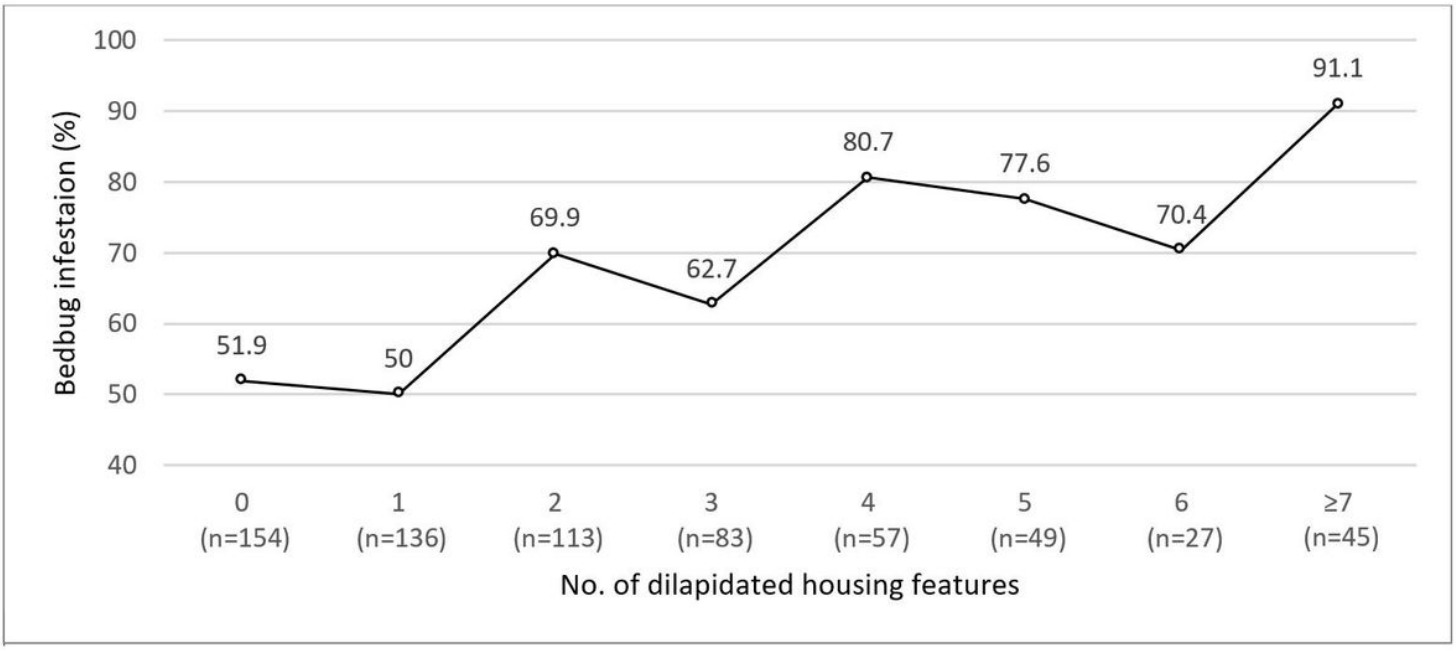

Figure 5

Association between number of dilapidated housing features and bedbug infestation (N=664)

Figure 6

Selected photographs taken at the residence of bedbug victims. (a. Darkened corridoor of a subdivided flat; b. Ceiling paint peeling with rebar showing through walls above a rusty and leaking pipe; c. Sleeping area next to a wall covered with blood streaks from dead bedbugs; d. Bedbugs coming out and hidden in cracks in walls; e. Cluttered public rental housing apartment)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Appendix1.docx
- Appendix2.docx

- Appendix3.xlsx