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Possible association between recent migration and hospitalisation for dengue in an urban population: A prospective case-control study in northern Vietnam

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Abstract. A prospective case–control study was conducted in urban districts in Hanoi, northern Vietnam to evaluate the effect of migration on the risk of hospitalisation for dengue in a Vietnamese urban population. We enrolled laboratory-confirmed dengue patients aged ≥18 years who were hospitalised in local hospitals in November and December 2010. Four neighbourhood-matched controls for each case were recruited within a week of hospitalisation. Sociodemographic data were collected by interviews, and the number of immature and adult mosquitoes within household premises was counted by entomological survey. Matched-pair analyses were conducted using conditional logistic regression models. Among 43 cases and 168 controls, 84% and 83% were migrants from rural areas, respectively. Although statistical significance was marginal, recent migration (residing in study area for ≤5 years) independently increased the risk of hospitalisation for dengue compared with inhabitants after controlling for potential confounders (adjusted odds ratio [aOR] = 3.78; 95% confidence interval [CI] = 0.99–14.27), whereas longer-term migration (residing in study area for ≥6 years) did not change the risk (aOR = 1.1; 95% CI = 0.30–4.05). Younger age (18–34 years) (aOR = 7.26; 95% CI = 2.39–22.06) and higher adult *Aedes aegypti* infestation level within household premises (aOR = 9.25; 95% CI = 1.68–51.09) were also independently associated with hospitalisation for dengue. Recent migration from rural areas seems to increase the risk of hospitalisation for dengue in urban populations in endemic areas. Further research including cohort study should be done to confirm the impact of migration on the risk of dengue in urban areas.

INTRODUCTION

Although recent study estimated that there are 390 million dengue infections per year (Bhatt *et al.*, 2013), there is no promising vaccine for preventing dengue. Reduction in the population density of vector mosquitoes such as *Aedes aegypti* and *Ae. albopictus* has been the only option for controlling dengue virus transmission in the human population (Farrar *et al.*, 2007).

Hanoi City, the second largest city and the capital of Vietnam, is located in northern Vietnam and has a subtropical climate with a distinctive hot rainy season from April to October and a cool dry season between November and March. The city experiences annual seasonal dengue outbreaks with little or no transmission in the intervening months (Cuong *et al.*, 2011). DENV-1 and DENV-2 were the only serotypes identified in Hanoi (Fox *et al.*, 2011), whereas all serotypes were detected in southern Vietnam (Thai *et al.*, 2005). The urban population in Vietnam including urban districts in Hanoi has been increasing rapidly, and the average annual population growth between 1999 and 2009 was 3.4% per year in urban areas but only 0.4% per year in rural areas (General Statistics Office Of Vietnam 2009). It is reported that inadequate water supply (i.e. no system installed or frequent suspension of water supply) resulting from the unintentional expansion of residential areas due to rapid urbanization is one of the primary reason for the increasing infestation level of dengue vectors since the shortage makes people tend to store water in containers that become breeding sites for dengue mosquitoes in densely populated urban areas, where the dengue virus can be easily transmitted among people (Tauil 2001; Ríos-Velásquez *et al.*, 2007).

In Hanoi, urban central districts have installed a reliable water supply system with rare occasions of water outage in the last decade (ADB 2007); recent urbanisation appears to have only limited effect on increasing the number of breeding sites of the dengue vector, such as water storage containers in urban residential areas (Phong & Num 1999). However, with rapid urbanisation, the influx of new residents into urban areas may account for the increasing annual incidence of notified dengue in the city, as it increases the number of susceptible adult people who have migrated from peri-urban or rural areas where there is a low dengue risk due to the low infestation levels of the primary dengue vector mosquitoes (i.e. *Ae. aegypti*) (Kawada *et al.*, 2009; Cuong *et al.*, 2011). It is also known that variety of housing conditions, including housing structures and the presence of water-holding containers alter the probability of human–vector contact among urban residents (Tun-Lin *et al.*, 1995; Howell & Chadee 2007; Tsuzuki *et al.*, 2009;). Most of the new migrants from suburbs are students or young labourers who usually live in different housing conditions with people who have lived for a longer time in urban Hanoi (i.e., new migrants usually rent a room or small 1-storey link house because real estate values in urban Hanoi have increased markedly, whereas people who have lived for a longer time in urban Hanoi often live in high-rise houses with or without a small front yard). The difference of the housing conditions may also influence the risk of dengue as it alters the infestation level of *Ae. aegypti* and the probability of human–vector contact.

We conducted this study to identify the sociodemographic and entomological risk factors for hospitalisation for dengue in an urban population in northern Vietnam, particularly those related to migration history.

MATERIALS AND METHODS

Study area

Hanoi has a population of approximately 6 million; it is divided into 10 urban districts (2 million people) and 19 peri-urban districts (4 million people). This study was conducted in 3 adjacent central urban districts (Hai Ba Trung, Dong Da, and Hoan Mai), where the highest number of dengue cases was reported in 2009.

Case-control study

In Hanoi City, 10 general hospitals treat almost all dengue inpatients and report patient information such as name, age, sex, residential address and date of hospitalisation to the Hanoi Preventive Medicine Centre (PMC) daily, whereas other health facilities such as private clinics and community health centres treat only outpatients and do not have a daily reporting system for these patients. We included hospitalised dengue patients for our case-control study not only because we could use the existing well-organised reporting system, but also because we aimed to evaluate the public health importance of the effect of migration on the dengue burden in the city. Dengue diagnosis was made following the same standard procedures as the all hospitals in the city; initial clinical diagnosis was based on the standard World Health Organisation criteria (WHO 1997); inpatients were categorised as classic DF or DHF according to symptoms; results were confirmed for the all inpatients by a single rapid test (e.g. Platelia Dengue Ns1 AG; Bio-Rad, California, USA). If the test was negative despite clinical evidence suggesting dengue, an antigen enzyme-linked immunosorbent assay was performed (e.g. SD Bioline Dengue IgG/IgM; SD BioStandard Diagnostics). Although the WHO 1997 criteria has limitation to measure the severity of dengue (WHO 2009), it did not influence the analysis in our study since dengue patients were hospitalized not because they were diagnosed as DHF/DSS but because they had severe symptom(s) and/or because of the request from patient's caregivers.

For the present study, we confirmed new dengue inpatients 3 times per week based on Hanoi PMC records. Among these patients, we included those with the current residential address in the 3 study districts and had no history of travel or migration in the current residences within 2 weeks before hospital admission (to exclude persons who might have been infected at a former residence or while travelling) as cases. In addition, patients <18 years of age at hospital admission were excluded because we aimed to determine the effect of migration status on the risk of hospitalisation for dengue among adults. Household visits for cases were conducted within 1 week after hospital admission. Most dengue cases reported in the city's urban districts occur from August to December, with a peak in September or October. We estimated 36 case-control sets (case to control ratio = 1:4) as a sample size for our matched case-control study to evaluate the effect of migration based on the assumption that 60% of controls have migrated, with 80% power, 0.05 significance level and a minimum odds ratio of 3 (Connett *et al.*, 1987).

Within regions with low dengue endemicity such as Hanoi, the presence (or absence) of dengue virus circulation may differ between residential areas even within the same city (Kan *et al.*, 2008). In this study, to account for potential variations in infection risk by residential area, we used adjacent neighbourhood controls in our case-control analysis. We identified 4 controls who lived in the first- to fourth-nearest neighbouring households identified for each case on sites. These controls were randomly selected from the member lists of each household with the same criteria as the cases (i.e. age ≥18 years at the time of household visit and no history of travel or migration in the current residences within 2 weeks before the household visit). The questionnaire survey for the case and control households was conducted in the same manner to clarify information regarding demographic status (age, sex, duration of stay in current residence and former residential area), history of hospitalisation within 2 weeks before our visit, history of travel or migration of all household members in the current residence within 2 weeks before our visit, and socioeconomic status of the households (level of household wealth was estimated based on household ownership of 7 main durable assets, building type, presence of outdoor space and number of household members). The head of the household or spouse of the head was interviewed to gather accurate information. Study participants were classified into 3 groups according to their residential status: inhabitants (born in the study districts), recent migrants (born outside the study districts and moved to the study districts ≤5 years ago), and long-term migrants (born outside the study districts and moved to the study districts >5 years ago). The cut-off for recent and long-term migrants to measure the risk of hospitalisation for dengue was set to 5 years because the chance of dengue infection was supposed to be different between the migrants moved into the study districts before and after 5 years since dengue epidemic usually occur 3-5 years interval (Gubler, 1998). Additionally, the recent migrants (born outside the study districts and moved to the study districts ≤5 years ago) were re-categorized in two groups (<2 years ago and 2–5 years ago) for more analysis on the effect of migration period.

During the household visits, an entomological survey was conducted to collect immature (larvae and pupae) and adult mosquitoes from the household premises, including all indoor rooms and outdoor areas such as front yards, verandas and rooftops. Immature mosquitoes were collected using previously described standardised procedures (Tsuzuki *et al.*, 2009). Although the backpack aspirator is considered a standard *Aedes* adult mosquito collection method (WHO, 2003), we used hand-held nets to collect adult mosquitoes because dwellings in the study areas were crowded and movement in the narrow alleys and small rooms would have been difficult considering the size and weight of the backpack aspirator. Two well-trained investigators carefully searched in and around the household premises to find and collect resting and flying mosquitoes by sweeping back and forth with a hand-held net. A torchlight was used to detect mosquitoes in indoor spaces. We usually spent 20–30 minutes at each household, but the inspection was complete regardless of the time. Collected mosquitoes were stored in glass tubes and identified at local laboratories. Female *Ae. aegypti* and *Ae. albopictus* were stored at –80ºC for virus isolation. Dengue virus isolation was conducted on female mosquitoes pooled according to each household following previously described standardised procedures (Igarashi 1978; Tesh 1979; Morita *et al.*, 1994). When reverse transcription–polymerase chain reaction with dengue consensus primers was positive, the serotype and sequences were confirmed using serotype-specific primers (Lanciotti *et al.*, 1992).

Statistical analysis

We performed a matched case-control analysis with neighbourhood controls using a conditional logistic regression model. Determinants in univariate analysis with a cut-off point of $P < 0.15$, as the traditional level of 0.05 can fail in identifying variables known to be important (Bendel & Afifi, 1977), were selected for multivariate analysis using a forward selection procedure. In multivariate analysis, we tested statistically significant ($P < 0.05$) interactions between the determinants in the final model with a log-likelihood ratio test. From the model output, adjusted odds ratios (aORs) and their 95% confidence intervals (CIs) were calculated. We assessed collinearity between variables using variance inflation factors. Data were entered into the Microsoft Office Access 2003 program (Microsoft, Redmond, WA, USA) and analysed using Stata version 10.0 (StataCorp, College Station, Texas, USA).

Ethical considerations

This study received clearance from the ethical committee that oversees research of the Institute of Tropical Medicine, Nagasaki University, Nagasaki, Japan, and from the bioethics committee of the National Institute of Hygiene and Epidemiology, Hanoi, Vietnam. Written informed consent was obtained from each participant included in the study.

RESULTS

We identified 43 eligible hospitalised dengue cases reported to the Hanoi PMC from 1 November to 14 December 2010. Their households and each of the nearest 4 neighbouring households (172 neighbouring households) were visited within 1 week (usually 2 or 3 days) of hospitalisation and all of these households agreed with the participation in the study. Most of the reported hospitalised patients were diagnosed with DHF (88.4%); the remainder had DF, but no DSS cases or deaths were reported. The average hospitalisation period of the patients was 4.9 days (SD = 1.6 days, range, 1–9 days). The mean age of the patients was 27.6 years (SD = 10.4 years; range, 18–63 years).

We excluded 4 of the 172 neighbour controls selected because their households had unreported cases (i.e. residents with a history of hospitalisation for dengue within 2 weeks before our visit but not detected at routine confirmation of the PMC records because they had been hospitalised just after the confirmation). No control had migrated to their current residence or travelled within 2 weeks before our visit. After exclusion of the 4 controls, 168 people were defined as neighbourhood controls (i.e. 39 case-control sets with 1 case and 4 controls, and 4 case-control sets with 1 case and 3 controls). Among the 211 households (i.e. 43 case households and 168 neighbouring households), we collected 60 (40 female) *Ae. aegypti* and 19 (1 female) *Ae. albopictus* adult mosquitoes from 41 and 10 households, respectively (32 and 1 household was home to *Ae. aegypti* and *Ae. albopictus* female mosquitoes, respectively). Among these, we detected dengue virus only from a pool of *Ae. aegypti* female adult mosquitoes collected in 1 case household but not from any *Ae. albopictus* or *Ae. aegypti* samples collected in control households. The serotype of the detected dengue virus was DEN-1, which was currently circulating in urban Hanoi. Additionally, distinctive features of the base sequence of the isolated virus strain were identical to that of dengue virus isolated from blood samples of dengue patients in Hanoi.

In the case-control analysis, cases presented similar characteristics to controls, the exception being that cases were likelier to be recent migrants (58.1% and 29.8% of cases and controls, respectively, lived in their current residence for $\leq$5 years), young (86.0% and 45.2% of cases and controls, respectively, were 18–34 years old), and living in household premises containing *Ae. aegypti* adults (in 13.9% and 3.6% of case and control households, respectively, $\geq$2 *Ae. aegypti* adults were collected) (Table 1). Among the 36 cases and 140 controls who had migrated to their current residence, almost all were from rural districts in Hanoi or rural provinces in northern Vietnam (97.2% and 100% of cases and controls, respectively). Only 1 case was from southern Vietnam. In univariate analysis, being recent migrants (duration of stay in current residence $\leq$5 years) (OR = 3.31; 95% CI = 1.04–10.54), age 18–34 years (OR = 8.85; 95% CI = 3.32–23.60), a higher adult *Ae. aegypti* mosquito infestation level in the residence (OR = 5.89; 95% CI = 1.42–24.36), and being apartment/dormitory residents (OR = 3.98; 95% CI = 1.26–12.57) appeared to be important factors for increasing the risk of hospitalisation for dengue (Table 2). Except for apartment/dormitory residents, all of the above factors were statistically significant in the multivariate analysis (aOR = 3.78 with 95% CI = 0.99–14.25 for duration of stay in current residence $\leq$5 years; aOR = 7.26 with 95% CI = 2.39–22.06 for age 18–34 years; and aOR = 9.25 with 95% CI = 1.68–51.09 for $\geq$2 *Ae. aegypti* adults in the household). Collinearity between variables was not detected (variance-inflation factors = 1.00).

Among the 25 cases and 50 controls who had recently migrated to their current residence (duration of stay in current residence $\leq$5 years), 11 cases and 27 controls were moved to the study districts <2 years ago, respectively. In univariate analysis, migration to the study districts 2–5 years ago appeared to be an important factor for increasing the risk of hospitalisation for dengue (OR = 3.39; 95% CI = 1.00–11.56). Although odds ratio for migration to the study districts <2 years ago was almost same as the odds ratio for migration to the study districts 2–5 years ago, it was not statistically significant (OR = 3.15; 95% CI = 0.79–12.51). Even after adjustment of the effect of age and adult *Ae. aegypti* mosquito infestation in the multivariate analysis, migration to the study districts 2–5 years ago was statistically significant but migration to the study districts <2 years ago was not statistically significant (aOR = 4.26 with 95% CI = 1.02–17.81 for duration of stay in current residence 2–5 years; aOR = 3.13 with 95% CI = 0.69–14.25 for duration of stay in current residence <2 years;). Migration to the study districts >5 years ago appeared to have little or no effect on increasing the risk of hospitalisation for dengue based on the both analysis (OR = 0.51 with 95% CI = 0.17–1.54 in the univariate analysis; aOR = 1.12 with 95% CI = 0.30–4.11 in the multivariate analysis).

DISCUSSION

The results of the present study indicated that recent migration (duration of stay in current residence $\leq$5 years) increases the risk of hospitalization for dengue in urban Hanoi; however, being a long-term migrant (duration of stay in current residence >5 years) did not influence the risk (Table 2). The proportion of people immune to a specific type of dengue virus might be lower among recent migrants

Table 1. Sociodemographic and entomological characteristics of hospitalised dengue cases and their neighbourhood controls

Characteristic	Cases (n = 43)		Neighborhood controls (n = 168)	
	No.	%	No.	%
Migration status				
Inhabitant	7	16.3	28	16.7
Recent mingrant (≤ 5 years)	25	58.1	50	29.8
Long-term migrant (> 5 years)	11	25.6	90	53.6
Age				
Middle/old (≥ 35 years)	6	14.0	92	54.8
Young (18-34 years)	37	86.0	76	45.2
Sex				
Male	22	51.2	90	53.6
Female	21	48.8	78	46.4
Household wealth level†				
Low (0-2)	23	53.5	108	64.3
High (3-7)	20	46.5	60	35.7
House building				
Single house	25	58.1	119	70.8
Apartment/dormitory	18	41.9	49	29.2
Outdoor space				
None	28	65.1	103	61.3
With front yard	15	34.9	65	38.7
Household member				
Few (1-3 persons)	19	44.2	79	47.0
Many (≥ 4 persons)	24	55.8	89	53.0
Ae. aegypti adult infestation				
None (0 adult)	30	69.8	140	83.3
Low (1 adult)	7	16.3	22	13.1
High (≥ 2 adults)	6	13.9	6	3.6
Ae. albopictus adult infestation				
None (0 adult)	42	97.7	159	(94.6)
Low (1 adult)	1	2.3	4	(2.4)
High (≥ 2 adults)	0	0.0	5	(3.0)
Ae. aegypti pupae infestation				
None (0 pupae)	39	90.7	158	(94.1)
Low (1 pupae)	3	7.0	4	(2.4)
High (≥ 2 pupae)	1	2.3	6	(3.5)
Ae. albopictus pupae infestation				
None (0 pupae)	43	100	160	(95.2)
Low (1 pupae)	0	0	3	(1.8)
High (≥ 2 pupae)	0	0	5	(3.0)
Aedes larvae infestation				
None (0 larva)	36	83.7	140	(83.3)
Presence (≥ 1 larvae)	7	16.3	28	(16.7)

* Household wealth level was estimated based on ownership of 7 durable assets such as motorcycle, LCD/plasma television, washing machine, refrigerator, air-conditioner, and personal computer as well as the residential building itself.

Table 2. Association between risk of hospitalisation for dengue and sociodemographic and entomological characteristics among adults aged ≥18 years in Hanoi in 2006

Characteristic	Odds ratio (95% confidence interval)			
	Crude	p value	Adjusted (final model)	*P* -value
Migration status				
Inhabitant	Ref.		Ref.	
Recent migrant (≤ 5 years)	3.31 (1.04-10.54)	0.043	3.78 (0.99-14.27)	0.05
Long-term migrant (> 5 years)	0.51 (0.17-1.54)	0.23	1.10 (0.30-4.05)	0.88
Age				
Middle/old (≥ 35 years)	Ref.		Ref.	
Young (18-34 years)	8.85 (3.32-23.60)	< 0.001	7.26 (2.39-22.06)	< 0.001
Sex				
Male	Ref.		-	-
Female	1.66 (0.81-3.42)	0.78	-	-
Household wealth level†				
Low (0-2)	Ref.		-	-
High (3-7)	3.98 (1.26-12.57)	0.17	-	-
House building				
Single house	Ref.		-	-
Apartment/dormitory	3.98 (1.26-12.57)	0.016	-	-
Outdoor space				
None	Ref.		-	-
With front yard	0.73 (0.29-1.83)	0.50	-	-
Household member				
Few (1-3 persons)	Ref.		-	-
Many (≥ 4 persons)	1.12 (0.57-2.20)	0.73	-	-
Ae. aegypti adult infestation				
None (0 adult)	Ref.		Ref.	
Low (1 adult)	1.37 (0.49-3.80)	0.55	1.12 (0.36-3.48)	0.83
High (≥ 2 adults)	5.89 (1.42-24.36)	0.014	9.25 (1.68-51.09)	0.011
Ae. albopictus adult infestation*				
None (0 adult)	Ref.		-	-
Low and Hihg (≥ 1 adult)	0.40 (0.05-3.45)	0.36	-	-
Ae. aegypti pupae infestation				
None (0 pupae)	Ref.		-	-
Low (1 pupae)	2.97 (0.66-13.27)		-	-
High (≥ 2 pupae)	0.70 (0.84-5.85)	0.37	-	-
Ae. albopictus pupae infestation†				
None (0 pupae)	-		-	-
Low (1 pupae)	-		-	-
High (≥ 2 pupae)	-		-	-
Aedes larvae infestation				
None (0 larva)	Ref.		-	-
Presence (≥ 1 larvae)	0.98 (0.39-2.46)	0.96	-	-

* Low (1 adult) and high (≥ 2 adults) was combined as only 1 *Ae. albopictus* adult was collected from a case house.

† Odds ratio could not be calculated as no *Ae. albopictus* pupae were collected from case houses.

from the peri-urban areas in Hanoi and rural provinces than among people born in their current residences or who have lived in urban Hanoi for a longer time since almost all of the migrant residents in our study were from the peri-urban districts of Hanoi or other rural provinces in northern Vietnam, where the risk of dengue infection is low due to the low infestation levels of the primary dengue vector mosquitoes (i.e. *Ae. aegypti*) (Kawada *et al.*, 2009; Cuong *et al.*, 2011). Numerous studies, including several prospective cohort studies have indicated that the risk of severe dengue is higher during a secondary infection, with new serotypes being identified in children as a result of antibody-dependent enhancement (ADE) (Burke *et al.*, 1988; Thein *et al.*, 1997; Guzmán *et al.*, 2000; Wichmann *et al.*, 2004). However, ADE may not fully account for severe dengue because some studies have found no association between severity and secondary infection in adults (Harris *et al.*, 2000; Wichmann *et al.*, 2004; Guilarde *et al.*, 2008). In addition, a recent study from Hanoi indicated that there was no trend of higher DHF rates in patients with secondary infection, as opposed to primary infection (Fox *et al.*, 2011). A substantial proportion of the newly migrated or younger adults in our study who were infected with DENV-1 or DENV-2 that circulated in the city might have been hospitalized with their first or second infection during the period of the study. However, most of the adults with a longer duration of stay in their current residence (>5 years) and older adults ($\geq$35 years) might not have visited health facilities even after effective infectious bites from vector mosquitoes during the period of the study, because they are immune to specific dengue serotypes. Therefore, most of the reported dengue cases in Hanoi (Cuong *et al.*, 2011) were adults probably not only because the force of infection is low that ended in the first and second DENV infections during adulthood but also because the risk of dengue among newly arrived young adult individuals is high. Although odds ratio for migration to the study districts <2 years ago was not statistically significant probably due to the limitation of sample size in our study, the risk seems to be same level as migration to the study districts 2–5 years (aOR = 4.26 with 95% CI = 1.02–17.81 for duration of stay in current residence 2–5 years; aOR = 3.13 with 95% CI = 0.69–14.25 for duration of stay in current residence <2 years). These results suggested most of adult migrants need a certain period of time (i.e. 5 years) to have experience of DENV infection due to relatively low level of the force of infection in Hanoi.

An increasing variety of housing conditions, including housing structures and the presence of water-holding containers, alter the probability of human-vector contact among urban residents (Tun-Lin *et al.*, 1995; Howell & Chadee 2007; Tsuzuki *et al.*, 2009). Most new migrants from the suburbs are students or young labourers, and they usually rent a room or small 1-storey link house without outdoor space because real estate values in urban Hanoi have increased markedly, whereas middle-aged or elderly people who have lived for a longer time in urban Hanoi often live in high-rise ($\geq$2 floors) houses with or without a small front yard. Thus, the vector mosquito infestation level in residences and the age of the residents might become a confounder of the effect of migration status on dengue risk. In other words, the vector mosquito infestation level in each residence and age of the residents should be considered in the analysis to adequately measure the effect of migration status on dengue risk that is not mediated through age and infestation level in each residence. People living in households with a high infestation level of *Ae. aegypti* adult mosquitoes appeared to have increased risk of dengue in our study, and some housing conditions that we did not evaluate (e.g. premises with fewer openings that maintain adult mosquitoes that have emerged from indoor breeding sites, premises with more indoor breeding sites for immature mosquitoes and/or premises with more resting places for adult mosquitoes) might have increased the infestation level of adult *Ae. aegypti* in the household premises. The presence of immature *Aedes* mosquitoes (larvae and pupae) in the household premises appeared to have no influence on the risk of dengue. Our study was conducted in urban residential areas of the city where house buildings are densely packed (usually neighbour households are located within a 5-meter radius). Dengue virus is transmitted only by adult mosquitoes and an infestation of immature mosquitoes in the household premises does not necessarily increase the risk of dengue. However, the presence of adult mosquitoes in the household that might have flown in from neighbouring households (or presence of gathering spots of adult mosquitoes in the households) probably increase the risk even without immature infestation. We collected a few female *Ae. aegypti* adult mosquitoes in the survey even in infested houses (i.e. 1–4 *Ae. aegypti* female adults); however, the adult infestation level was probably high enough to circulate dengue virus because *Ae. aegypti* is well known as a notoriously effective dengue vector with a high level of anthropophilia and endophagy, and with multiple blood feedings within a single gonotrophic period (Scott & Takken, 2012). Although individuals in these *Ae. aegypti*–infested households could have been infected with dengue outside their residences, *Ae. aegypti* is a crepuscular mosquito and a higher level of *Ae. aegypti* adult infestation in the household probably increase the human–mosquito contact in household at early morning and dusk when most people are in their residences. Although we collected *Ae. albopictus* adult and immature mosquitoes, the infestation was not an important risk factor for dengue. Furthermore, we confirmed the presence of dengue virus in a pool of adult female *Ae. aegypti* collected from 1 case household but not from any *Ae. albopictus* or *Ae. aegypti* samples collected from control households. Therefore, *Ae. aegypti* is probably the most important dengue vector in urban areas in Hanoi regardless of the presence of *Ae. albopictus* in the city.

Our study has limitations resulting from its observational nature. Migration status was recorded according to participant interviews, which are prone to recall bias. There may be potential clustering of migrants within residential areas; however, our conclusion was less affected by this because such biasness works to lower the chance to detect migration effect on dengue. Although all potential confounders were considered in our multivariate analyses, unmeasured confounders such as education and insurance status may have remained. The sample size was sufficient for our primary objective, but a larger sample size is required to perform stratified analyses.

Our study indicated that recent migration (lived in current residence for $\leq$5 years) were an important risk factor for hospitalisation of adult dengue patients in urban Hanoi. A high household infestation level of adult *Ae. aegypti* (but not *Ae. albopictus*) also appeared to be an important risk factor. With the large population influx to Hanoi's urban districts set to continue into the next decade due to rapid urbanisation of the city, high-risk groups such as newly arrived college students and migrant workers should be considered as primary targets for health education particularly on early admissions to health facilities for appropriate treatment of dengue infections. In addition, further research including cohort study should be done to confirm the impact of migration on the risk of dengue in urban areas.

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