A Systematic Review and Meta-Analysis of Practices Exposing Humans to Avian Influenza Viruses, Their Prevalence, and Rationale

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Abstract.

Almost all human infections by avian influenza viruses (AIVs) are transmitted from poultry. A systematic review was conducted to identify practices associated with human infections, their prevalence, and rationale. Observational studies were identified through database searches. Meta-analysis produced combined odds ratio estimates. The prevalence of practices and rationales for their adoptions were reported. Of the 48,217 records initially identified, 65 articles were included. Direct and indirect exposures to poultry were associated with infection for all investigated viral subtypes and settings. For the most frequently reported practices, association with infection seemed stronger in markets than households, for sick and dead than healthy poultry, and for H7N9 than H5N1. Practices were often described in general terms and their frequency and intensity of contact were not provided. The prevalence of practices was highly variable across studies, and no studies comprehensively explored reasons behind the adoption of practices. Combining epidemiological and targeted anthropological studies would increase the spectrum and detail of practices that could be investigated and should aim to provide insights into the rationale(s) for their existence. A better understanding of these rationales may help to design more realistic and acceptable preventive public health measures and messages.

INTRODUCTION

All four of the influenza virus strains that resulted in pandemics in the last century have had an avian origin. While the 1918–1919 H1N1 pandemic strain was entirely derived from an avian virus,[1] the subsequent pandemic strains of H2N2 in 1957, H3N2 in 1968, and H1N1 in 2009 all acquired gene segments from avian viruses by reassortment.[2,3] Within the last 20 years, a variety of avian influenza virus (AIV) subtypes affecting domestic poultry—especially H5N1, H7N9, and H9N2—has resulted in human infections in mainly Asia and Egypt.[4–6] Although these zoonotic transfers are sporadic and their transmission is not sustained within human populations, they also show a potential for reassortment with human viruses[7]; a very few nucleotide substitutions in some circulating strains might allow them to be transmissible between humans.[8] It is widely feared that ongoing circulation of zoonotic AIVs within poultry populations and their transfer to humans could result in emergence of a novel human pandemic strain. As almost all human cases result from exposure to poultry or to environments contaminated by poultry,[9–11] mitigation measures intended to prevent zoonotic infections and reduce the risk of adaptation of these viruses to human hosts must be carefully targeted, not only toward the poultry populations sustaining these viruses[12] but also toward practices exposing people to infected poultry and contaminated environments. Mitigation measures have to take into account the complexity and difficulty of behavior change strategies and techniques, recognizing that "behavior" should not be construed as exclusively "individual" but as located within a socioeconomic and cultural milieu.

This study presents a systematic review of the scientific literature relating to practices exposing humans to AIVs in Asia and Egypt. The objectives of the review are to identify poultry exposure practices associated with human infection, describe their prevalence within human populations, and examine the rationales for their persistence. This review is informed by insights from social anthropology. It recognizes that the analytical category "practice(s)" as deployed in the literature reviewed largely ignores the social, economic, and cultural context(s) and the subjective meanings of such "practices" for the "practitioners."

MATERIALS AND METHODS

Search strategy and selection criteria.

This systematic review adheres to PRISMA guidelines (see checklist in Supplemental Material).[13] A database search of MEDLINE, Science Citation Index, Social Science Citation Index, and The Zoological Record was conducted during the period October 10, 2014, to January 12, 2015. The search used the Boolean search criteria "A AND B", as follows:

A: "avian influenza" OR "avian flu" OR "bird flu" OR "influenza A" OR "H5N1" OR "H7N7" OR "H7N9" OR "H9N2" and
B: "animal-human" OR "backyard farms" OR "biosecurity" OR "chicken farms" OR "commercial farms" OR "cultural practices" OR "disease transmission" OR "duck farms" OR "exposure" OR "face masks" OR "farms" OR "gloves" OR "human exposure" OR "human infection" OR "live bird markets" OR "live poultry markets" OR "market practices" OR "markets" OR "occupational exposure" OR "poultry farms" OR "prevention" OR "risk" OR "risk + exposure" OR "risk behavior" OR "risk practices" OR "seroconversion" OR "seroprevalence" OR "transmission."

The "Title", "Keywords," and "Abstract" fields were selected in all databases, except for the MEDLINE database which offered to search "All Fields." EndNote was used to manage citations and remove duplicates.

Eligible articles had to be published between January 1, 1997, and December 31, 2014. This review start date was chosen because the first H5N1 human case was reported during that year.[14] Articles had to either assess 1) the association between poultry exposure practices and clinical or asymptomatic infection by AIVs (hereafter referred to as risk factor studies) or 2) the prevalence of these practices in human populations (hereafter referred as practice prevalence studies). The poultry exposure practices under consideration had to result in physical contact with poultry or contact with environments potentially contaminated by poultry. Human infections with AIVs could be either clinical cases that were laboratory confirmed or seropositive, asymptomatic individuals. If the association between a practice and human infection was assessed, a measure of effect had to be reported.

Practice prevalence studies included studies assessing proportions of individuals adopting defined practices in a given population, as well as studies only mentioning the presence or absence of defined practices in the study population. For both study types, searches were restricted to English-language publications and studies based in Asia and Egypt, where the subtypes currently causing most human cases (H5N1, H9N2, and H7N9) are endemic.[4–6] In addition, we assessed all studies identified in the initial search if they explored the reasons why people adopt practices, which may promote human exposure to avian influenza, whether they gave quantitative information on risk factors for infection or prevalence of practices.

Screening of titles and abstracts was carried out by one reviewer and checked by a second to remove studies unlikely to contain relevant information. Where exclusion could not be justified by one reviewer based solely on screening of a record's title and abstract, the full text was retrieved to allow both reviewers to reach a consensus.

Data analysis.

The quality of included risk factor studies was assessed using an adaptation of the Cochrane Risk of Bias Tool.[15] Risk of bias was assessed for the following domains: bias due to confounding, bias in the selection of participants into the study, bias in measurement of exposures, bias due to missing data and bias in measurement of outcome. Based on these domain-level assessments, the overall risk of bias of each study was assessed as low, moderate, serious, or critical (Supplemental Text 1, Supplemental Table 1). The quality of the practice prevalence studies was based on the rigor of the sampling strategy and the representativeness of the findings either at the province or country level. To be classified as Quality 1, participants had to be recruited using random sampling at the provincial (first administrative division) or national level. If sampling was not random (e.g., purposive and convenience) and/or the study was conducted at the level of a district (second administrative division) or lower, the study was classified as Quality 2.

For all studies, the following variables were extracted: study period, location, study design, study population, sample size, setting (household, live bird market [LBM], and farm). For risk factor studies, the following variables were also extracted: case definitions, poultry exposure practices measured, and their associated non-adjusted and adjusted measure of association with outcomes (e.g., odds ratio [OR]) along with their 95% confidence interval (CI) and *P* value. For practices that were investigated in two or more studies, we examined heterogeneity between studies using the I^2 statistic,[16] and computed overall OR estimates using the random-effect model of DerSimonian and Laird.[17] As adjusted ORs were not reported in all studies, ORs that were not adjusted for other exposures were used as model inputs. A sensitivity analysis was conducted by differentiating studies according to their risk of bias and locations (Supplemental Text 2, Supplemental Tables 2 and 3).

For the practice prevalence studies, we focused on those practices identified a priori to be associated with human infection. For each practice, the proportion of people or households adopting it was extracted, along with the associated CI. When the CI of a proportion was not mentioned in a paper, the binomial proportion CI (also referred to as the exact method) was calculated. These practices included raising poultry at home, keeping birds inside the house, visiting LBMs, touching poultry during purchase, handling (touching, selling, throwing, and incinerating) or eating sick or dead poultry, slaughtering poultry, and using personal protective equipment (PPE). We did not aim to compute overall estimates for the prevalence of each practice, but rather to describe variations in prevalence estimates for given practices across settings and studies. The range and median of reported prevalences and I^2 statistic were reported. If some practice prevalence studies explored reasons why people adopted some of the practices of interest based on responses to interviews and observations, these rationales were extracted. Data were extracted by a first reviewer and then checked for missing data and inaccuracies by a second reviewer. A sensitivity analysis was conducted by differentiating studies according to their geographical location and their quality score (Supplemental Text 2, Supplemental Tables 4 and 5).

All analyses were run using R 3.2.2[18] and the package “metafor”.[19]

Roles of the funding source.

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

RESULTS

Study selection and characteristics.

In total, 547 full texts were screened. Of these, 65 articles were included in the systematic review (Figure 1). Some articles reported multiple studies conducted in different countries over different years, targeting different populations (e.g., households and market workers) or focusing on different virus subtypes, and exploring both the presence of risk factors and the prevalence of practices. They were considered as separate studies. Twenty-three articles incorporated 24 *risk factor studies* (Table 1) and 46 articles presented 51 *practice prevalence studies* (Supplemental Table 8).

Twenty of the 24 risk factor studies investigated either H5N1 (N = 11) or H7N9 (N = 9) infections. Three studies detected H9 and one detected H7. Cases were defined as patients with a clinically apparent infection—as opposed to asymptomatic infection—in half of H5N1 studies and in all but one H7N9 studies. Most studies had either a case–control (N = 10) or a cross-sectional (N = 8) study design. Four out of the five ecological studies focused on H7N9, and there was only one cohort study. Half of the H5N1 studies and all H7N9 studies were conducted in China (including Hong Kong). Other study sites were Cambodia, Egypt, Indonesia, Pakistan, Thailand, and Vietnam. Six studies focused on workers in commercial poultry farms (as opposed to household flocks), markets, and/or abattoirs. The other 18 studies recruited participants from the general or rural populations. The number of cases in the 10 case–control studies ranged from 7 to 89, with a median of 27. In seven of the eight cross-sectional studies, the prevalence of infection was lower than 6%. The quality assessment of these studies is detailed in Supplemental text 1. Ten studies were assessed as being at moderate risk of bias and 14 at serious risk of bias.

All 51 practice prevalence studies were cross-sectional and conducted in 14 countries, mostly in southeast Asia (N = 25, 49%) and China (N = 11, 22%, including Hong Kong). Thirty-six studies explored poultry exposure practices in households, whereas practices adopted by poultry market, farm, and/or abattoir workers were explored in 15 studies. All but three studies explored practices using standardized questionnaires. The remaining three studies, conducted in Bangladesh, used observations and in-depth interviews. Sample sizes were highly variable, ranging from 34 to 4950, with a median of 312. We classified 21 studies as Quality 1 and 30 studies as Quality 2 (Supplemental Table 8).

Association between poultry exposure practices and AIV infection.

Study-specific and pooled ORs for each poultry exposure practice explored in the included case–control, cohort, and cross-sectional studies are shown in Figures 2–5 (detailed exposures in Supplemental Table 12).

Indirect exposure.

Indirect exposure to poultry was generally expressed as the co-occurrence of poultry and study participants in a given environment: within the neighborhood, at home, in a LBM, or at the worksite. Poultry could be described as healthy, sick, or dead. The evidence for an association between infection and presence of poultry in backyard or commercial farms in the vicinity of study participants' homes was variable across studies (Figure 2). Meta-analysis results suggested that the presence of poultry at home substantially increased the odds of infection by H5N1 (pooled OR = 3, 95% CI = 1.7–5.5) and H7N9 (pooled OR = 3.6, 95% CI = 1.4–8.9). Heterogeneity was, however, large among H7N9 studies (I^2 = 69%). Odds of infection were even further increased if poultry raised at home became sick or died (H5N1, pooled OR = 9.5, 95% CI = 5.1–17.8).

Occupational exposure to poultry was explored in only three studies, of which two suggested an association with human infection.[21,26] Visits to LBMs were associated with infection in all studies reporting such exposure. The pooled OR estimate for H7N9 infection was 5.2 (95% CI = 3.6–7.3) and for H5N1 3.5 (95% CI = 1.7–7). These results were in agreement with ecological study findings (Supplemental Table 6). H5N1 infection in Indonesia was associated with the occurrence of poultry outbreaks in the same area (RR = 1.3, 95% CI = 1.1–17).[24] Two studies found an association between H7N9 cases and the density of LBMs,[36,37] whereas two others noted a drastic reduction in H7N9 incidence with LBM closure.[35,38]

Increase in the odds of infection with the proximity between poultry and humans, the size of the susceptible poultry population, and the frequency of exposure was further suggested through the exploration of additional variables (Supplemental Table 7). Keeping poultry cages inside rather than outside the home[21] and raising larger backyard[28] and commercial[29] flocks with suboptimal vaccination coverage[21] increased the odds of infection.

In three studies, ORs were shown to increase with the frequency of visits to LBMs.[21,31,34] The effect of occupational exposure was found to further vary with premise type: breeder and layer farms were at higher risk for their employees than other farm types in two studies,[40,41] whereas working in retail markets was riskier than in wholesale markets and farms in another study.[26]

Regarding poultry species, there was weak evidence in one study that the OR of H5N1 infection was higher when raising waterfowl at home than when raising chickens only.[21] In one study, exposure to geese and turkeys, respectively, increased the odds of H5N1 infection, whereas exposure to ducks increased the odds of H9 infection.[30] However, the odds of H9 infection were not different as between duck and chicken keepers in another study[42] (Supplemental Table 7).

Only seven out of the 19 case–control, cohort, and cross-sectional studies described specific activities leading to indirect exposures. Most studies found weak evidence of association between infection and poultry husbandry-related activities (Figure 3). Feeding poultry in farms, witnessing poultry slaughter in markets, and storing products from sick/dead poultry at home were found to be associated with H5N1 infection, each of them in one study. Some investigated activities were unrelated to poultry management but to contact with water potentially contaminated by poultry. Although pooled OR estimates revealed weak evidence of an association between H5N1 infection and the use of outdoor water (pooled OR = 2.5, 95% CI = 0.5–12.1), the evidence was stronger for bathing in water bodies (pooled OR = 3.1, 95% CI = 1.5–6.4).

Direct exposure.

As with indirect exposure, direct exposure to poultry was often described in general terms as direct contact with, touching or handling poultry. Meta-analysis suggested an association between handling poultry and infection (Figure 4). Heterogeneity was high among studies and could not only be explained by the diversity of settings, as the level of heterogeneity was not reduced when only considering households (Supplemental Table 3). This association seemed slightly stronger for H7N9 (pooled OR = 5.5, 95% CI = 2.3–13.1) than H5N1 (pooled OR = 2.8, 95% CI = 1.1–7.4), and when sick or dead poultry were concerned (H5N1, pooled OR = 4.8, 95% CI = 1.2–19.2). However, handling poultry did not seem to result in higher odds of infection than indirect exposure at home or in markets.

The investigated activities resulting in direct exposure to poultry were related to poultry husbandry, processing, and consumption (Figure 4). While consumption of healthy-appearing or sick poultry was not associated with H5N1 or H7N9 infection, several stages of poultry processing—such as slaughtering, evisceration, and preparation—were found in the meta-analysis to increase the odds of H5N1 infection. Regarding poultry husbandry practices, vaccinating and handling birds to place them into cages were found associated with H9 and H5N1 infection in two different studies. Although a study found weak evidence for higher odds of H9 infection among chicken butchers than keepers (OR = 3.4, 95% CI: 0.8–14.5),[42] the small number of studies for each processing and husbandry activity, and the often high level of heterogeneity among them limit the comparisons that can be performed across activities, viral subtypes and poultry health status.

Protective factors.

Regarding hygiene practices (Figure 5), meta-analysis provided weak evidence for frequent handwashing being a protective factor (H5N1 pooled OR = 0.5, 95% CI = 0.2–1.3; H7N9 pooled OR = 0.2, 95% CI = 0–1.2). Only one study examined use of masks and frequent disinfection of worksites (e.g., farms). It noted a reduced odds of infection (ORs = 0.1, 95% CI = 0–1 and ORs = 0.1, 95% CI = 0–0.6, respectively).[41]

Prevalence of poultry exposure practices.

Exposure to live birds was widespread in studied populations. Although the proportion of households raising backyard poultry was higher in rural than in peri-urban and urban areas, purchasing live poultry in markets was more frequent in peri-urban and urban rather than rural settings (Table 2, Supplemental Figures 1 and 2). Levels of contact with poultry at markets and households greatly varied across studies: the proportion of households keeping poultry inside their own house ranged from 1% to 87% (Table 2), and the proportion of households slaughtering birds at home ranged from 12% to 85% (Table 3, Supplemental Figure 3). The proportion of respondents who reported touching poultry when purchasing it in markets was lower than 18% in the three surveys conducted in Hong Kong, whereas it was higher than 58% in five of six surveys conducted in mainland China, Viet Nam, and Thailand (Supplemental Figure 2).

The surveyed populations were highly heterogeneous in terms of their management of sick and dead poultry (Table 3). In Bangladesh, Egypt and, to a lesser extent, Cambodia, the proportion of survey participants burying or incinerating dead poultry was generally lower and the proportion consuming, selling, or throwing sick or dead poultry into open spaces was generally higher when compared with other study sites (including China, India, Indonesia, Lao, Thailand, and Viet Nam) (Supplemental Figure 4).

The proportion of household survey participants reporting handwashing with soap after contact with poultry was higher than 80% in all studies exploring this practice, except in one study in Bangladesh where the proportion dropped to 4%. The adoption of PPE was higher among farm and market workers than in households. However, most workers generally reported not wearing PPE (Supplemental Figure 5).

Some additional practices were reported by only a couple of studies, including practices exposing humans to potentially contaminated environments. This included cleaning places where poultry are kept, bathing in water bodies in Cambodia, washing carcasses in water bodies in Cambodia and Bangladesh, and barefoot contact with blood in Bangladesh.

Rationale for poultry exposure practices.

None of the reviewed studies sought to explore the rationales behind practices at risk of human exposure to AIVs. Eight practice prevalence studies did address some of the reasons for conducting some practices, but not comprehensively (Supplemental Table 10). Other studies discussed these rationales as post hoc hypotheses (Supplemental Table 11). However, exploring rationales requires targeted research and in none of the papers were these dealt with according to the canons of social anthropology and ethnography.

The eight prevalence studies, in which reasons for some practices were briefly discussed, took place in Bangladesh, Egypt, Indonesia, Lao, and Turkey. In Bangladesh, backyard farmers reported keeping poultry in their bedroom because they are concerned about predation and thieves.[43] Some kept sick poultry in their bedroom to separate them from their healthy poultry and to keep them under observation.[44] This practice was related to the perception that people are not at risk of illness. Some people may have been aware of avian influenza, but they considered the risks associated with poultry handling as negligible. Moreover, several practices were described by the authors as a matter of preference, rooted in tradition (based on interviews of residents or developed as post hoc hypotheses).[45] For instance, live poultry bought in markets were preferred to chilled or frozen meat for consumption as the latter was considered to be of lower quality.[46] Poultry slaughtered immediately before cooking were traditionally believed to be fresher, more flavorsome and nutritious, and less likely to be contaminated.[47] Likewise, reasons for touching poultry before buying were related to consumer traditions, relying on their own judgment of the quality and safety of the poultry.[47] Authors also related the adoption of certain risky practices to poverty. High poultry prices meant that purchasing poultry meat was not affordable for the poorest, and thereby encouraged the consumption of sick or dead poultry.[44,47,48]

The non-adoption of preventive measures was mainly explained by authors by financial constraints, such as implementation costs and potential impact on business, absence of supporting legislation, time and space constraints, and "risk fatigue" from repeated outbreaks.[45,49–52] This is generally analyzed in the context of poor populations that do not consider avian influenza to be a major health threat, and for whom the perceived chance of an adverse outcome from poultry exposure is considered to be relatively low compared with the adverse outcome of worsening poverty.

Heterogeneity in practices across settings was often explained by authors by differing religious beliefs. In Bangladesh, sick poultry were slaughtered and consumed if it was thought that they were about to die because of religious bans on eating animals that die of natural causes.[44,48] In contrast, consumption of dead poultry was reported in non-Muslim populations. According to Buddhist principles, killing is considered to have karmic consequences. Thai people were therefore considered to be less likely to slaughter poultry themselves.[47]

DISCUSSION

Both direct and indirect exposures to poultry in households, farms, or markets were associated with human infection by AIVs in most of the reviewed risk factor studies. The strength of this association seemed stronger for H7N9 than for H5N1, for sick and dead compared with healthy poultry, and in markets compared with any other setting. Several studies also suggested that the odds of infection further increased with the proximity between humans and poultry, the size of the poultry population to which humans were exposed, and the frequency of exposure. Direct exposure was not associated with higher odds of infection than indirect exposure. This apparent association between AIV infection and indirect exposure to poultry, and the possible role of handwashing and environmental disinfection as protective factors suggest that contacts with contaminated environments followed by ingestion, intranasal or conjunctival self-inoculation of the virus may be a major mode of AIV transmission. Infected poultry shed a high viral load, which may survive in the environment for a few days under favorable conditions.[53] In households, virus survival in the environment may represent an infection pressure to which people may have prolonged contact, in particular when poultry are kept inside home, including in bedrooms. Even when environmental exposure is of a shorter duration, such as in the case of people visiting markets, the frequent introduction of infected poultry in markets and the associated viral circulation among marketed poultry[54] means that humans may be exposed to high virus loads. However, high uncertainty remains regarding the actual modes of transmission involved. Contributions of aerosols and large droplets cannot be ruled out, as investigated exposures may be associated with several modes of transmission.[55] H5N1 was shown to be transmitted between poultry by aerosols.[56] Some practices, such as mechanical defeathering, may generate contaminated aerosols and large droplets, and result in the infection of people visiting markets.[57] These results suggest that interventions aiming to reduce virus load in markets,[58] and behavioral change strategies leading to higher biosafety standards when handling poultry, especially sick or dead specimens, could substantially reduce human exposure to AIVs. The adoption of risky and protective practices varied greatly across studies, and was frequently explained as motivated by financial constraints and religious beliefs. These variations could also result from temporal changes in people's perception of their risk of infection. As these factors were expected to vary across the heterogeneous socioeconomic and cultural landscape covered by the reviewed articles, risk mitigation interventions should be tailored to these local contexts. However, none of the studies reviewed here aimed to assess the rationale behind practices at risk of human exposure to AIVs. Reviewed knowledge, attitude, and practice studies investigated questions related to awareness and knowledge, and a few studies did touch on some reasons behind specific practices and discussed these as post hoc hypotheses, but neither in sufficient detail nor at the appropriate level of conceptualization.

LIMITATIONS

Our review was exposed to recall bias, as exposures were captured in all risk factor studies, and most practice prevalence studies, through structured interviews of study participants, or proxies when study participants have died. Bias in the measurement of exposures was more pronounced in risk factor studies using serology to define prevalent cases: AIVs being endemic in most settings, there was uncertainty about whether the reported exposures preceded, or not, the infection. However, this bias might be limited as most investigated exposures were daily, routine practices, which might not greatly change in the medium-term in AIV-endemic settings.

The use of structured interviews to measure exposure in all risk factor studies and most practice prevalence studies implied further limitations. Although the observed heterogeneity in the prevalence of practices was generally explained, as mentioned earlier, by variations in socioeconomic and cultural landscapes, this pattern could also result from the limited representativeness induced by the geographically small study sites, and response bias. Asking about past behavior or about practices that may be officially banned or enforced by regulation, or of which their adoption may be positively or negatively perceived by people may in addition result in biased answers, leading to an underestimation of the real levels of exposure. For instance, high compliance to handwashing was reported in all questionnaire surveys that investigated this practice, but it was only actually done by a small proportion of participants observed in one study.[48] Moreover, structured questionnaire surveys can only investigate the adoption of practices of which the study designers have an awareness. For instance, several practice prevalence studies explored whether participants wear boots dedicated to the care of poultry. Based on observations of poultry rearing by Bangladeshi rural communities, one study was able to identify that people stepped barefoot into poultry blood.[43] Stepping barefoot in poultry blood might be a more relevant practice than the failure to wear special boots dedicated to poultry care.

The pooled OR estimates often relied on a small number of heterogeneous studies, and, therefore, need to be interpreted with caution. Also, terms used to refer to practices were often only merely named or briefly described. The same term could have different uses, and therefore, different meanings across studies. Multiple specific practices may have been encompassed within these descriptions. Only a few specific practices were investigated, but the frequency and intensity of contact were not detailed, preventing further discrimination of practices according to the degree of exposure to poultry. Overall, investigated practices—or their descriptions in the literature which are not the same as the practices themselves—appear not to have changed significantly within the last 17 years. Investigations have yet to be comprehensive, in-depth analyses of given and related practices. For example, while visiting live bird markets was found to be a risk factor for AIV infection in the first risk factor study in 1997, subsequent studies were rarely able to explore in more detail which types of practices within markets could lead to infection, given the retrospective nature of outbreak investigations.

FUTURE RESEARCH

To address these limitations, epidemiological surveys could benefit from being combined with anthropological investigations. Anthropological studies may help to identify practices that would be better described with observations and in-depth interviews to develop a more accurate and detailed understanding. Such practices may, for instance, include handwashing and the use of PPEs. Moreover, the development of structured interview protocols would greatly benefit from a prior anthropological exploration of both the conceptualization of "practices" and of practices of interest. Whether "practices" are of interest may alter in the light of more detailed description and contextualization. Practices that are not systematically investigated, but which may reveal to be of epidemiological importance, may thus be characterized. Further description of practices could include a characterization of the contacts involved, and a measure of their intensity and frequency. The more detailed and grounded into the local contexts these descriptions are, the less comparable they may be across settings characterized by heterogeneous populations. On the other hand, the more general these descriptions are, the less likely it would be possible to tailor interventions to the local contexts that shape those practices. Detailed descriptions are required to identify the most relevant practices and populations at risk that should be targeted by risk mitigation strategies. Nevertheless, the small number of cases identified in most risk factor studies may limit the exploration of the association between AIV infection and specific, detailed practices. If these practices were only adopted by a small fraction of the population, the statistical power would be low, and even if the actual association with AIV infection was strong, the measured strength of association would be uncertain.

Epidemiological studies typically investigate the most significant causal relationships between practices and the human exposure to AIVs as part of outbreak investigations and interventions to control them. Although causal relationships are difficult to identify, they nevertheless seek to achieve this by examining associations between an exposure variable and a health outcome.[59,60] However, identifying the specific practices promoting AIV transmission to humans is often not enough to improve preventive public health interventions and messages. For these messages to be heard and strategies to be adhered to by populations at risk, their design needs to be informed by a thorough understanding of the factors and theories influencing persistence of risky or preventive practices. Of use in such investigations is the rationale behind certain risky practices for exposure to disease: Why do people do what they do? Under which circumstances do they engage in risky practices? At what point do practices become habitual behavior as opposed to a conscious decision in light of the level of risk of pathogen transmission? How do these practices relate to the tradition, culture, and socioeconomic circumstances? How are these practices influenced by disease awareness and knowledge? These questions were not part of the main objectives of reviewed studies. Contextual research appeared to be merely a by-product. As mentioned earlier, practices and their rationales were often only briefly described. These "descriptions" may on closer examination, and informed by ethnographic studies, turn out to have been dealing in homogenizing "labels" rather than in "heterogenizing" "descriptions." This is important because terms such as "fresh," "nutritious," "quality," and "wholesome", are each supported by an implicit local "theory" of these things, their importance and significance. Understanding these theories would help to tailor interventions to local circumstances (which may vary within countries), increasing their acceptance in populations at risk. A challenge to achieve this is to access the relation between individual actions and the socioeconomic and cultural environment in which those actions are situated and produced. Recent theoretical[61,62] and empirical works explored the use of emergent properties, such as “hope” or “disgust,” as quantitative variables capturing people’s experiences of the social, economic, and cultural world they inhabit. In Uganda, the level of hope that a person experienced was measured and found to be associated with some known risk factors for HIV infection.[63] In India, disgust was associated with handwashing behavior.[64] Applying this approach may provide new insights about practice adoption and inform the development of preventive public health messages. Such messages would aim to alter the level of a given emergent property (e.g., “hope” and “disgust”) in the targeted population to promote the uptake of protective practices.

In conclusion, the descriptions of practices exposing humans to poultry and their shared environment are often general and with little information to aid understanding of underlying rationales, limiting their usefulness for developing effective control and preventive measures. The assessment of the prevalence of reported practices in populations at risk was also prone to biases acting to underestimate the actual level of exposure. Epidemiological surveys aiming to explore potentially infectious contacts at the human–animal interface would greatly benefit from being combined with anthropological investigations. Such an approach would not only allow a more accurate identification and detailed description of risky as well as preventive practices, but would also allow the exploration of the reasons behind these practices. This would in turn facilitate the development of preventive public health measures and messages more likely to lead to positive behavior change in targeted populations.

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FIGURE 1. Flow of selected studies**.**

FIGURE 2. Association between human AIV infection and indirect exposure to poultry in various locations. HH = Household; NS = not specified; Prem = premises, include farms, markets and abattoirs; non-adj OR = odds ratio is not adjusted for other exposure practices; adj OR = odds ratio is adjusted for other exposure practices; not reported = multivariate analysis was conducted but adjusted OR was not reported for the practice of interest. This figure appears in color at www.ajtmh.org.

FIGURE 3. Association between human AIV infection and practices resulting in indirect exposure. HH = household; NS = not specified; Prem = premises, include farms, markets and abattoirs; non-adj OR = odds ratio is not adjusted for other exposure practices; adj OR = odds ratio is adjusted for other exposure practices; not reported = multivariate analysis was conducted but adjusted OR was not reported for the practice of interest. This figure appears in color at www.ajtmh.org**.**

FIGURE 4. Association between human AIV infection and practices resulting in direct exposure. HH = household; NS = not specified; Prem = premises, include farms, markets and abattoirs; non-adj OR = odds ratio is not adjusted for other exposure practices; adj OR = odds ratio is adjusted for other exposure practices; not reported = multivariate analysis was conducted but adjusted OR was not reported for the practice of interest. This figure appears in color at www.ajtmh.org.

FIGURE 5. Association between human AIV infection and preventive practices. HH = household; NS = not specified; Prem = premises, include farms, markets and abattoirs; non-adj OR = odds ratio is not adjusted for other exposure practices; adj OR = odds ratio is adjusted for other exposure practices; not reported = multivariate analysis was conducted but adjusted OR was not reported for the practice of interest. This figure appears in color at www.ajtmh.org.

TABLE 1

Characteristics of studies exploring risk or protective factors for avian influenza virus infection in humans

Reference	Location	Year(s)	Design	Study population and selection criteria	*N* (cases)	Case definition
						Incident cases of laboratory confirmed H5N1 clinical infection
Mounts and others[20]	China (HK)	1997	CC	H5N1 clinical cases, controls matched by age, sex, location	56 (15)	H5N1 clinical infection: respiratory illness and either a viral culture or a 4-fold rise in Ab titer
Zhou and others[21]	China	2005–2008	CC	H5N1 clinical cases, controls matched by age, sex, location	162 (28)	H5N1 clinical infection: respiratory illness and either a viral culture, a 4-fold rise in Ab titer or a RT-PCR
Areechokchai and others[22]	Thailand	2004	CC	H5N1 clinical cases, controls matched by age, location	80 (16)	H5N1 clinical infection: respiratory illness and viral culture or a RT-PCR
Dinh and others[23]	Vietnam	2004	CC	H5N1 clinical cases, controls matched by age, sex, location	134 (28)	H5N1 clinical infection: respiratory illness and a RT-PCR
Yupiana and others[24]	Indonesia	2005–2008	E	H5N1 clinical cases	34 (34)	H5N1 clinical infection: respiratory illness and either a viral culture, a 4-fold rise in Ab titer, a RT-PCR or MN Ab titer ≥ 1:80 and another serological test
						Prevalent cases of laboratory confirmed H5N1 asymptomatic infection
Vong and others[25]	Cambodia	2006	CC	H5N1 seropositive rural residents, controls matched by age, sex, location and H5N1 poultry flock status	31 (7)	H5N1 seropositive: MN Ab titer ≥ 1:80 and Western blot
Bridges and others[26]	China (HK)	1997–1998	CC	Poultry workers	1312 (81)	H5N1 seropositive: MN Ab titer ≥ 1:80 and Western blot
Cavailler and others[27]	Cambodia	2007	CS	Rural residents	700 (18)	H5N1 seropositive: MN Ab titer ≥ 1:80 and HI Ab titer ≥ 1:160
Huo and others[28]	China	2010	CS	Residents raising poultry nearby lakes with wildfowl	306 (8)	H5N1 seropositive: HI Ab titer ≥ 1:160
Li and others[29]	China	2010–2012	CS	Poultry workers	1169 (55)	H5N1 seropositive: HI Ab titer ≥ 1:160 and MN
Gomaa and others[30]	Egypt	2010–2011	CS	Rural residents	708 (15)	H5N1 seropositive: MN Ab titer ≥ 1:80 and HI test
						Incident cases of laboratory confirmed H7N9 clinical infection
Li and others[31]	China	2013	CC	H7N9 clinical cases, controls matched by age, sex, location	100 (25)	H7N9 clinical infection: respiratory illness and either a viral culture, a 4-fold rise in Ab titer or a RT-PCR
Liu and others[32]	China	2013	CC	H7N9 clinical cases, controls matched by age, sex, location	429 (89)	H7N9 clinical infection: respiratory illness and either a viral culture, a 4-fold rise in Ab titer or a RT-PCR
He and others[33]	China	2013	CC	H7N9 clinical cases, controls matched by age, sex, location	258 (43)	H7N9 clinical infection: respiratory illness and either a viral culture, a 4-fold rise in Ab titer or a RT-PCR
Ai and others[34]	China	2013	CC	H7N9 clinical cases, controls matched by age, sex, location	118 (25)	H7N9 clinical infection: respiratory illness and a RT-PCR
Yu and others[35]	China	2013	E	H7N9 clinical cases	60 (60)	H7N9 clinical infection: respiratory illness and either a viral culture, a 4-fold rise in Ab titer or a RT-PCR. Eighteen rural cases, two cluster cases and four mild cases were excluded.
Fang and others[36]	China	2013	E	H7N9 clinical cases	113 (113)	H7N9 clinical infection: respiratory illness and either a viral culture, a 4-fold rise in Ab titer or a RT-PCR
Fuller (2014)[37]	China	2013	E	Individuals with respiratory illness tested for H7N9	NS	H7N9 clinical infection: respiratory illness and either a viral culture, or a RT-PCR
Wu and others[38]	China	2013–2014	E	H7N9 clinical cases	182 (182)	H7N9 clinical infection: respiratory illness and either a viral culture, a 4-fold rise in Ab titer, or a RT-PCR
						Incident cases of laboratory confirmed H7N9 asymptomatic infection
Wang and others[39]	China	2013	C	Poultry market workers in districts with H7N9-infected market	96 (52)	H7N9 seroconversion: HI Ab titer ≥ 1:40 in December, and a ≥ 4-fold rise from May to December.
						Prevalent cases of laboratory confirmed H7 asymptomatic infection
Ahad and others[40]	Pakistan	2010–2011	CS	Chicken farm workers	354 (120)	H7 seropositive: HI Ab titer ≥ 1:160
						Prevalent cases of laboratory confirmed H9 asymptomatic infection
Yang and others[41]	China	2011	CS	Duck farm workers	1741 (12)	H9 seropositive: HI Ab titer ≥ 1:40
Yu and others[42]	China	2009–2010	CS	Poultry farm and abattoir workers	305 (14)	H9 seropositive: 2 MN Ab titer ≥ 1:80
Gomaa and others[30]	Egypt	2010–2011	CS	Rural residents	648 (38)	H9 seropositive: MN Ab titer ≥ 1:80

Ab titer = antibody titer; C = cohort; CC = case–control; CS = cross-sectional; E = ecological; HI = hemagglutination inhibition; HK = Hong Kong; MN = microneutralization assay; PCR = polymerase chain reaction. In case definition, respiratory illness includes pneumonia and influenza-like illness.

TABLE 2

Prevalence of practices related to backyard poultry rearing and purchase of poultry in LBMs

	All households			Urban households			Peri-urban households			Rural households		
	n (c)	p (range)	I^2	*n* (c)	p (range)	I^2	*n* (c)	p (range)	I^2	*n* (c)	p (range)	I^2
Raise backyard poultry	24 (10)	65 (19–96)	99	4 (3)	45 (19–51)	98	3 (2)	50 (34–55)	91	15 (9)	78 (50–96)	98
Keep poultry inside house	6 (4)	20 (1–87)	100									
Visit LBMs to purchase poultry	11 (4)	38 (7–81)	100	3 (1)	38 (33–81)	100	1 (1)	77	–	3 (1)	8 (7–9)	0
Touch when purchasing	9 (4)	59 (5–92)	100									

LBM = live bird market; *n* (c) = number of studies along with the number of countries in which these studies took place in brackets; p (range) = median prevalence (%) and range.

TABLE 3

Prevalence of preventive practices and practices related to the slaughtering and processing of poultry, and the management of sick and dead poultry

	Households			Premises			Farms			Live bird markets		
	n (c)	p (range)	I^2	*n* (c)	p (range)	I^2	*n* (c)	p (range)	I^2	*n* (c)	p (range)	I^2
Slaughtering and processing poultry	11 (7)	45 (12–85)	99				2 (2)	22 (6–38)	98	4 (4)	73 (39–100)	98
Management of sick and dead poultry												
Touching	9 (3)	33 (14–75)	99	2 (1)	11 (8–13)	86				1 (1)	41	–
Consumption	13 (6)	12 (2–100)	99							1 (1)	16	–
Selling	7 (6)	26 (0–100)	99				1 (1)	81	–	2 (2)	28 (2–53)	99
Returning to suppliers				1 (1)	50	–				1 (1)	9	–
Throwing in open spaces	11 (7)	45 (2–87)	99	1 (1)	20	–						
Burying/Incinerating	13 (8)	72 (2–95)	99				2 (2)	62 (30–95)	99			
Preventive practices												
Washing hands with soap after contacts with poultry	6 (4)	97 (4–99)	96							1 (1)	68	–
Wearing gloves	3 (3)	2 (1–2)	0	2 (1)	51 (47–54)	81	4 (4)	18 (1–30)	90	1 (1)	60	–
Wearing facemask	4 (3)	2 (0–2)	0	2 (1)	44 (42–46)	37	4 (4)	21 (6–66)	98	4 (4)	18 (13–45)	93
Wearing aprons/changing clothes	2 (2)	3 (0–5)	0	1 (1)	89	–	3 (3)	4 (3–34)	94	4 (2)	42 (15–80)	96
Wearing boots	1 (1)	6	–				3 (3)	15 (7–16)	6	4 (2)	60 (30–80)	92
Rinsing/washing equipment after use	2 (2)	66 (33–99)	98				1 (1)	41	–	4 (1)	50 (19–100)	97

n (c) = number of studies along with the number of countries in which these studies took place in brackets; p (range) = median prevalence (%) and range.
Premises include farms, markets, and abattoirs.

SUPPLEMENTAL FIGURE 1. Prevalence of practices related to backyard poultry rearing. Premise includes farms, markets, and abattoirs. HH = household.

SUPPLEMENTAL FIGURE 2. Prevalence of practices related to purchase of poultry in live bird markets. Premise includes farms, markets, and abattoirs. HH = household.

SUPPLEMENTAL FIGURE 3. Prevalence of practices related to the slaughtering and processing of poultry. Premise includes farms, markets, and abattoirs. HH = household.

SUPPLEMENTAL FIGURE 4. Prevalence of practices related to the management of sick and dead poultry. Premise includes farms, markets, and abattoirs. HH = household.

SUPPLEMENTAL FIGURE 5. Prevalence of preventive practices. Premise includes farms, markets, and abattoirs. HH = household.

SUPPLEMENTAL TABLE 1

Assessment of study quality

Author (year) and study design	Confounding	Selection of participants	Measurement of exposures	Missing data	Measurement of outcomes	Overall
Mounts (1999) (CC)[8]	Serious	Low	Moderate	Low	Low	Serious
Zhou (2009) (CC)[2]	Moderate	Low	Moderate	Low	Low	Moderate
Areechokchai (2006) (CC)[11]	Serious	Moderate	Moderate	Low	Moderate	Serious
Dinh (2006) (CC)[3]	Moderate	Moderate	Moderate	Low	Low	Moderate
Yupiana (2010) (E)[22]	Serious	Low	Serious	Low	Serious	Serious
Vong (2009) (CC)[10]	Serious	Low	Serious	Low	Moderate	Serious
Bridges (2002) (CC)[9]	Serious	Low	Moderate	Low	Moderate	Serious
Cavailler (2010) (CS)[23]	Moderate	Low	Moderate	Low	Moderate	Moderate
Huo (2012) (CS)[12]	Serious	Low	Moderate	Low	Moderate	Serious
Li (2013) (CS)[24]	Moderate	Low	Moderate	Low	Moderate	Moderate
Gomaa (2015) (CS)[16]	Moderate	Serious	Moderate	Low	Moderate	Serious
Li (2014) (CC)[4]	Moderate	Low	Moderate	Low	Low	Moderate
Liu (2014) (CC)[5]	Moderate	Low	Moderate	Low	Low	Moderate
He (2014) (CC)[6]	Moderate	Low	Moderate	Low	Moderate	Moderate
Ai (2013) (CC)[7]	Moderate	Low	Moderate	Low	Low	Moderate
Yu (2014) (E)[14]	Serious	Low	Serious	Low	Serious	Serious
Fang (2013) (E)[25]	Serious	Low	Serious	Low	Serious	Serious
Fuller (2014) (E)[26]	Serious	Low	Serious	Low	Serious	Serious
Wu (2014) (E)[15]	Serious	Low	Serious	Low	Serious	Serious
Wang (2014) (C)[17]	Moderate	Moderate	Moderate	Low	Moderate	Moderate
Ahad (2014) (CS)[19]	Moderate	Moderate	Moderate	Low	Moderate	Moderate
Yang (2012) (CS)[18]	Moderate	Moderate	Moderate	Low	Serious	Serious
Yu (2013) (CS)[13]	Serious	Moderate	Moderate	Low	Moderate	Serious

CC = case–control; CS = cross-sectional; E = ecological. Low, moderate, and serious refer to the level of risk of bias.

SUPPLEMENTAL TABLE 2

Sensitivity analysis of risk factor studies according to their overall risk of bias

Practice	Subtype	Health status	Sub-group	*n*	pOR (95% CI)	I^2
Raising poultry at home	H5N1	Healthy/NS	All studies	3	3 (1.7–5.5)	18
			Moderate bias	2	3.7 (2–6.7)	0
			Serious bias	1	1.4 (0.3–6.4)	-
Raising poultry at home	H5N1	Sick/dead	All studies	3	9.5 (5.1–17.8)	0
			Moderate bias	2	8.4 (4–17.7)	0
			Serious bias	1	13 (1.8–96.3)	-
Raising poultry at home	H7N9	Healthy/NS	All studies	4	3.6 (1.4–8.9)	69
			Moderate bias	4	3.6 (1.4–8.9)	69
			Serious bias	0	–	–
Visiting LBM	H7N9	Healthy/NS	All studies	4	5.2 (3.6–7.3)	0
			Moderate bias	4	5.2 (3.6–7.3)	0
			Serious bias	0	–	–
Poultry husbandry: Cleaning	H5N1	Healthy/NS	All studies	3	1.5 (0.7–3)	35
			Moderate bias	1	0.8 (0.3–2.3)	–
			Serious bias	2	2 (0.8–4.7)	26
Bathing in ponds	H5N1	–	All studies	3	3.1 (1.5–6.4)	5
			Moderate bias	2	2.5 (1.1–5.3)	0
			Serious bias	1	11.3 (1.3–102.2)	–
Using outdoor water source	H5N1	–	All studies	3	2.5 (0.5–12.1)	81
			Moderate bias	2	1.8 (0.3–12.6)	89
			Serious bias	1	6.8 (0.7–66.4)	–
Touching (unspecified practice)	H5N1	Healthy/NS	All studies	5	2.8 (1.1–7.4)	67
			Moderate bias	4	2.5 (0.9–7.5)	73
			Serious bias	1	5.8 (0.9–113.6)	–
Touching (unspecified practice)	H5N1	Sick/dead	All studies	5	4.8 (1.2–19.2)	88
			Moderate bias	3	4.7 (0.9–23.3)	88
			Serious bias	2	4.4 (0.1–195.7)	93
Touching (unspecified practice)	H7N9	Healthy/NS	All studies	6	5.5 (2.3–13.1)	71
			Moderate bias	6	5.5 (2.3–13.1)	71
			Serious bias	0	–	–
Preparing poultry	H5N1	Healthy/NS	All studies	3	3.3 (1.1–9.5)	77
			Moderate bias	1	2.2 (0.6–10.4)	–
			Serious bias	2	4.8 (0.5–45.6)	88

CI = confidence interval; *n* = number of studies; NS = not specified; pOR = pooled odds ratio along with its 95% CI.

SUPPLEMENTAL TABLE 3

Sensitivity analysis of risk factor studies according to their location.

Practice	Subtype	Health status	Sub-group	*n*	pOR (95% CI)	I^2
Poultry husbandry: cleaning	H5N1	Healthy/NS	All studies	3	1.5 (0.7–3)	35
			Households	2	1.7 (0.3–9.9)	65
			Premises	1	1.6 (0.9–2.7)	–
Touching (unspecified practice)	H5N1	Healthy/NS	All studies	5	2.8 (1.1–7.4)	67
			Households	2	1.4 (0.3–7.6)	85
			Premises	3	5.5 (2.3–13.2)	0
Touching (unspecified practice)	H5N1	Sick/dead	All studies	5	4.8 (1.2–19.2)	88
			Households	4	5.6 (0.8–39.5)	90
			Premises	1	2.6 (1.3–5.4)	–
Touching (unspecified practice)	H7N9	Healthy/NS	All studies	6	5.5 (2.3–13.1)	71
			Households	4	7.6 (2.8–20.1)	75
			Premises	2	2 (0.4–9.9)	34
Preparing poultry	H5N1	Healthy/NS	All studies	3	3.3 (1.1–9.5)	77
			Households	2	5.6 (0.8–41.5)	81
			Premises	1	1.7 (1.1–2.7)	–

CI = confidence interval; *n* = number of studies; NS = not specified; pOR = pooled odds ratio along with its 95% CI.
Premises: commercial farms, live bird markets, and abattoirs.

SUPPLEMENTAL TABLE 4

Sensitivity analysis of practice prevalence studies according to their location

Practice	Setting	Subgroups	*n*	Range	I^2
Raise backyard poultry	Urban HHs	All countries	4	19–51	98
		Lao	2	40–51	81
Raise backyard poultry	Semi-urban HHs	All countries	3	34–55	91
		Lao	2	51–55	20
Raise backyard poultry	Rural HHs	All countries	15	50–96	98
		China	3	50–52	0
		Lao	3	64–86	92
		Thailand	3	68–80	74
Keep poultry inside house	HHs	All countries	6	1–87	100
		Bangladesh	2	27–80	99
		Lao	2	1–3	0
Touch when purchasing	HHs	All countries	9	5–92	100
		China (HK)	3	5–14	80
		China	3	17–71	100
		Vietnam	2	63–92	99
Slaughtering and processing poultry	HHs	All countries	11	12–85	99
		Cambodia	3	28–38	93
		China	2	12–45	100
		Thailand	2	19–59	99
Management of sick and dead poultry					
Touching	HHs	All countries	9	14–75	99
		Cambodia	5	31–75	99
		Thailand	3	28–39	73
Consumption	HHs	All countries	13	2–100	99
		Cambodia	5	14–87	99
		Lao	2	3–5	0
		Thailand	2	2–12	85
		Vietnam	2	5–5	0
Selling	HHs	All countries	7	0–100	99
		Lao	2	0–0	0
Throwing in open spaces	HHs	All countries	11	2–87	99
		Bangladesh	3	45–87	89
		Lao	2	5–16	93
		Vietnam	2	12–23	90
Burying/Incinerating	HHs	All countries	13	2–95	99
		Bangladesh	3	2–12	10
		Egypt	2	16–19	0
		Lao	2	78–87	90
		Vietnam	2	76–79	26
Preventive practices					
Handwashing	HHs	All countries	6	4–99	96
		Thailand	2	80–99	94
		Vietnam	2	96–99	0
Wearing facemask	HHs	All countries	4	0–2	0
		Thailand	2	2–2	0
Wearing aprons/changing clothes	LBMs	All countries	4	15–80	96
		Indonesia	3	15–55	81
Wearing boots	LBMs	All countries	4	30–80	92
		Indonesia	3	30–65	79

HHs = households; HK = Hong Kong; LBMs = live bird markets. Handwashing: washing hands with soap after contacts with poultry. The ranges of practice prevalence and I2 indices are presented for studies conducted within the same countries.

SUPPLEMENTAL TABLE 5

Sensitivity analysis of practice prevalence studies according to their quality score

Practice	Setting	Subgroup	*n*	Range	I^2
Raise backyard poultry	Urban HHs	All countries	4	19–51	98
		Quality 1	3	19–51	98
		Quality 2	1	51	–
Raise backyard poultry	Semi-urban HHs	All countries	3	34–55	91
		Quality 1	3	34–55	91
		Quality 2	0	–	–
Raise backyard poultry	Rural HHs	All countries	15	50–96	98
		Quality 1	6	52–90	98.1
		Quality 2	9	50–96	97.9
Keep poultry inside house	HHs	All countries	6	1–87	100
		Quality 1	4	1–87	100
		Quality 2	2	14–80	99
Visit LBMs	Urban HHs	All countries	3	33–81	99.8
		Quality 1	1	81	–
		Quality 2	2	33–38	91.2
Visit LBMs	Semi-urban HHs	All countries	1	77	–
		Quality 1	1	77	–
		Quality 2			
Visit LBMs	Rural HHs	All countries	3	7–9	0
		Quality 1	3	7–9	0
		Quality 2			
Touch when purchasing	HHs	All countries	9	5–92	100
		Quality 1	7	5–92	99.7
		Quality 2	2	17–71	99.8
Slaughtering and processing poultry	HHs	All countries	11	12–85	99
		Quality 1	9	19–85	99.4
		Quality 2	2	12–85	99.6
Management of sick and dead poultry					
Touching	HHs	All countries	9	14–75	99
		Quality 1	5	14–75	99.4
		Quality 2	4	28–39	64.6
Consumption	HHs	All countries	13	2–100	99
		Quality 1	6	2–45	98.5
		Quality 2	7	2–100	99.4
Selling	HHs	All countries	7	0–100	99
		Quality 1	4	0–26	95.7
		Quality 2	3	72–100	83.1
Throwing in open spaces	HHs	All countries	11	2–87	99
		Quality 1	6	2–45	97.9
		Quality 2	5	48–87	87.8
Burying/Incinerating	HHs	All countries	13	2–95	99
		Quality 1	6	2–95	99.4
		Quality 2	7	10–76	98
Preventive practices					
Handwashing	HHs	All countries	6	4–99	96
		Quality 1	1	80	–
		Quality 2	5	4–99	96.3
Wearing gloves	HHs	All countries	3	1–2	0
		Quality 1	0	–	–
		Quality 2	3	1–2	0
Wearing facemask	HHs	All countries	4	0–2	0
		Quality 1	1	2	–
		Quality 2	3	0–2	0
Wearing aprons/changing clothes	HHs	All countries	2	0–5	0
		Quality 1	0	–	–
		Quality 2	2	0–5	0
Wearing boots	HHs	All countries	1	6	–
		Quality 1	0	–	–
		Quality 2	1	6	–
Rinsing/washing equipment	HHs	All countries	2	33–99	97.7
		Quality 1	0	–	–
		Quality 2	2	33–99	97.7

HHs = households; LBMs = live bird markets. Handwashing: washing hands with soap after contacts with poultry.
The ranges of practice prevalence and I2 indices are presented for studies from the same quality group.

Supplemental Table 6

Risky practices of which their association with AIV infection was assessed in ecological studies

Exposure	Measure of association (95% CI)	Author (year)
Poultry density (1,000/km^2)	RR = 1 (0.8–1.1), *P* = 0.59	Yupiana (2010)
The number of poultry outbreaks	RR = 1.3 (1.1–1.7), *P* = 0.02	Yupiana (2010)
LBM density	BRT weight > 5	Fang (2013)
	OR = 1.1 (1–1.1), *P* < 0.001	Fuller (2014)
LBM closure	Reduction in daily incidence	
	Shanghai: 99% (93–100%)	
	Hangzhou: 99% (92–100%)	
	Huzhou: 97% (68–100%)	
	Nanjing: 97% (81–100%)	Yu (2014)
	Reduction in daily incidence	
	Overall estimate: 97% (89–100%)	Wu (2014)

BRT = boosted regression tree; CI = confidence interval; LBM = live bird market; OR = odds ratio; RR = relative risk.

Supplemental Table 7

Additional variables assessing the association between AIV infection and proximity between poultry and humans, size of susceptible poultry populations, frequency of exposure, and premise type

Exposure category	Exposure	Subtype	Non-adj OR (95% CI)	Adj OR (95% CI)	Author (year)
Raising poultry at home: cages inside/outside the house	Poultry cages inside the house vs. no poultry	H5N1	9.7 (1.8–53.3)		Zhou (2009)
	Poultry cages outside the house vs. no poultry	H5N1	3.7(0.9–15.3)		Zhou (2009)
Raising poultry at home: vaccinated flocks	Poultry H5 vaccination coverage < 80% vs. no poultry	H5N1	7.1 (1.6–31.6)		Zhou (2009)
	Poultry H5 vaccination coverage > 80% vs. no poultry	H5N1	4.0 (0.9–17.9)		Zhou (2009)
	Waterfowl H5 vaccination coverage < 80% vs. no waterfowl	H5N1	8.4 (1.6–45.1)		Zhou (2009)
	Waterfowl H5 vaccination coverage > 80% vs. no waterfowl	H5N1	2.4 (0.5–11.2)		Zhou (2009)
Raising poultry at home: flock size	Poultry number	H5N1	2.4(1–5.7)		Huo (2012)
Working with poultry: flock size	Number of poultry bred > 1,000	H5N1		3.8 (1.7–8.7)	Li (2013)
Visiting LBM: visit frequency	1–5 visits within 2 weeks before illness vs. no visits	H5N1	2.8 (0.9–8.1)		Zhou (2009)
	6–10 visits within 2 weeks before illness vs. no visits	H5N1	7.6 (1.1–53.7)		Zhou (2009)
	> 10 visits within 2 weeks before illness vs. no visits	H5N1	5.8 (1.2–28.6)		Zhou (2009)
	1–9 visits vs. no visits	H7N9	3.4 (1.2–9.3)	3.8 (1.3–10.8)	Li (2014)
	> 10 visits vs. no visits	H7N9	5.6 (1.2–26.9)	10.6 (1.9–60.7)	Li (2014)
	1–5 visits vs. no visits	H7N9	1.5 (0.4–5.5)		Ai (2013)
	6–9 visits vs. no visits	H7N9	0.8 (0.1–7.4)		Ai (2013)
	> 10 visits vs. no visits	H7N9	8.8 (2.2–35.1)		Ai (2013)
Working with poultry: premise type	Farm type: layer vs. broiler	H7		0.8 (0.3–2.5)	Ahad (2014)
	Farm type: breeder vs. broiler	H7		3.8 (1.4–10.1)	Ahad (2014)
	Farm type: layer vs. broiler duck	H9	6.4 (1.7–23.6)		Yang (2012)
	Work in retail vs. wholesale/farm/other premises	H5N1	2.7 (1.5–4.9)		Bridges (2002)
Working with poultry: type of activity	Chicken butcher vs. chicken keeper	H9	3.4 (0.8–14.5)		Yu (2013)
Poultry species	Raise chickens only (no waterfowls)	H5N1	2.6 (0.6–12.1)		Zhou (2009)
	Raise waterfowl	H5N1	6.4 (1.6–26.3)		Zhou (2009)
	Exposed to geese	H5N1	3.6 (1.2–10.2)	3.1 (0.9–10.4)	Gomaa (2015)
	Exposed to turkeys	H5N1	3.8 (1.3–11.3)	2.7 (0.8–9.5)	Gomaa (2015)
	Exposed to ducks	H9	4.7 (1.1–19.7)	5.7 (1.3–25.2)	Gomaa (2015)
	Duck keeper vs. chicken keeper	H9	1.1 (0.3–4)		Yu (2013)

adj OR = odds ratios adjusted for other exposures, along with 95% confidence interval; CI = confidence interval; LBM = live bird market; non-adj OR = odds ratios non-adjusted for other exposures, along with 95% confidence interval.

SUPPLEMENTAL TABLE 8

Characteristics of studies exploring the prevalence of poultry exposure practices

Reference	Country	Year	Study population	*n*	Sampling	Data	Study level	Q
Leslie (2008)[27]	Afghanistan	2007	Residents	304	prob.	quest.	National	1
Vong (2006)[28]	Cambodia	2005	Residents	155	non-prob.	quest.	District	2
Liao (2009)[29]	China	2006	Residents	1550	prob.	quest.	Province	1
Wang (2014)[30]	China	2013	Residents	3731	non-prob.	quest.	National	2
Radwan (2011)[31]	Egypt	2011	Residents	150	non-prob.	quest.	District	2
Santhia (2009)[32]	Indonesia	2005	Residents	291	prob.	quest.	Province	1
Barennes (2010)[33]	Lao	2007	Residents	1098	prob.	quest.	National	1
Wilson (2007)[34]	Lao	2007	Residents	ns	non-prob.	quest.	National	2
Maton (2007)[35]	Thailand	2005	Residents	784	prob.	quest.	Province	1
Somrongthong (2012)[36]	Thailand	2008	Residents	968	non-prob.	quest.	Province	2
Edirne (2011)[37]	Turkey	2007–2008	Residents	1046	prob.	quest.	Province	1
Rimi (2014)[38]	Bangladesh	2009	Residents	252	non-prob.	obs./int.	District	2
Cavailler (2010)[23]	Cambodia	2007	Residents	700	non-prob.	quest.	District	2
Peng (2014)[39]	China	2007	Residents	4950	prob.	quest.	District	2
Gai (2008)[40]	China	2007–2008	Residents	1379	prob.	quest.	National	1
Fielding (2005)[41]	China (HK)	2004	Residents	986	prob.	quest.	National	1
Fielding (2007)[42]	China (HK)	2005–2006	Residents	1760	prob.	quest.	National	1
Fielding (2014)[43]	China (HK)	2010	Residents	461	prob.	quest.	National	1
Barennes (2007)[44]	Lao	2006	Residents	461	prob.	quest.	National	1
Olsen (2005)[45]	Thailand	2004	Residents	200	prob.	quest.	District	2
Dejpichai (2009)[46]	Thailand	2005	Residents	131	non-prob.	quest.	National	2
Liao (2014)[47]	Thailand	2006	Residents	907	prob.	quest.	Province	1
Fielding (2007)[42]	Vietnam	2005–2006	Residents	1988	prob.	quest.	National	1
Liao (2014)[47]	Vietnam	2006	Residents	994	prob.	quest.	National	1
Manabe (2011)[48]	Vietnam	2009	Residents	418	prob.	quest.	District	2
Manabe (2012)[49]	Vietnam	2011	Residents	322	prob.	quest.	District	2
Sultana (2012a)[50]	Bangladesh	2008	Res. with birds	106	non-prob.	obs./int.	District	2
Sultana (2012b)[51]	Bangladesh	2008	Resident with birds	40	non-prob.	obs./int.	District	2
Khan (2012)[52]	Bangladesh	2011	Resident with birds	300	prob.	quest.	National	1
Ly (2007)[53]	Cambodia	2006	Resident with birds	269	prob.	quest.	National	1
Van Kerkhove (2009)[54]	Cambodia	2006	Resident with birds	452	prob.	quest.	National	1
Van Kerkhove (2008)[55]	Cambodia	2007	Resident with birds	3600	prob.	quest.	National	1

Van Kerkhove (2009)[54]	Cambodia	2007	Resident with birds	800	prob.	quest.	National	1
Khun (2012)[56]	Cambodia	2009	Resident with birds	246	prob.	quest.	District	2
Negro-Calduch (2013)[57]	Egypt	2009–2010	Resident with birds	102	non-prob.	quest.	Province	2
Kayali (2011)[58]	Lebanon	2010	Resident with birds	200	non-prob.	quest.	National	2
Nasreen (2013)[59]	Bangladesh	2009	Farm workers	212	non-prob.	quest.	National	2
Yu (2013)[13]	China	2009–2010	Farm workers	305	non-prob.	quest.	Province	2
Negro-Calduch (2013)[57]	Egypt	2009–2010	Farm workers	124	non-prob.	quest.	Province	2
Robert (2010)	Indonesia	2007	Farm workers	495	non-prob.	quest.	District	2
Neupane (2012)	Nepal	2009	Farm workers	96	prob.	quest.	District	2
Sarker (2011)	Bangladesh	2008–2009	Market workers	318	non-prob.	quest.	District	2
Ma (2014)	China	2013	Market workers	306	prob.	quest.	Province	1
Kumar (2013)	India	2008	Market workers	207	non-prob.	quest.	District	2
Santhia (2009)	Indonesia	2005	Market workers	87	non-prob.	quest.	District	2
Samaan (2012)[65]	Indonesia	2008	Market workers	34	non-prob.	quest.	District	2
Samaan (2011)[66]	Indonesia	2010	Market workers	37	non-prob.	quest.	District	2
Sutanto (2013)[52]	Indonesia	2012	Market workers	100	prob.	quest.	District	2
Kuo (2011)[67]	Taiwan	2009–2010	Market workers	177	non-prob.	quest.	District	2
Li (2013)[24]	China	2010–2012	Poultry workers	1169	non-prob.	quest.	Province	2
Yang (2012)[18]	China	2011	Poultry workers	1741	prob.	quest.	Province	1

HK = Hong Kong; obs./int. = observations and/or in-depth interviews; Q = quality grade; quest.: standardized questionnaires. National: several provinces are included in the study; district: the study was conducted at the level of a district, or below. Sampling refers to the sampling strategy, probabilistic (prob.) or non-probabilistic (non-prob.) sampling.

SUPPLEMENTAL TABLE 9

Prevalence of poultry exposure practices

Practice/country	Population/year	*n*	p	CI	Author (year)
Bury/incinerate dead birds/	Household/				
Bangladesh		40	12	4–27	Sultana (2012b)
Bangladesh	2009	30	10	2–27	Rimi (2014)
Bangladesh	2011	300	2	1–4	Khan (2012)
Cambodia	2009	246	72	65–77	Khun (2012)
China	2007	127	38	29–47	Peng (2014)
Egypt	2009–2010	102	19	12–28	Negro-Calduch (2013)
Egypt	2011	127	16	10–23	Radwan (2011)
Indonesia	2005	291	80	75–85	Santhia (2009)
Lao	2006	399	78	73–82	Barennes (2007)
Lao	2007	1098	87	85–89	Barennes (2010)
Thailand	2006	907	95	93–96	Liao (2014)
Vietnam	2006	994	79	76–81	Liao (2014)
Vietnam	2009	418	76	71–80	Manabe (2011)
Bury/incinerate dead birds/	Farm/				
Egypt	2009–2010	124	30	22–39	Negro-Calduch (2013)
Nepal	2009	96	95	88–98	Neupane (2012)
Consuming dead birds/	Household/				
Bangladesh	2008	40	100	91–100	Sultana (2012b)
Cambodia	2006	269	45	39–51	Ly (2007)
Cambodia	2006	452	45	40–50	Van Kerkhove (2009)
Cambodia	2007	700	56	52–60	Cavailler (2010)
Cambodia	2007	800	14	11–16	Van Kerkhove (2009)
Cambodia	2009	246	87	83–91	Khun (2012)
China	2007	127	3	1–8	Peng (2014)
Lao	2006	399	2	1–5	Barennes (2007)
Lao	2007	1098	5	4–6	Barennes (2010)
Thailand	2004	200	12	8–17	Olsen (2005)
Thailand	2008	968	2	1–3	Somrongthong (2012)
Vietnam	2005–2006	253	5	3–9	Fielding (2007)
Vietnam	2009	418	5	3–8	Manabe (2011)
Consuming dead birds/	Market/				
Bangladesh	2008–2009	318	16	12–21	Sarker (2011)
Keep poultry inside house/	Household/				
Bangladesh	2008	106	80	71–87	Sultana (2012a)
Bangladesh	2011	300	27	22–32	Khan (2012)
Cambodia	2007	2401	87	85–88	Van Kerkhove (2008)
Egypt	2011	118	14	8–21	Radwan (2011)
Lao	2006	428	3	1–5	Barennes (2007)
Lao	2007	1098	1	0–1	Barennes (2010)
Raise backyard poultry/	Household/				
Turkey	2007–2008	1046	66	63–69	Erdine (2011)
Vietnam	2005–2006	1988	53	51–55	Fielding (2007)
Raise backyard poultry/	Peri-urban household/				
Lao	2006	192	50	43–58	Barennes (2007)
Lao	2007	364	55	50–61	Barennes (2010)

Raise backyard poultry/	Rural household/				
Afghanistan	2007	304	65	59–70	Leslie (2008)
Bangladesh	2009	252	81	76–86	Rimi (2014)
Cambodia	2005	155	96	92–99	Vong (2006)
China	2007	1043	51	48–54	Peng (2014)
China	2007–2008	1379	52	49–54	Gai (2008)
China	2013	1227	50	47–53	Wang (2014)
Egypt	2011	150	78	71–84	Radwan (2011)
Indonesia	2005	291	90	86–93	Santhia (2009)
Lao	2006	189	84	78–89	Barennes (2007)
Lao	2007	570	64	60–68	Barennes (2010)
Lao	2007	NA	88	85–90	Wilson (2007)
Thailand	2004	200	74	67–80	Olsen (2005)
Thailand	2005	131	68	59–76	Dejpichai (2009)
Thailand	2005	784	80	77–83	Maton (2007)
Vietnam	2011	322	92	89–95	Manabe (2012)
Raise backyard poultry/	Peri-urban household/				
China	2006	187	34	27–42	Liao (2009)
Raise backyard poultry/	Urban household/				
China	2006	1363	19	17–21	Liao (2009)
Lao	2006	461	40	36–45	Barennes (2007)
Lao	2007	164	51	43–58	Barennes (2010)
Vietnam	2011	221	51	44–57	Manabe (2012)
Return sick birds to supplier/	Market/				
Bangladesh	2008–2009	318	9	6–13	Sarker (2011)
Return sick birds to supplier/	LBM/farm worker/				
India	2008	207	50	43–57	Kumar (2013)
Rinse/wash equipment/	Household/				
Bangladesh	2009	30	33	17–53	Rimi (2014)
Egypt	2011	127	99	96–100	Radwan (2011)
Rinse/wash equipment/	Farm/				
Nepal	2009	96	41	31–51	Neupane (2012)
Rinse/wash equipment/	Market/				
Indonesia	2008	34	38	22–56	Samaan (2012)
Indonesia	2009	29	62	42–79	Samaan (2012)
Indonesia	2010	37	19	8–35	Samaan (2011)
Indonesia	2012	100	100	96–100	Sutanto (2013)
Sell sick/dead poultry/	Household/				
Afghanistan	2007	304	26	22–32	Leslie (2008)
Bangladesh	2008	40	100	91–100	Sultana (2012b)
Cambodia	2009	246	89	85–93	Khun (2012)
Egypt	2009–2010	102	72	63–81	Negro-Calduch (2013)
Lao	2006	399	0	0–1	Barennes (2007)
Lao	2007	1098	0	0–1	Barennes (2010)
Vietnam	2005–2006	253	5	3–9	Fielding (2007)
Sell sick/dead poultry/	Farm/				
Egypt	2009–2010	124	81	73–87	Negro-Calduch (2013)
Sell sick/dead poultry	Market/				
Bangladesh	2008–2009	318	53	48–59	Sarker (2011)
India	2008	105	2	0–7	Kumar (2013)
Slaughter poultry/	Farm/				
Bangladesh	2009	212	38	32–45	Nasreen (2013)
Indonesia	2007	495	6	4–9	Robert (2010)

Slaughter poultry/	Household/				
Bangladesh	2011	300	84	80–88	Khan (2012)
Cambodia	2006	452	38	34–43	Van Kerkhove (2009)
Cambodia	2007	3600	28	27–30	Van Kerkhove (2008)
Cambodia	2007	800	36	32–39	Van Kerkhove (2009)
China	2006	1550	45	42–47	Liao (2009)
China	2013	685	12	9–14	Wang (2014)
Egypt	2011	150	85	78–90	Radwan (2011)
Indonesia	2005	841	55	52–58	Santhia (2009)
Thailand	2005	147	19	13–26	Maton (2007)
Thailand	2006	907	59	56–62	Liao (2014)
Vietnam	2006	994	85	83–87	Liao (2014)
Slaughter poultry/	Market/				
Bangladesh	2009	210	39	32–46	Nasreen (2013)
China	2013	306	87	83–91	Ma (2014)
India	2008	105	100	97–100	Kumar (2013)
Indonesia	2005	87	58	46–68	Santhia (2009)
Throw dead birds/	Household/				
Bangladesh	2008	40	48	32–64	Sultana (2012b)
Bangladesh	2009	30	87	69–96	Rimi (2014)
Bangladesh	2011	300	45	40–51	Khan (2012)
Cambodia	2009	246	75	69–80	Khun (2012)
China	2007	127	57	48–65	Peng (2014)
Egypt	2011	127	84	77–90	Radwan (2011)
Lao	2006	399	16	13–20	Barennes (2007)
Lao	2007	1098	5	3–6	Barennes (2010)
Thailand	2006	907	2	1–3	Liao (2014)
Vietnam	2005–2006	253	12	8–16	Fielding (2007)
Vietnam	2006	994	23	20–26	Liao (2014)
Throw dead birds/	LBM/Farm worker/				
India	2008	207	20	15–26	Kumar (2013)
Touch dead/sick poultry/	Household/				
Cambodia	2006	269	75	69–80	Ly (2007)
Cambodia	2006	452	75	71–79	Van Kerkhove (2009)
Cambodia	2007	700	31	28–35	Cavailler (2010)
Cambodia	2007	3600	33	31–34	Van Kerkhove (2008)
Cambodia	2007	800	42	39–46	Van Kerkhove (2009)
Thailand	2004	200	39	32–46	Olsen (2005)
Thailand	2005	131	28	21–37	Dejpichai (2009)
Touch dead/sick poultry/	Farm/				
China	2011	1741	13	12–15	Yang (2012)
Touch dead/sick poultry/	Market/				
Indonesia	2005	87	41	31–52	Santhia (2009)
Touch dead/sick poultry/	Poultry workers/				
China	2010–2012	1169	8	7–10	Li (2013)
Touch dead/sick poultry/	Rural household/				
Indonesia	2005	841	14	12–17	Santhia (2009)
Thailand	2008	968	28	25–31	Somrongthong (2012)

Touch when purchasing/	Household/				
China	2006	1550	59	56–61	Liao (2009)
China	2007	2058	17	15–19	Peng (2014)
China	2013	685	71	67–74	Wang (2014)
China (HK)	2004	774	14	12–17	Fielding (2005)
China (HK)	2005–2006	1191	8	6–9	Fielding (2007)
China (HK)	2010	189	5	2–9	Fielding (2014)
Thailand	2006	907	63	60–66	Liao (2014)
Vietnam	2005–2006	676	63	59–67	Fielding (2007)
Vietnam	2006	994	92	90–94	Liao (2014)
Visit LBMs/	Household/				
China (HK)	2004	986	78	76–81	Fielding (2005)
China (HK)	2005–2006	1760	71	69–73	Fielding (2007)
China (HK)	2010	461	41	36–46	Fielding (2014)
Vietnam	2005–2006	1988	34	32–36	Fielding (2007)
Visit LBMs/	Rural household/				
Cambodia	2006	452	9	7–12	Van Kerkhove (2009)
Cambodia	2007	3600	7	6–8	Van Kerkhove (2008)
Cambodia	2007	800	8	6–10	Van Kerkhove (2009)
Visit LBMs/	Peri-urban household/				
China	2006	187	77	70–83	Liao (2009)
Visit LBMs/	Urban household/				
China	2006	1363	81	79–83	Liao (2009)
China	2007	2058	38	36–40	Peng (2014)
China	2013	2504	33	31–35	Wang (2014)
Wash hands with soap/	Household/				
Bangladesh	2009	30	4	0–17	Rimi (2014)
Egypt	2011	118	98	94–100	Radwan (2011)
Thailand	2005	147	80	73–86	Maton (2007)
Thailand	2008	691	99	98–100	Somrongthong (2012)
Vietnam	2009	418	96	94–98	Manabe (2011)
Vietnam	2011	322	99	97–100	Manabe (2012)
Wash hands with soap/	Market/				
Bangladesh	2008–2009	318	68	63–73	Sarker (2011)
Wear aprons/change clothes/	Household/				
Egypt	2011	118	5	2–11	Radwan (2011)
Lebanon	2010	128	0	0–3	Kayali (2011)
Wear aprons/change clothes/	Farm/				
Bangladesh	2009	212	34	28–41	Nasreen (2013)
Lebanon	2010	72	4	1–12	Kayali (2011)
Nepal	2009	96	3	1–9	Neupane (2012)
China	2009–2010	305	89	85–92	Yu (2013)
Wear aprons/change clothes/	Market/				
China	2013	306	80	75–84	Ma (2014)
Indonesia	2008	34	15	5–31	Samaan (2012)
Indonesia	2009	29	55	36–74	Samaan (2012)
Indonesia	2010	37	30	16–47	Samaan (2011)
Wear boots/	Household/	128	6	3–12	Kayali (2011)
Lebanon	2010				
Wear boots/	Farm/				
Bangladesh	2009	212	16	11–22	Nasreen (2013)
Lebanon	2010	72	15	8–26	Kayali (2011)
Nepal	2009	96	7	3–14	Neupane (2012)

Wear boots/	Market/				
China	2013	306	80	75–84	Ma (2014)
Indonesia	2008	34	65	46–80	Samaan (2012)
Indonesia	2009	29	55	36–74	Samaan (2012)
Indonesia	2010	37	30	16–47	Samaan (2011)
Wear facemask/	Household/				
Egypt	2011	127	2	0–6	Radwan (2011)
Lebanon	2010	128	0	0–3	Kayali (2011)
Thailand	2005	147	2	0–6	Maton (2007)
Thailand	2008	691	2	1–3	Somrongthong (2012)
Wear facemask/	Farm/				
Bangladesh	2009	212	66	59–72	Nasreen (2013)
Indonesia	2007	495	14	11–18	Robert (2010)
Lebanon	2010	72	6	2–14	Kayali (2011)
Nepal	2009	96	27	19–37	Neupane (2012)
China	2009–2010	305	46	40–52	Yu (2013)
China	2011	1741	42	40–44	Yang (2012)
Wear facemask/	Market/				
Bangladesh	2008–2009	318	17	13–21	Sarker (2011)
China	2013	306	20	16–25	Ma (2014)
Indonesia	2012	100	13	7–21	Sutanto (2013)
Taiwan	2009–2010	177	45	38–53	Kuo (2011)
Wear gloves/	Household/				
Egypt	2011	127	2	0–6	Radwan (2011)
Lebanon	2010	128	2	0–6	Kayali (2011)
Thailand	2008	691	1	0–2	Somrongthong (2012)
Wear gloves/	Farm/				
Bangladesh	2009	212	27	21–33	Nasreen (2013)
Indonesia	2007	495	10	8–13	Robert (2010)
Lebanon	2010	72	1	0–7	Kayali (2011)
Nepal	2009	96	30	21–40	Neupane (2012)
China	2009–2010	305	54	48–60	Yu (2013)
China	2011	1741	47	45–49	Yang (2012)
Wear gloves/	Market/				
China	2013	306	60	54–66	Ma (2014)

CI = confidence interval; HK = Hong Kong; LBM = live bird market; *n* = sample size; p = proportion of respondents adopting the practice. Wash hands with soap: handwashing after contacts with poultry; throw dead birds: throw dead birds in open space; visit LBMs: visit to LBMs to purchase poultry.

SUPPLEMENTAL TABLE 10

Identified rationales by authors based on responses to interviews and observation for poultry exposure practices in reviewed practice prevalence studies

Practice	Summary of rationale	Setting	Country	Author (year)
To keep poultry inside the bedroom	They are concerned about the security of their poultry. They want to protect them from jungle cats, foxes, and thieves.	HH	Bangladesh	Sultana (2012)
To keep sick poultry inside the bedroom	Sick poultry are kept under a basket in the yard during the daytime to separate them from their healthy poultry, and under the bed at night to observe if the poultry were about to die.	HH	Bangladesh	Sultana (2012b)
To consume sick poultry	They slaughter and consume the sick poultry if they thought that the poultry would not recover because Islam prohibits eating animals that die of natural causes	HH	Bangladesh	Sultana (2012b)
	Unable to sell sick poultry, they consume them, in accordance with the Islamic principles. They slaughter their healthy poultry in fear of losing them, when hearing about high mortality in neighboring flocks	HH	Bangladesh	Rimi (2014)
Cleaning ground after slaughter	First because they want to avoid disease among poultry, second because blood looks bad, and third because stepping on blood might cause harm to others, pregnant women in particular	HH	Bangladesh	Rimi (2014)
Buying live poultry	Traditional habit, lower meat quality of chilled or frozen meat	Market	China	Ma (2014)
Risky practices	These practices are traditional. Traditional practices are explained as a matter of preference.	HH	Turkey	Erdine (2011)
	They relate to the perception that people and poultry are not at risk. Most people were aware of avian influenza, but estimated the risks associated with poultry handling to be negligible.	Market	Lao	Barennes (2007)
No preventive practices	Farmers cannot afford their implementation	HH	Lao	Barennes (2010)
	Lack of willingness, economic dependence on limited resources, and low living standards.	HH	Turkey	Erdine (2011)
	Villagers do not believe that AIVs can transmit to humans. They consider the chance of an adverse outcome from poultry exposure to be quite low compared with the adverse outcome of worse poverty, and are therefore less likely to change their behavior to decrease the frequency of poultry–human interactions.	HH	Bangladesh	Sultana (2012)
	Absence of supporting legislation, financial constraints, time, and space constraints	HH/Farm	Egypt	Negro-Calduch (2013)
	Fear of losing costumers, may reduce sales, may increase costs.	Market	Indonesia	Sutanto (2013)

AIV = avian influenza virus; HH = household.

SUPPLEMENTAL TABLE 11

Examples of rationales discussed as post hoc hypotheses by authors of practice prevalence and risk factor studies

Practice	Summary of rationale	Setting	Country	Author (year)
Buying live poultry	They prefer live poultry to pre-killed for family consumption. Poultry slaughtered immediately before cooking are traditionally believed to be fresher, better in flavor, more nutritious and less likely to be contaminated	HH	Vietnam	Liao (2014)
Hygiene measures in markets/preventive measures	Resistance due to "risk fatigue" from repeated wet market-related outbreaks combined with economic concerns. Effective preventive measures would threaten economic security among traders with low education and few employment alternatives	Market	China	Ma (2014)
Rear backyard poultry	Poultry prices have increased, making poultry consumption a privilege of the wealthier Vietnamese. This encourages the continuation of backyard farming	HH	Vietnam	Liao (2014)
Consumption of sick and dead birds	Poultry prices have increased, making poultry consumption a privilege of the wealthier Vietnamese. This encourages the continuation of backyard farming, including the full use of sick/dead birds	HH	Vietnam	Liao (2014)
Slaughtering poultry	According to Buddhist principles, killing is considered to have karmic consequences. Thai people are therefore less likely to slaughter the poultry themselves	HH	Thailand	Liao (2014)
Touching poultry before purchase	The reason for touching and feeling the poultry before buying relates to the consumer tradition, relying on their own judgment on the quality and safety of the poultry	HH	Vietnam/Thailand	Liao (2014)
Risky practices	Farmers' inadequate knowledge, awareness, and information about zoonosis	HH	Bangladesh	Khan (2012)
	People have believed that people could never get infected with HPAI by engaging in risky practices. The study notes that this may be strongly related to poverty and illiteracy	HH	Cambodia	Khun (2012)

HH = household.

Supplemental Table 12

Risky and protective practices of which their association with AIV infection was assessed in the reviewed risk factor studies

Exposure	H.	L.	Non-adj OR (95% CI)	Adj OR (95% CI)	Author (year)
Poultry in the vicinity: neighbors raising poultry					
Live poultry in neighborhood	NS		1.1 (0.2–6.6), $P = 0.81$		Dinh (2006)
Poultry in the vicinity: poultry farms in the vicinity					
Poultry farms in the vicinity	NS		13 (2.4–133)	42 (2.3–1000)	He (2014)
Poultry in the vicinity: neighbors raising poultry					
Neighbors raising poultry at home	NS		6.4 (2.9–15)		He (2014)
Raising poultry or pigeons in the neighborhood	NS		0.9 (0.4–2.2), $P = 0.82$		Li (2014)
Sick or dead poultry in the neighborhood	Sick		3.9 (1.0–55.7), $P = 0.05$		Dinh (2006)
In location with poultry: attending cockfight					
Attended cockfight	NS		1.5 (0.3–5.5), $P = 0.47$		Cavailler (2010)
In location with poultry: visiting LBM, neighbors raising poultry					
Visiting markets, and poultry raised in the neighborhood	NS		6.9 (1.9–25.2), $P = 0.003$	4.2 (0.9–19.6), $P = 0.064$	Ai (2013)
In location with poultry					
In location with poultry	NS		2.3 (1.0–5.3), $P = 0.06$		Liu (2014)
In location with poultry: raising poultry at home					
Raise poultry	NS	H	0.7 (0.1–6.7), $P = 0.75$		Ai (2013)
Being < 1 m away from dead poultry	Sick	H	13 (1.8–96.3)		Areechokchai (2006)
Live poultry in household	NS	H	3 (0.9–10), $P = 0.1$		Dinh (2006)
Sick or dead poultry in household	Sick	H	7.4 (2.7–59), $P < 0.001$	4.9 (1.2–20.2), $P = 0.03$	Dinh (2006)
Raising poultry at home	NS	H	9 (2.6–39)		He (2014)
Indirect contact with poultry at home	NS	H	4.4 (1.1–18.2), P 0.04		Li (2014)
Exposure to backyard poultry at home (raise)	NS	H	2.4 (1.1–5.6), $P = 0.04$	1.5 (0.5–4.4), $P = 0.48$	Liu (2014)
Sick or dying backyard poultry in month before symptoms	Sick	H	9.4 (2.5–36.1), $P < 0.01$	9.8 (2.2–43.2) $P < 0.01$	Liu (2014)
Live birds in home	NS	H	1.4 (0.3–6.4), $P < 0.9$		Mounts (1999)
Raise backyard poultry	NS	H	4.5 (1.1–17.5) $P = 0.03$		Zhou (2009)
Indirect contact with sick and/or dead poultry	Sick	NS	11.3 (2.2–58.5), $P = 0.004$	57 (4.3–746), $P = 0.002$	Zhou (2009)
Raising poultry at home: cages inside the house					
Poultry cages inside the house vs. no poultry	NS	H	9.7 (1.8–53.3) $P = 0.009$		Zhou (2009)
Raising poultry at home: cages outside the house					
Poultry cages outside the house vs. no poultry	NS	H	3.7 (0.9–15.3) $P = 0.07$		Zhou (2009)
Raising poultry at home: vaccinated flocks					
Poultry H5 vaccination coverage < 80% vs. no poultry	NS	H	7.1 (1.6–31.6), $P = 0.01$		Zhou (2009)
Poultry H5 vaccination coverage > 80% vs. no poultry	NS	H	4.0 (0.9–17.9), $P = 0.07$		Zhou (2009)
Waterfowl H5 vaccination coverage < 80% vs. no waterfowl	NS	H	8.4 (1.6–45.1), $P = 0.01$		Zhou (2009)
Waterfowl H5 vaccination coverage > 80% vs. no waterfowl	NS	H	2.4 (0.5–11.2), $P = 0.26$		Zhou (2009)

Raising poultry at home: flock size					
Poultry number	NS	H	2.4 (1–5.7), P = 0.03		Huo (2012)
In location with poultry: Poultry species					
Raise chickens only (no waterfowls)	NS	H	2.6 (0.6–12.1)		Zhou (2009)
Raise waterfowl	NS	H	6.4 (1.6–26.3)		Zhou (2009)
Exposed to geese	NS	NS	3.6 (1.2–10.2)	3.1 (0.9–10.4)	Gomaa (2015)
Exposed to turkeys	NS	NS	3.8 (1.3–11.3)	2.7 (0.8–9.5)	Gomaa (2015)
Exposed to ducks	NS	NS	4.7 (1.1–19.7)	5.7 (1.3–25.2)	Gomaa (2015)
Duck keeper vs. chicken keeper	NS	F	1.1 (0.3–4)		Yu (2013)
In location with poultry: working on a poultry premise					
Occupational poultry exposure	NS	P	13.1 (1.4–125.4), P = 0.03		Zhou (2009)
> 10% Mortality among poultry	Sick	P	2.2 (1.3–3.7)		Bridges (2002)
Occurrence of sick/dead ducks at worksite	Sick	F	1.1 (0.2–4.9), P = 0.94		Yang (2012)
Working with poultry: premise type					
Farm type: layer vs. broiler	NS	F		0.8 (0.3–2.5)	Ahad (2014)
Farm type: breeder vs. broiler	NS	F		3.8 (1.4–10.1)	Ahad (2014)
Farm type: layer vs. broiler duck	NS	F	6.4 (1.7–23.6), P = 0.006		Yang (2012)
Work in retail vs. wholesale/farm/other poultry industry	NS	M	2.7 (1.5–4.9)		Bridges (2002)
Working with poultry: flock size					
Number of poultry bred > 1,000	NS	P		3.8 (1.7–8.7), P = 0.001	Li (2013)
In location with poultry: visiting LBM					
Visiting a wet poultry market	NS	M	3.1 (1.2–7.9), P = 0.02	15.4 (3.0–80.2), P = 0.001	Zhou (2009)
Visiting a wet poultry market (computed)	NS	M	3.8 (1.5–9.8)		Li (2014)
Visit LBM	NS	M	10.4 (4.9–22.0), P < 0.01	3.4 (1.8–6.7), P < 0.01	Liu (2014)
Purchasing of live or freshly slaughtered poultry in a market	NS	M	7.9 (3–23)	4.9 (1.2–24)	He (2014)
Visited LBM	NS	M	3.1 (1.1–8.3), P = 0.03		Ai (2013)
Exposure to poultry in market	NS	M	4.5 (1.2–21.7), P = 0.05		Mounts (1999)
In location with poultry: visiting informal LBM					
Visiting a temporary roadside poultry vendor	NS	M	7 (1.2–40.6), P = 0.03		Li (2014)
Visiting LBM: visit frequency					
1–5 visits within 2 weeks before illness vs. no visits	NS	M	2.8 (0.9–8.1), P = 0.06		Zhou (2009)
6–10 visits within 2 weeks before illness vs. no visits	NS	M	7.6 (1.1–53.7), P = 0.04		Zhou (2009)
> 10 visits within 2 weeks before illness vs. no visits	NS	M	5.8 (1.2–28.6), P = 0.03		Zhou (2009)
Visiting a live poultry market: 1–9 times vs. no	NS	M	3.4 (1.2–9.3), P = 0.02	3.8 (1.3–10.8), P = 0.01	Li (2014)
Visiting a live poultry market: > 10 times vs. no	NS	M	5.6 (1.2–26.9), P = 0.03	10.6 (1.9–60.7), P = 0.008	Li (2014)
Market: 1–5 visits vs. no visits	NS	M	1.5 (0.4–5.5), P = 0.55		Ai (2013)
Market: 6–9 visits vs. no visits	NS	M	0.8 (0.1–7.4), P = 0.82		Ai (2013)
Market: > 10 visits vs. no visits	NS	M	8.8 (2.2–35.1), P = 0.002		Ai (2013)
Poultry husbandry: cleaning					
Removed/cleaned feces from poultry areas	NS	H	5 (0.7–36.3), P = 0.09		Vong (2009)
Cleaning poultry stalls (job duty)	NS	P	1.6 (0.9–2.7)		Bridges (2002)
Cleaning henhouse	NS	M	2.6 (0.8–8), P = 0.1		Wang (2014)
Cleaned poultry stalls	NS	H	0.8 (0.3–2.3), P = 0.71		Cavailler (2010)

Poultry husbandry: collecting eggs					
Touched/collected eggs	NS	H	2.5 (0.2–26), $P = 0.44$		Vong (2009)
Collecting eggs (job duty)	NS	P	1.2 (0.6–2.2)		Bridges (2002)
Poultry husbandry: feeding					
Fed poultry	NS	H	0.6 (0–19.5), $P = 0.64$		Vong (2009)
Feeding poultry (job duty)	NS	P	2.4 (1.4–4.1)		Bridges (2002)
Feeding	NS	M	1.8 (0.3–10), $P = 0.53$		Wang (2014)
Selling poultry: handling money					
Handling money (job duty)	NS	P	1.6 (1.0–2.5)		Bridges (2002)
Processing, preparing poultry: helped/witnessed					
Helped prepare or cook sick or dead poultry	Sick	H	2.6 (0.8–8.7), $P = 0.1$		Dinh (2006)
Witnessed poultry slaughtering at market	NS	M	5 (1.7–14.9), $P = 0.004$		Zhou (2009)
Processing, preparing poultry: storing poultry products					
Storing products of sick or dead poultry in house	Sick	H	9.3 (2.1–41.3)		Areechokchai (2006)
Bathing in pond					
Swim/bathe in ponds	NS	H	11.3 (1.3–102.2), $P = 0.03$		Vong (2009)
Swam/bathed in pond	NS	H	2.5 (1–6.5), $P = 0.05$	3 (1.1–8.4), $P = 0.04$	Cavailler (2010)
Wading in ponds	NS	H	2.4 (0.4–19.2), $P = 0.47$		Dinh (2006)
Using outdoor water sources					
Use pond as source of water	NS	H	6.8 (0.7–66.4), $P = 0.08$		Vong (2009)
No indoor water source (use outdoor sources)	NS	H	5 (1.3–77), $P = 0.01$	6.5 (1.2–34.8), $P = 0.03$	Dinh (2006)
Lack of indoor water supply	NS	H	0.7 (0.1–4.3), $P = 0.73$		Zhou (2009)
Touching (unspecified practice)					
Direct contact with poultry	NS	NS	13.7 (2.9–64.8), $P < 0.001$	9.1 (1.6–50.9), $P = 0.012$	Ai (2013)
Direct touching of unexpectedly dead poultry	Sick	H	29 (2.7–308)		Areechokchai (2006)
Touching poultry (job duty)	NS	P	5.8 (0.9–113.6)		Bridges (2002)
Touched/fed live poultry	NS	H	0.6 (0.2–1.6), $P = 0.34$		Cavailler (2010)
Touched sick poultry	Sick	H	1.4 (0.6–3.8), $P = 0.46$		Cavailler (2010)
Tending to home-raised poultry	NS	H	19 (4–182)	9.9 (0.4–318)	He (2014)
Direct or close contact with poultry	NS	P	5.9 (1.8–19), $P < 0.001$	5.2 (1.5–17.7), $P = 0.008$	Li (2013)
Direct or close contact with sick/dead poultry	Sick	P	2.6 (1.3–5.4), $P < 0.02$		Li (2013)
Occupational direct contact with poultry	NS	P	6.4 (0.6–74.2), $P = 0.14$		Li (2014)
Raising poultry or pigeons at home (direct contact)	NS	H	3.2 (0.6–17.2), $P = 0.16$		Li (2014)
Touching live poultry with bare hands in a market	NS	M	1.1 (0.6–2.2), $P = 0.74$		Li (2014)
Poultry contact (feeding, capturing, cleaning, etc.)	NS	NS	3.6 (1.7–7.3), $P < 0.01$		Liu (2014)
Touched sick and/or dead poultry with bare hands	Sick	H	0.6 (0.1–4.5), $P = 0.61$		Vong (2009)
Handling ducks with wounds on hands	NS	F	6.3 (2–20.1), $P = 0.002$	4.1 (1.3–13.6), $P = 0.02$	Yang (2012)
Close contact with sick/dead ducks	Sick	F	0.6 (0.1–4.6), $P = 0.61$		Yang (2012)
Direct contact with healthy-appearing poultry	H	NS	3.3 (1.0–10.4), $P = 0.04$		Zhou (2009)
Direct contact with live poultry at the market	NS	M	4.6 (0.4–51.9), $P = 0.22$		Zhou (2009)
Direct contact with sick and/or dead poultry	Sick	NS	34.7 (4.3–277), $P < 0.001$	507 (16–16320), $P < 0.001$	Zhou (2009)
Direct contacts: butchers vs. keepers					
Occupational exposure: butchers vs. keepers	NS	P	3.4 (0.8–14.5), $P = 0.09$		Yu (2013)

Contact with poultry from home vs. markets					
Indirect or direct contact with poultry (backyard or from markets) at home	NS	H	3.9 (2–7.5), $P < 0.01$		Liu (2014)
Indirect or direct contact at home only with backyard poultry	NS	H	1.2 (0.6–2.5), $P = 0.56$		Liu (2014)
Indirect or direct contact at home with poultry traded in markets	NS	H	6.3 (2.9–13.7), $P < 0.01$		Liu (2014)
Processing, preparing poultry: slaughtering					
Butchering poultry (job duty)	NS	P	3.1 (1.6–5.9)		Bridges (2002)
Chopped/butchered sick poultry	Sick	H	1.6 (0.6–4.6), $P = 0.37$		Cavailler (2010)
Poultry contact during slaughtering or processing	NS	NS	3.1 (1.7–5.9), $P < 0.01$		Liu (2014)
Slaughtered and/or bled poultry	NS	H	2.5 (0.3–10.8), $P = 0.45$		Vong (2009)
Processing	NS	M	0.9 (0.3–2.4), $P = 0.85$		Wang (2014)
Processing, preparing poultry: plucking					
Plucking poultry	NS	H	14 (1.3–153)		Areechokchai (2006)
Plucked sick poultry	Sick	H	1.7 (0.6–4.8), $P = 0.33$		Cavailler (2010)
Defeathered poultry that died of illness	Sick	H	3.1 (0.3–34.9), $P = 0.35$		Vong (2009)
Processing, preparing poultry: eviscerating					
Touching poultry intestines (job duty)	NS	P	1.7 (0.9–2.9)		Bridges (2002)
Eviscerated sick poultry	Sick	H	1.2 (0.4–3.6), $P = 0.77$		Cavailler (2010)
Removed internal organs	NS	H	1.5 (0.3–8.7), $P = 0.64$		Vong (2009)
Processing, preparing poultry: preparing					
Prepared and cooked poultry or birds at home	NS	H	8.1 (2.1–31.7), $P = 0.003$		Ai (2013)
Dressing poultry	NS	H	17 (1.6–177)		Areechokchai (2006)
Preparing poultry for restaurants (job duty)	NS	P	1.7 (1.1–2.7)		Bridges (2002)
Cooked sick poultry	Sick	H	1.2 (0.4–3.6), $P = 0.78$		Cavailler (2010)
Prepared and cooked sick or dead poultry	Sick	H	31 (3.4–1150), $P < 0.001$	9 (1–82), $P = 0.05$	Dinh (2006)
Prepared and cooked healthy poultry	H	H	2.2 (0.6–10.4), $P = 0.25$		Dinh (2006)
Preparing or cooking at home	NS	H	1.4 (0.4–5), $P = 0.61$		Li (2014)
Processing, preparing poultry: washing carcass/meat					
Washed sick poultry carcasses	Sick	H	1.3 (0.5–3.8), $P = 0.59$		Cavailler (2010)
Cut/wash internal meat	NS	H	2.0 (0.27–14.9), $P = 0.49$		Vong (2009)
Consumption					
Consumed healthy-appearing poultry	H	NS	1.3 (0.4–4.2), $P = 0.61$		Zhou (2009)
Consumed poultry organs or poultry	NS	NS	0.6 (0.0–7.5), $P = 1$		Mounts (1999)
Poultry consumption	NS	NS	1.2 (0.7–2.0), $P = 0.52$	0.7 (0.4–1.4), $P = 0.28$	Liu (2014)
Ate sick poultry	Sick	H	1.3 (0.5–3.3), $P = 0.64$		Cavailler (2010)
Poultry husbandry: gathering, placing in cages					
Gathered poultry and placed in cages/poultry areas	NS	H	5.8 (1–34.1), $P = 0.05$		Vong (2009)
Poultry husbandry: transporting					
Transportation of poultry	NS	M	2.2 (0.4–12.1), $P = 0.35$		Wang (2014)
Poultry husbandry: vaccinating					
Vaccinate poultry	NS	NS	2.4 (1.2–4.8), $P = 0.009$	2.4 (1.1–5)	Gomaa (2015)
Poultry husbandry: selling					
Selling poultry	NS	M	0.7 (0.3–2), $P = 0.55$		Wang (2014)

Frequent handwashing					
Frequent handwashing		H	0.1 (0–0.6), *P* = 0.008		Ai (2013)
Handwashing > 3 times/day		H	0.5 (0.1–2.4), *P* = 0.57		Dinh (2006)
Infrequent (or no) handwashing at home		H	1.8 (0.6–6.1), *P* = 0.32		Li (2014)
Washed hands with soap after handling poultry		H	0.4 (0–3.9), *P* = 0.4		Vong (2009)
Wearing gloves					
Do not use gloves		F	2.7 (0.7–9.9), *P* = 0.14		Yang (2012)
Wearing masks					
Do not use mask		F	8.1 (1–62.6), *P* = 0.05		Yang (2012)
Poor hygiene conditions					
Poor hygiene conditions		H	1 (0.3–3.4), *P* = 0.83		Dinh (2006)
Frequent disinfection of worksite					
Frequency of worksite disinfection: < twice monthly		F	7.5 (1.6–34.2), *P* = 0.01	5.1 (1.1–24.6), *P* = 0.04	Yang (2012)
Cleaning knife after preparing poultry					
Household uses soap to clean		H	0.3 (0.1–1), *P* = 0.06		Mounts (1999)
Ecological study: markets					
Number of LBMs	NS			BRT weight > 5	Fang (2013)
LBM density	NS			1.1 (1–1.1), *P* < 0.001	Fuller (2014)
LBM closure	NS	M		Red. in daily incidence	Yu (2014)
LBM closure	NS	M		Red. in daily incidence	Wu (2014)
Ecological study: poultry density					
Poultry density (1,000/km^2)	NS			RR = 1 (0.8–1.1), *P* = 0.59	Yupiana (2010)
Ecological study: outbreaks in poultry					
The number of poultry outbreaks	Sick			RR = 1.3 (1.1–1.7), *P* = 0.02	Yupiana (2010)

BRT = boosted regression tree; CI = confidence interval; LBM = live bird market; RR = risk relative. "H." refers to the health status of poultry (H: healthy; NS: not specified; sick: sick or dead poultry); "L." refers to the location where exposure (NS: not specified, H: households, M: markets, F: farms, P: premises, including markets, farms, and abattoirs); non-adj OR: odds ratios non-adjusted for other exposures, along with 95% confidence interval and P value; adj OR: odds ratios adjusted for other exposures, along with 95% confidence interval and P value; If other measures of association than odds ratios are assessed, they are mentioned in the table.

Figure 1

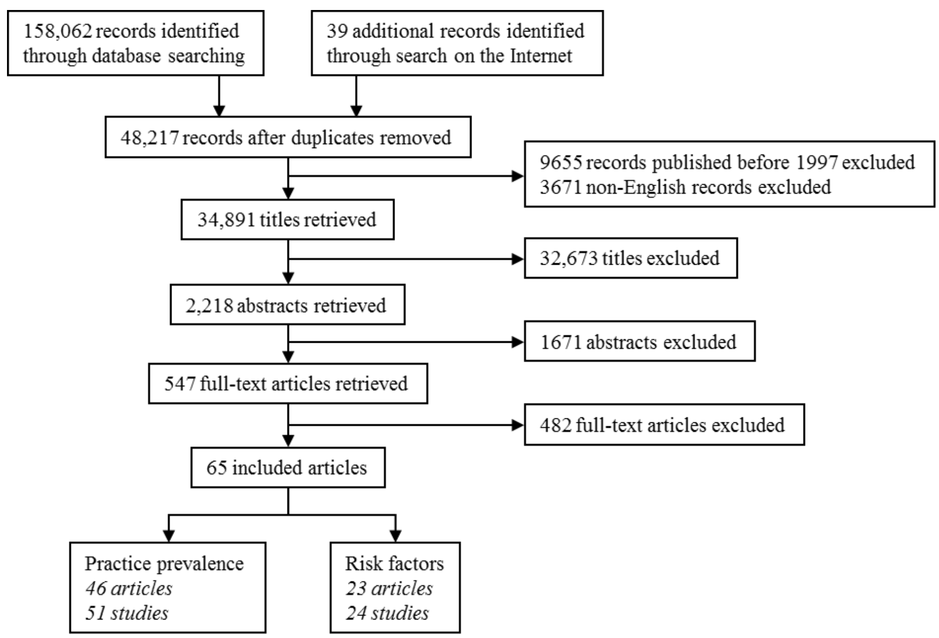

158,062 records identified through database searching
39 additional records identified through search on the Internet
48,217 records after duplicates removed
9655 records published before 1997 excluded
3671 non-English records excluded
34,891 titles retrieved
32,673 titles excluded
2,218 abstracts retrieved
1671 abstracts excluded
547 full-text articles retrieved
482 full-text articles excluded
65 included articles
Practice prevalence
46 articles
51 studies
Risk factors
23 articles
24 studies

Figure 2

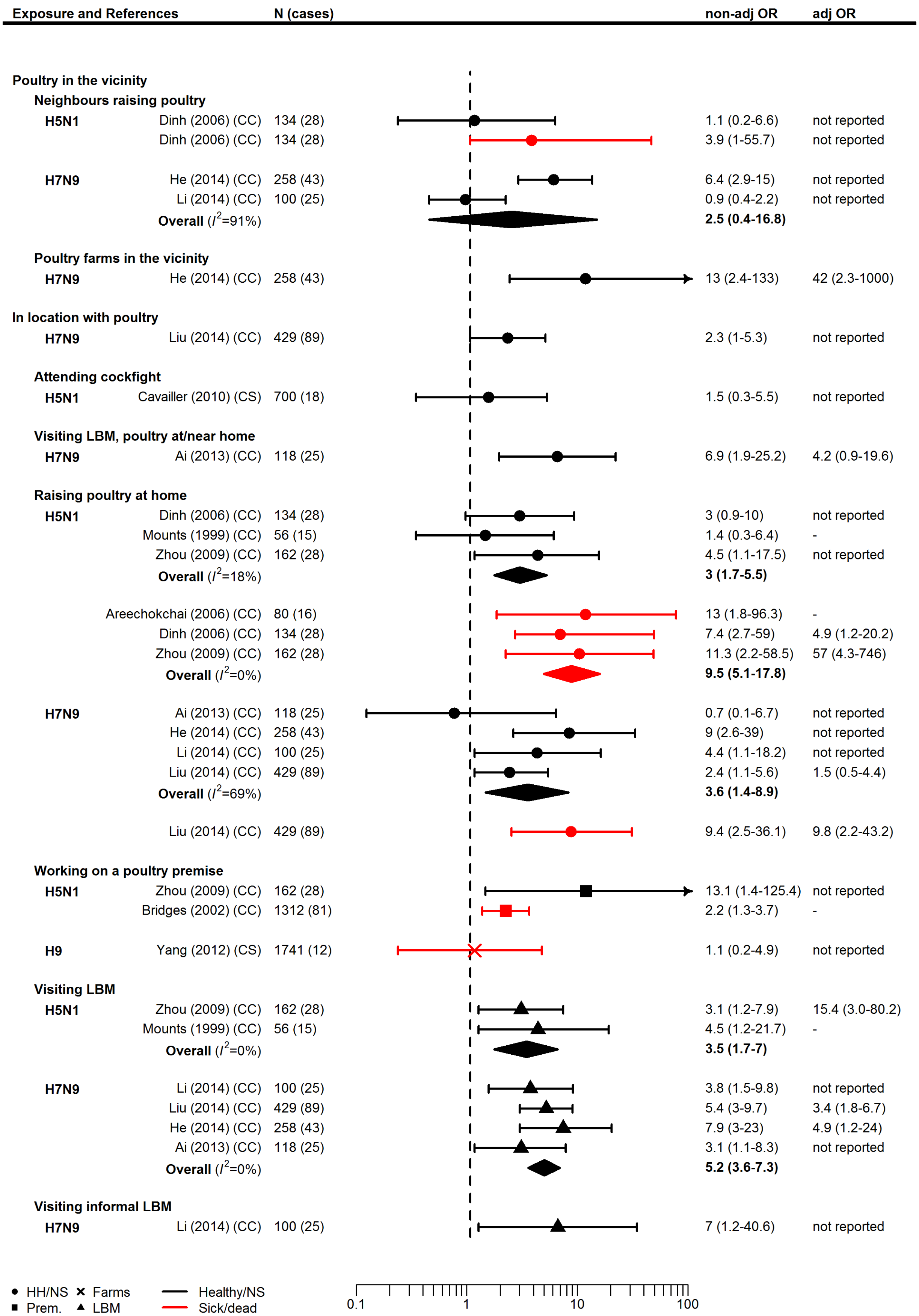

Exposure and References | N (cases) | non-adj OR | adj OR
Poultry in the vicinity
Neighbours raising poultry
H5N1 Dinh (2006) (CC) 134 (28) 1.1 (0.2-6.6) not reported
Dinh (2006) (CC) 134 (28) 3.9 (1-55.7) not reported
H7N9 He (2014) (CC) 258 (43) 6.4 (2.9-15) not reported
Li (2014) (CC) 100 (25) 0.9 (0.4-2.2) not reported
Overall (I^2=91%) 2.5 (0.4-16.8)
Poultry farms in the vicinity
H7N9 He (2014) (CC) 258 (43) 13 (2.4-133) 42 (2.3-1000)
In location with poultry
H7N9 Liu (2014) (CC) 429 (89) 2.3 (1-5.3) not reported
Attending cockfight
H5N1 Cavailler (2010) (CS) 700 (18) 1.5 (0.3-5.5) not reported
Visiting LBM, poultry at/near home
H7N9 Ai (2013) (CC) 118 (25) 6.9 (1.9-25.2) 4.2 (0.9-19.6)
Raising poultry at home
H5N1 Dinh (2006) (CC) 134 (28) 3 (0.9-10) not reported
Mounts (1999) (CC) 56 (15) 1.4 (0.3-6.4) -
Zhou (2009) (CC) 162 (28) 4.5 (1.1-17.5) not reported
Overall (I^2=18%) 3 (1.7-5.5)
Areechokchai (2006) (CC) 80 (16) 13 (1.8-96.3) -
Dinh (2006) (CC) 134 (28) 7.4 (2.7-59) 4.9 (1.2-20.2)
Zhou (2009) (CC) 162 (28) 11.3 (2.2-58.5) 57 (4.3-746)
Overall (I^2=0%) 9.5 (5.1-17.8)
H7N9 Ai (2013) (CC) 118 (25) 0.7 (0.1-6.7) not reported
He (2014) (CC) 258 (43) 9 (2.6-39) not reported
Li (2014) (CC) 100 (25) 4.4 (1.1-18.2) not reported
Liu (2014) (CC) 429 (89) 2.4 (1.1-5.6) 1.5 (0.5-4.4)
Overall (I^2=69%) 3.6 (1.4-8.9)
Liu (2014) (CC) 429 (89) 9.4 (2.5-36.1) 9.8 (2.2-43.2)
Working on a poultry premise
H5N1 Zhou (2009) (CC) 162 (28) 13.1 (1.4-125.4) not reported
Bridges (2002) (CC) 1312 (81) 2.2 (1.3-3.7) -
H9 Yang (2012) (CS) 1741 (12) 1.1 (0.2-4.9) not reported
Visiting LBM
H5N1 Zhou (2009) (CC) 162 (28) 3.1 (1.2-7.9) 15.4 (3.0-80.2)
Mounts (1999) (CC) 56 (15) 4.5 (1.2-21.7) -
Overall (I^2=0%) 3.5 (1.7-7)
H7N9 Li (2014) (CC) 100 (25) 3.8 (1.5-9.8) not reported
Liu (2014) (CC) 429 (89) 5.4 (3-9.7) 3.4 (1.8-6.7)
He (2014) (CC) 258 (43) 7.9 (3-23) 4.9 (1.2-24)
Ai (2013) (CC) 118 (25) 3.1 (1.1-8.3) not reported
Overall (I^2=0%) 5.2 (3.6-7.3)
Visiting informal LBM
H7N9 Li (2014) (CC) 100 (25) 7 (1.2-40.6) not reported
HH/NS
Farms
Prem.
LBM
Healthy/NS
Sick/dead
0.1
1
10
100

Figure 3

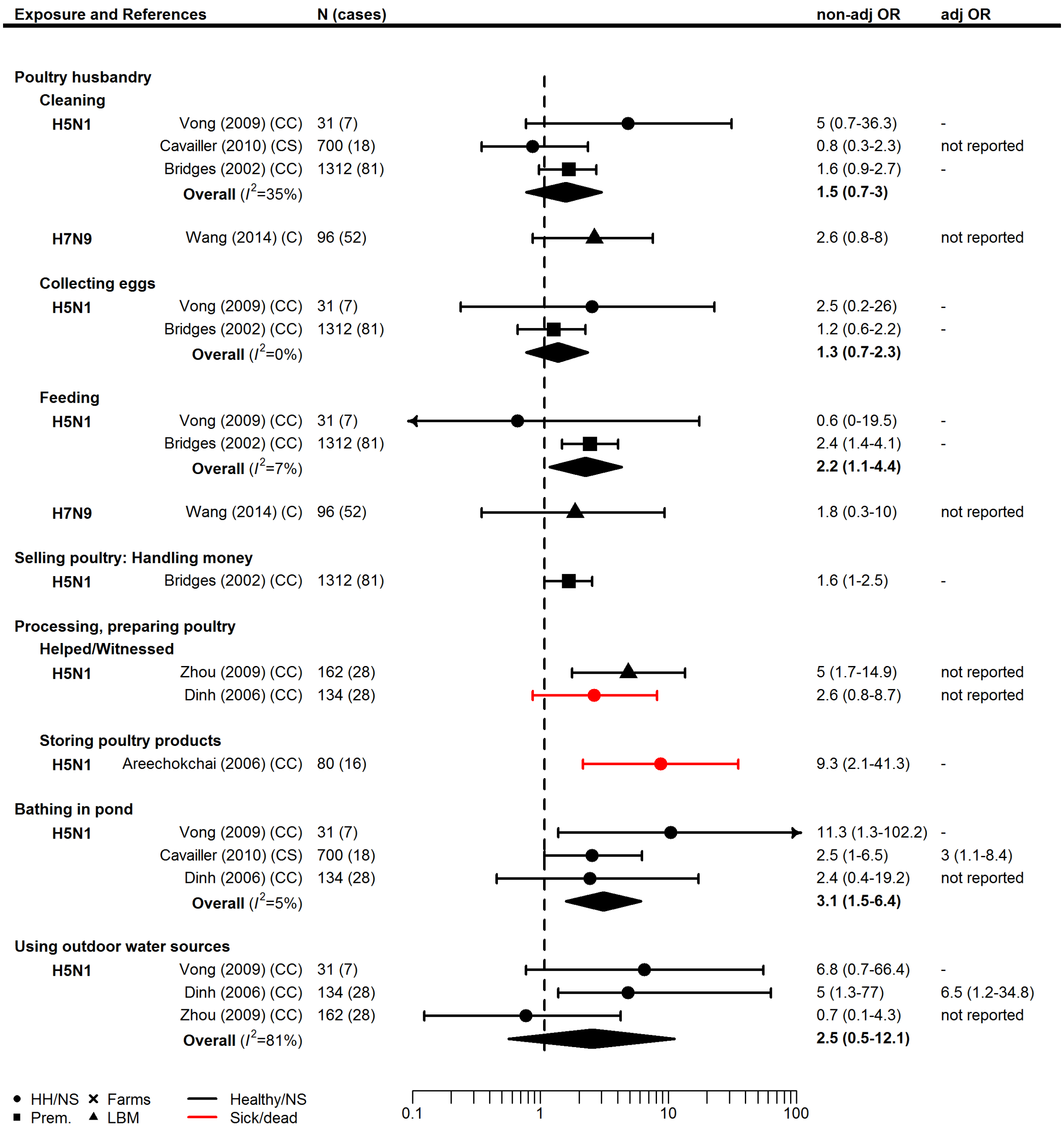
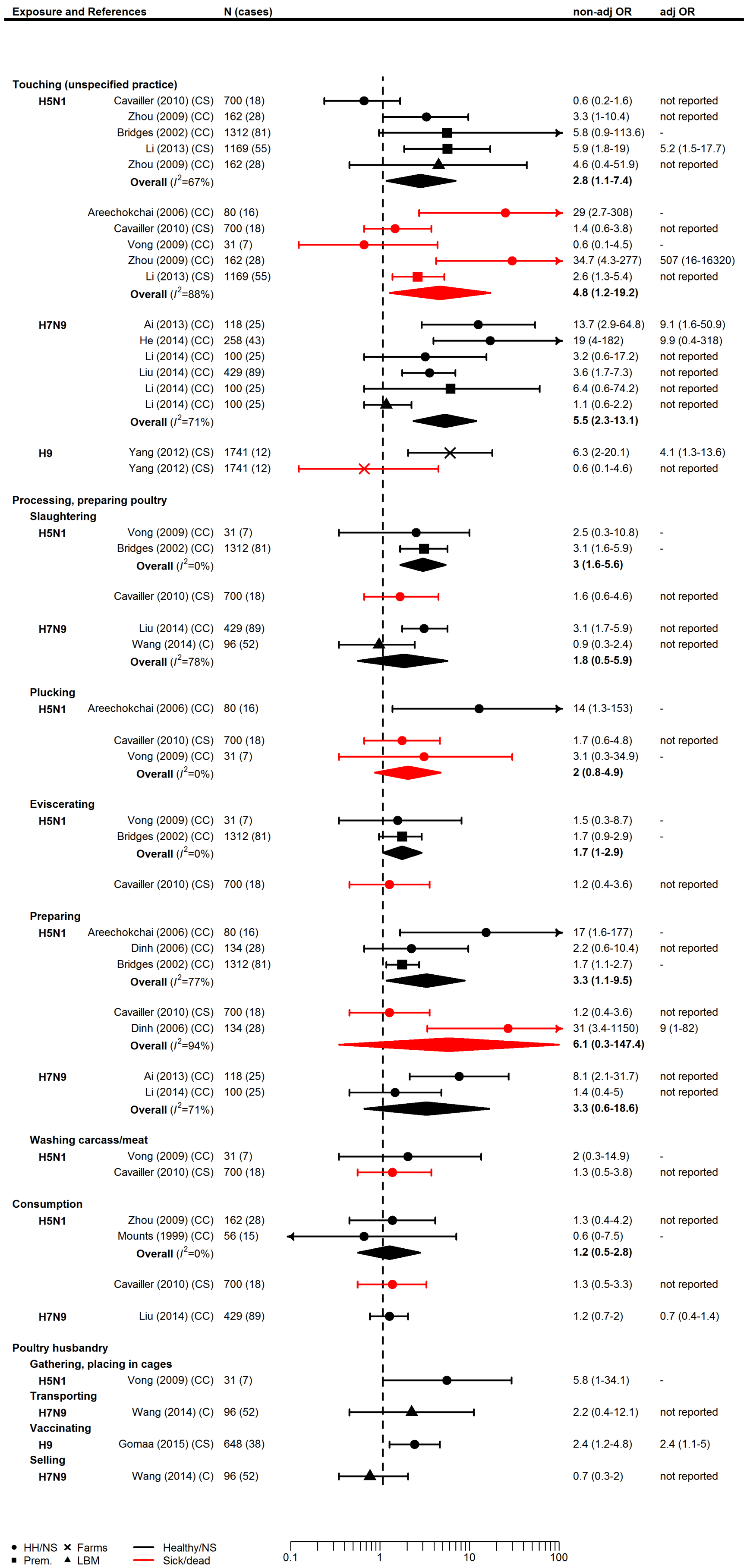
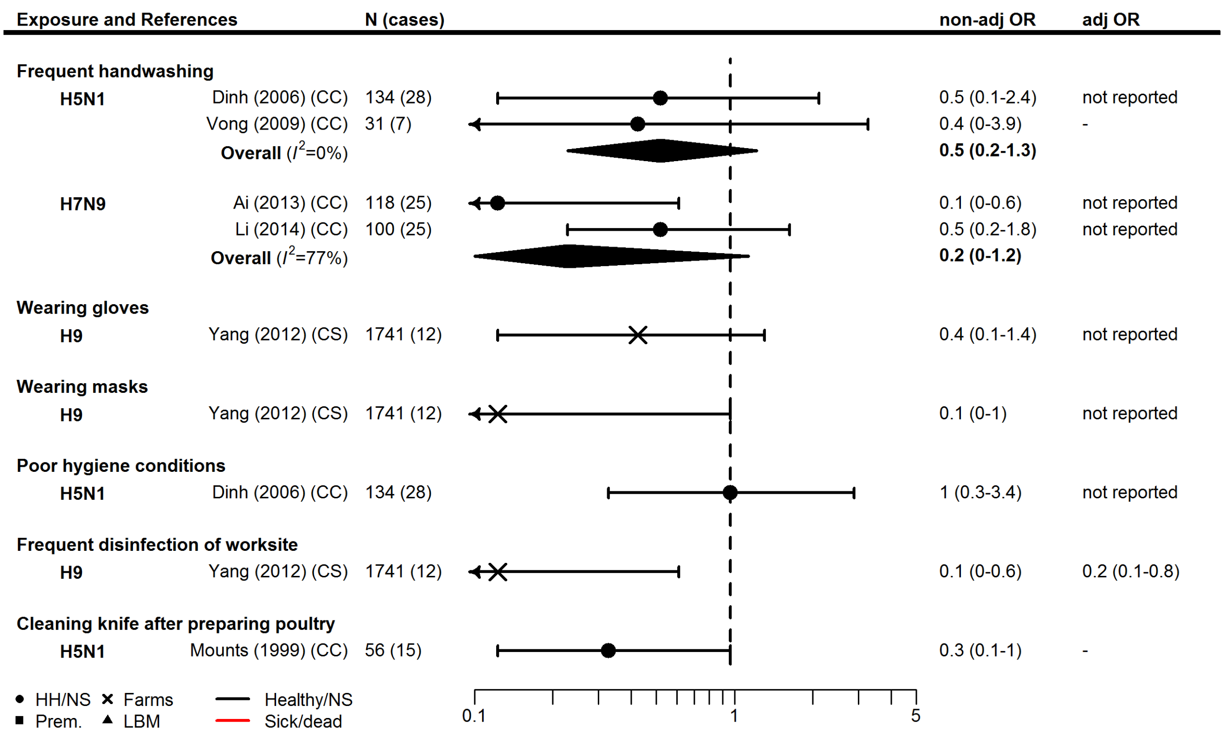

Exposure and References
N (cases)
non-adj OR
adj OR
Poultry husbandry
Cleaning
H5N1
Vong (2009) (CC) 31 (7) 5 (0.7-36.3) -
Cavailler (2010) (CS) 700 (18) 0.8 (0.3-2.3) not reported
Bridges (2002) (CC) 1312 (81) 1.6 (0.9-2.7) -
Overall (I^2=35%) 1.5 (0.7-3)
H7N9
Wang (2014) (C) 96 (52) 2.6 (0.8-8) not reported
Collecting eggs
H5N1
Vong (2009) (CC) 31 (7) 2.5 (0.2-26) -
Bridges (2002) (CC) 1312 (81) 1.2 (0.6-2.2) -
Overall (I^2=0%) 1.3 (0.7-2.3)
Feeding
H5N1
Vong (2009) (CC) 31 (7) 0.6 (0-19.5) -
Bridges (2002) (CC) 1312 (81) 2.4 (1.4-4.1) -
Overall (I^2=7%) 2.2 (1.1-4.4)
H7N9
Wang (2014) (C) 96 (52) 1.8 (0.3-10) not reported
Selling poultry: Handling money
H5N1
Bridges (2002) (CC) 1312 (81) 1.6 (1-2.5) -
Processing, preparing poultry
Helped/Witnessed
H5N1
Zhou (2009) (CC) 162 (28) 5 (1.7-14.9) not reported
Dinh (2006) (CC) 134 (28) 2.6 (0.8-8.7) not reported
Storing poultry products
H5N1
Areechokchai (2006) (CC) 80 (16) 9.3 (2.1-41.3) -
Bathing in pond
H5N1
Vong (2009) (CC) 31 (7) 11.3 (1.3-102.2) -
Cavailler (2010) (CS) 700 (18) 2.5 (1-6.5) 3 (1.1-8.4)
Dinh (2006) (CC) 134 (28) 2.4 (0.4-19.2) not reported
Overall (I^2=5%) 3.1 (1.5-6.4)
Using outdoor water sources
H5N1
Vong (2009) (CC) 31 (7) 6.8 (0.7-66.4) -
Dinh (2006) (CC) 134 (28) 5 (1.3-77) 6.5 (1.2-34.8)
Zhou (2009) (CC) 162 (28) 0.7 (0.1-4.3) not reported
Overall (I^2=81%) 2.5 (0.5-12.1)
HH/NS
Farms
Prem.
LBM
Healthy/NS
Sick/dead
0.1
1
10
100

Figure 4



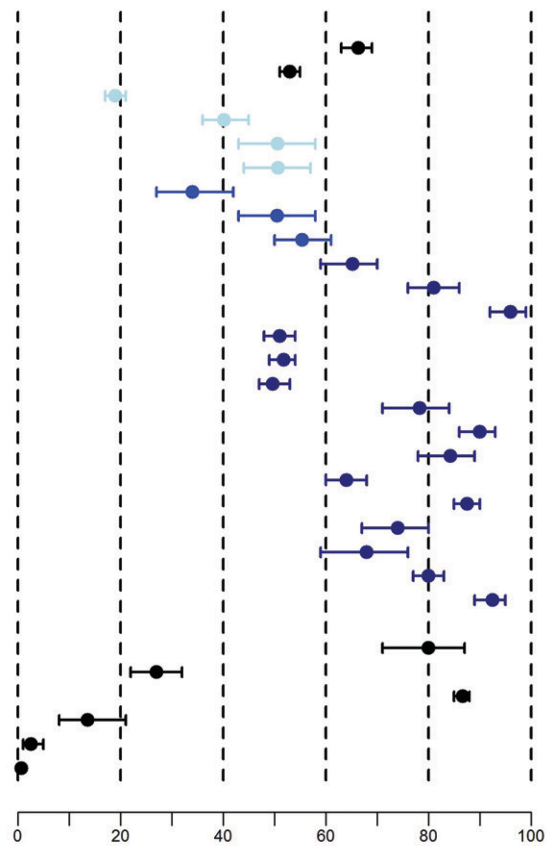
Exposure and References
N (cases)
non-adj OR
adj OR
Touching (unspecified practice)
H5N1
Cavailler (2010) (CS) 700 (18) 0.6 (0.2-1.6) not reported
Zhou (2009) (CC) 162 (28) 3.3 (1-10.4) not reported
Bridges (2002) (CC) 1312 (81) 5.8 (0.9-113.6) -
Li (2013) (CS) 1169 (55) 5.9 (1.8-19) 5.2 (1.5-17.7)
Zhou (2009) (CC) 162 (28) 4.6 (0.4-51.9) not reported
Overall (I^2=67%) 2.8 (1.1-7.4)
Areechokchai (2006) (CC) 80 (16) 29 (2.7-308) -
Cavailler (2010) (CS) 700 (18) 1.4 (0.6-3.8) not reported
Vong (2009) (CC) 31 (7) 0.6 (0.1-4.5) -
Zhou (2009) (CC) 162 (28) 34.7 (4.3-277) 507 (16-16320)
Li (2013) (CS) 1169 (55) 2.6 (1.3-5.4) not reported
Overall (I^2=88%) 4.8 (1.2-19.2)
H7N9
Ai (2013) (CC) 118 (25) 13.7 (2.9-64.8) 9.1 (1.6-50.9)
He (2014) (CC) 258 (43) 19 (4-182) 9.9 (0.4-318)
Li (2014) (CC) 100 (25) 3.2 (0.6-17.2) not reported
Liu (2014) (CC) 429 (89) 3.6 (1.7-7.3) not reported
Li (2014) (CC) 100 (25) 6.4 (0.6-74.2) not reported
Li (2014) (CC) 100 (25) 1.1 (0.6-2.2) not reported
Overall (I^2=71%) 5.5 (2.3-13.1)
H9
Yang (2012) (CS) 1741 (12) 6.3 (2-20.1) 4.1 (1.3-13.6)
Yang (2012) (CS) 1741 (12) 0.6 (0.1-4.6) not reported
Processing, preparing poultry
Slaughtering
H5N1
Vong (2009) (CC) 31 (7) 2.5 (0.3-10.8) -
Bridges (2002) (CC) 1312 (81) 3.1 (1.6-5.9) -
Overall (I^2=0%) 3 (1.6-5.6)
Cavailler (2010) (CS) 700 (18) 1.6 (0.6-4.6) not reported
H7N9
Liu (2014) (CC) 429 (89) 3.1 (1.7-5.9) not reported
Wang (2014) (C) 96 (52) 0.9 (0.3-2.4) not reported
Overall (I^2=78%) 1.8 (0.5-5.9)
Plucking
H5N1
Areechokchai (2006) (CC) 80 (16) 14 (1.3-153) -
Cavailler (2010) (CS) 700 (18) 1.7 (0.6-4.8) not reported
Vong (2009) (CC) 31 (7) 3.1 (0.3-34.9) -
Overall (I^2=0%) 2 (0.8-4.9)
Eviscerating
H5N1
Vong (2009) (CC) 31 (7) 1.5 (0.3-8.7) -
Bridges (2002) (CC) 1312 (81) 1.7 (0.9-2.9) -
Overall (I^2=0%) 1.7 (1-2.9)
Cavailler (2010) (CS) 700 (18) 1.2 (0.4-3.6) not reported
Preparing
H5N1
Areechokchai (2006) (CC) 80 (16) 17 (1.6-177) -
Dinh (2006) (CC) 134 (28) 2.2 (0.6-10.4) not reported
Bridges (2002) (CC) 1312 (81) 1.7 (1.1-2.7) -
Overall (I^2=77%) 3.3 (1.1-9.5)
Cavailler (2010) (CS) 700 (18) 1.2 (0.4-3.6) not reported
Dinh (2006) (CC) 134 (28) 31 (3.4-1150) 9 (1-82)
Overall (I^2=94%) 6.1 (0.3-147.4)
H7N9
Ai (2013) (CC) 118 (25) 8.1 (2.1-31.7) not reported
Li (2014) (CC) 100 (25) 1.4 (0.4-5) not reported
Overall (I^2=71%) 3.3 (0.6-18.6)
Washing carcass/meat
H5N1
Vong (2009) (CC) 31 (7) 2 (0.3-14.9) -
Cavailler (2010) (CS) 700 (18) 1.3 (0.5-3.8) not reported
Consumption
H5N1
Zhou (2009) (CC) 162 (28) 1.3 (0.4-4.2) not reported
Mounts (1999) (CC) 56 (15) 0.6 (0-7.5) -
Overall (I^2=0%) 1.2 (0.5-2.8)
Cavailler (2010) (CS) 700 (18) 1.3 (0.5-3.3) not reported
H7N9
Liu (2014) (CC) 429 (89) 1.2 (0.7-2) 0.7 (0.4-1.4)
Poultry husbandry
Gathering, placing in cages
H5N1
Vong (2009) (CC) 31 (7) 5.8 (1-34.1) -
Transporting
H7N9
Wang (2014) (C) 96 (52) 2.2 (0.4-12.1) not reported
Vaccinating
H9
Gomaa (2015) (CS) 648 (38) 2.4 (1.2-4.8) 2.4 (1.1-5)
Selling
H7N9
Wang (2014) (C) 96 (52) 0.7 (0.3-2) not reported
HH/NS
Farms
Prem.
LBM
Healthy/NS
Sick/dead
0.1
1
10
100

Figure 5


Exposure and References
N (cases)
non-adj OR
adj OR
Frequent handwashing
H5N1
Dinh (2006) (CC) 134 (28) 0.5 (0.1-2.4) not reported
Vong (2009) (CC) 31 (7) 0.4 (0-3.9) -
Overall (I^2=0%) 0.5 (0.2-1.3)
H7N9
Ai (2013) (CC) 118 (25) 0.1 (0-0.6) not reported
Li (2014) (CC) 100 (25) 0.5 (0.2-1.8) not reported
Overall (I^2=77%) 0.2 (0-1.2)
Wearing gloves
H9
Yang (2012) (CS) 1741 (12) 0.4 (0.1-1.4) not reported
Wearing masks
H9
Yang (2012) (CS) 1741 (12) 0.1 (0-1) not reported
Poor hygiene conditions
H5N1
Dinh (2006) (CC) 134 (28) 1 (0.3-3.4) not reported
Frequent disinfection of worksite
H9
Yang (2012) (CS) 1741 (12) 0.1 (0-0.6) 0.2 (0.1-0.8)
Cleaning knife after preparing poultry
H5N1
Mounts (1999) (CC) 56 (15) 0.3 (0.1-1) -
HH/NS
Farms
Prem.
LBM
Healthy/NS
Sick/dead
0.1
1
5

Supplementary Figure 1

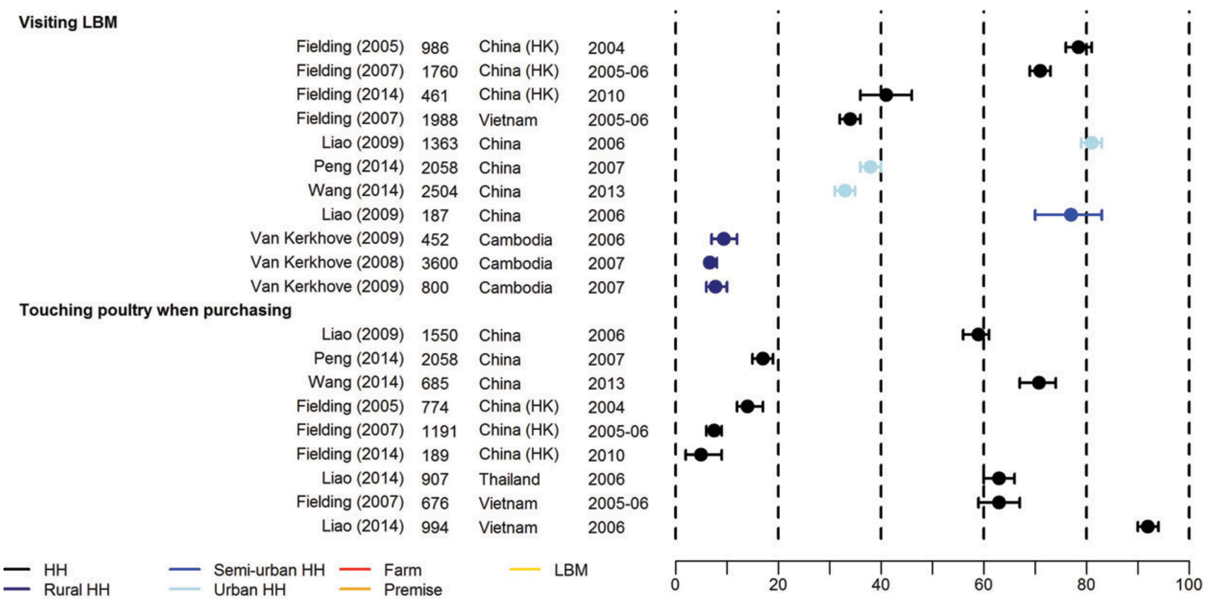
Exposure and References	N	Country	Year	p (95% CI)
Raising backyard poultry				
Erdine (2011)	1046	Turkey	2007-08	66.3 (63-69)
Fielding (2007)	1988	Vietnam	2005-06	53 (51-55)
Liao (2009)	1363	China	2006	19 (17-21)
Barennes (2007)	461	Lao	2006	40.2 (36-45)
Barennes (2010)	164	Lao	2007	50.6 (43-58)
Manabe (2012)	221	Vietnam	2011	50.7 (44-57)
Liao (2009)	187	China	2006	34 (27-42)
Barennes (2007)	192	Lao	2006	50.5 (43-58)
Barennes (2010)	364	Lao	2007	55.4 (50-61)
Leslie (2008)	304	Afghanistan	2007	65.2 (59-70)
Rimi (2014)	252	Bangladesh	2009	81 (76-86)
Vong (2006)	155	Cambodia	2005	96 (92-99)
Peng (2014)	1043	China	2007	51 (48-54)
Gai (2008)	1379	China	2007-08	51.8 (49-54)
Wang (2014)	1227	China	2013	49.7 (47-53)
Radwan (2011)	150	Egypt	2011	78.3 (71-84)
Santhia (2009)	291	Indonesia	2005	90 (86-93)
Barennes (2007)	189	Lao	2006	84.3 (78-89)
Barennes (2010)	570	Lao	2007	64 (60-68)
Wilson (2007)		Lao	2007	87.5 (85-90)
Olsen (2005)	200	Thailand	2004	74 (67-80)
Dejpichai (2009)	131	Thailand	2005	68 (59-76)
Maton (2007)	784	Thailand	2005	80 (77-83)
Manabe (2012)	322	Vietnam	2011	92.5 (89-95)
Keeping poultry inside house				
Sultana (2012a)	106	Bangladesh	2008	80 (71-87)
Khan (2012)	300	Bangladesh	2011	27 (22-32)
Van Kerkhove (2008)	2401	Cambodia	2007	86.7 (85-88)
Radwan (2011)	118	Egypt	2011	13.6 (8-21)
Barennes (2007)	428	Lao	2006	2.6 (1-5)
Barennes (2010)	1098	Lao	2007	0.7 (0-1)



HH — Rural HH — Semi-urban HH — Urban HH — Farm — Premise — LBM

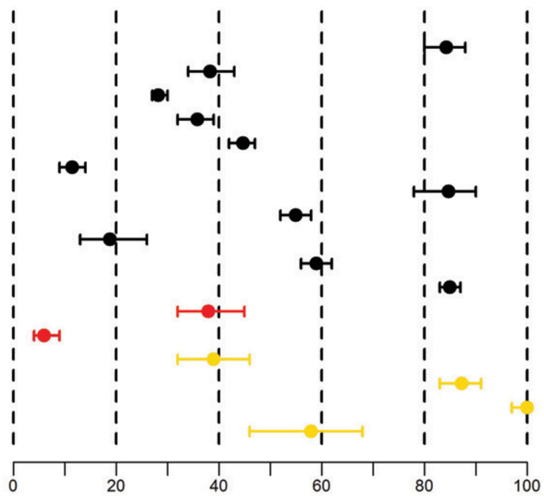
Supplementary Figure 2

Exposure and References	N	Country	Year	p (95% CI)
Visiting LBM				
Fielding (2005)	986	China (HK)	2004	78.5 (76-81)
Fielding (2007)	1760	China (HK)	2005-06	71 (69-73)
Fielding (2014)	461	China (HK)	2010	41 (36-46)
Fielding (2007)	1988	Vietnam	2005-06	34 (32-36)
Liao (2009)	1363	China	2006	81 (79-83)
Peng (2014)	2058	China	2007	38 (36-40)
Wang (2014)	2504	China	2013	33 (31-35)
Liao (2009)	187	China	2006	77 (70-83)
Van Kerkhove (2009)	452	Cambodia	2006	9.4 (7-12)
Van Kerkhove (2008)	3600	Cambodia	2007	6.7 (6-8)
Van Kerkhove (2009)	800	Cambodia	2007	7.8 (6-10)
Touching poultry when purchasing				
Liao (2009)	1550	China	2006	59 (56-61)
Peng (2014)	2058	China	2007	17 (15-19)
Wang (2014)	685	China	2013	70.8 (67-74)
Fielding (2005)	774	China (HK)	2004	14 (12-17)
Fielding (2007)	1191	China (HK)	2005-06	7.5 (6-9)
Fielding (2014)	189	China (HK)	2010	5 (2-9)
Liao (2014)	907	Thailand	2006	63 (60-66)
Fielding (2007)	676	Vietnam	2005-06	63 (59-67)
Liao (2014)	994	Vietnam	2006	92 (90-94)



Supplementary Figure 3

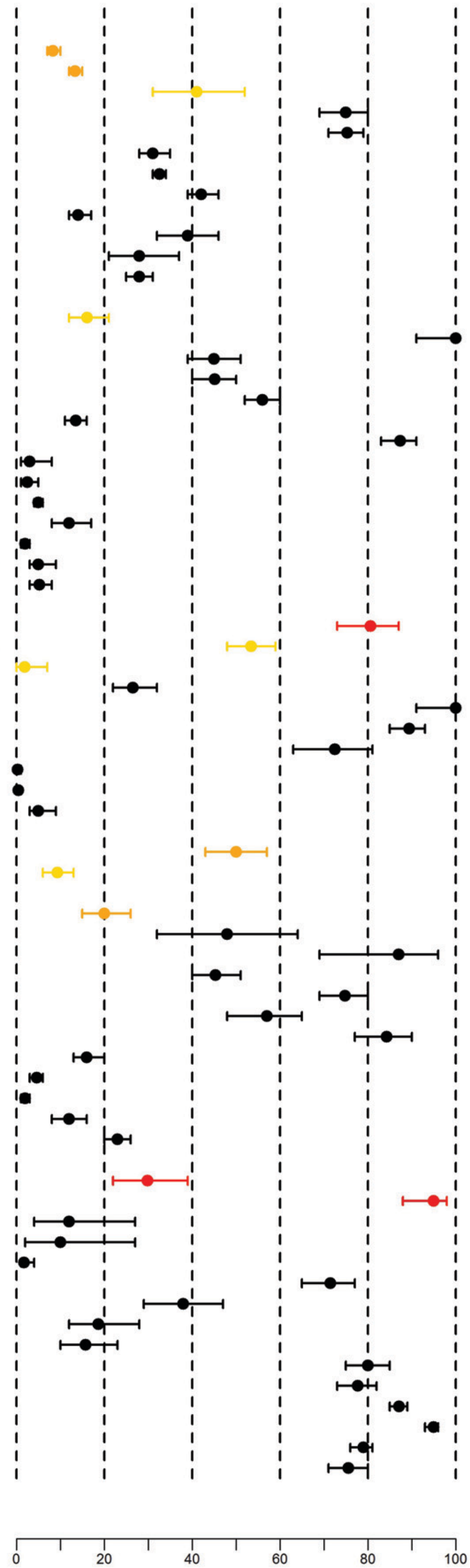
Exposure and References	N	Country	Year	p (95% CI)
Slaughtering and Processing poultry				
Khan (2012)	300	Bangladesh	2011	84.3 (80-88)
Van Kerkhove (2009)	452	Cambodia	2006	38.3 (34-43)
Van Kerkhove (2008)	3600	Cambodia	2007	28.2 (27-30)
Van Kerkhove (2009)	800	Cambodia	2007	35.8 (32-39)
Liao (2009)	1550	China	2006	44.7 (42-47)
Wang (2014)	685	China	2013	11.5 (9-14)
Radwan (2011)	150	Egypt	2011	84.7 (78-90)
Santhia (2009)	841	Indonesia	2005	55 (52-58)
Maton (2007)	147	Thailand	2005	18.8 (13-26)
Liao (2014)	907	Thailand	2006	59 (56-62)
Liao (2014)	994	Vietnam	2006	85 (83-87)
Nasreen (2013)	212	Bangladesh	2009	38 (32-45)
Robert (2010)	495	Indonesia	2007	6 (4-9)
Nasreen (2013)	210	Bangladesh	2009	39 (32-46)
Ma (2014)	306	China	2013	87.3 (83-91)
Kumar (2013)	105	India	2008	100 (97-100)
Santhia (2009)	87	Indonesia	2005	58 (46-68)



HH — Rural HH — Semi-urban HH — Urban HH — Farm — Premise — LBM

Supplementary Figure 4

Exposure and References	N	Country	Year	p (95% CI)
Management of sick/dead poultry				
Touching				
Li (2013)	1169	China	2010-12	8.3 (7-10)
Yang (2012)	1741	China	2011	13.3 (12-15)
Santhia (2009)	87	Indonesia	2005	41 (31-52)
Ly (2007)	269	Cambodia	2006	75 (69-80)
Van Kerkhove (2009)	452	Cambodia	2006	75.3 (71-79)
Cavailler (2010)	700	Cambodia	2007	31 (28-35)
Van Kerkhove (2008)	3600	Cambodia	2007	32.6 (31-34)
Van Kerkhove (2009)	800	Cambodia	2007	42.1 (39-46)
Santhia (2009)	841	Indonesia	2005	14 (12-17)
Olsen (2005)	200	Thailand	2004	39 (32-46)
Dejpichai (2009)	131	Thailand	2005	28 (21-37)
Somrongthong (2012)	968	Thailand	2008	28 (25-31)
Consumption				
Sarker (2011)	318	Bangladesh	2008-09	16.1 (12-21)
Sultana (2012b)	40	Bangladesh	2008	100 (91-100)
Ly (2007)	269	Cambodia	2006	45 (39-51)
Van Kerkhove (2009)	452	Cambodia	2006	45.1 (40-50)
Cavailler (2010)	700	Cambodia	2007	56 (52-60)
Van Kerkhove (2009)	800	Cambodia	2007	13.5 (11-16)
Khun (2012)	246	Cambodia	2009	87.4 (83-91)
Peng (2014)	127	China	2007	3 (1-8)
Barennes (2007)	399	Lao	2006	2.5 (1-5)
Barennes (2010)	1098	Lao	2007	5 (4-6)
Olsen (2005)	200	Thailand	2004	12 (8-17)
Somrongthong (2012)	968	Thailand	2008	2 (1-3)
Fielding (2007)	253	Vietnam	2005-06	5 (3-9)
Manabe (2011)	418	Vietnam	2009	5.2 (3-8)
Selling				
Negro-Calduch (2013)	124	Egypt	2009-10	80.6 (73-87)
Sarker (2011)	318	Bangladesh	2008-09	53.4 (48-59)
Kumar (2013)	105	India	2008	1.9 (0-7)
Leslie (2008)	304	Afghanistan	2007	26.5 (22-32)
Sultana (2012b)	40	Bangladesh	2008	100 (91-100)
Khun (2012)	246	Cambodia	2009	89.4 (85-93)
Negro-Calduch (2013)	102	Egypt	2009-10	72.5 (63-81)
Barennes (2007)	399	Lao	2006	0.3 (0-1)
Barennes (2010)	1098	Lao	2007	0.4 (0-1)
Fielding (2007)	253	Vietnam	2005-06	5 (3-9)
Returning to supplier				
Kumar (2013)	207	India	2008	50 (43-57)
Sarker (2011)	318	Bangladesh	2008-09	9.3 (6-13)
Throwing in open spaces (e.g. water body, bushes)				
Kumar (2013)	207	India	2008	20 (15-26)
Sultana (2012b)	40	Bangladesh	2008	48 (32-64)
Rimi (2014)	30	Bangladesh	2009	87 (69-96)
Khan (2012)	300	Bangladesh	2011	45.3 (40-51)
Khun (2012)	246	Cambodia	2009	74.8 (69-80)
Peng (2014)	127	China	2007	57 (48-65)
Radwan (2011)	127	Egypt	2011	84.3 (77-90)
Barennes (2007)	399	Lao	2006	16 (13-20)
Barennes (2010)	1098	Lao	2007	4.6 (3-6)
Liao (2014)	907	Thailand	2006	2 (1-3)
Fielding (2007)	253	Vietnam	2005-06	12 (8-16)
Liao (2014)	994	Vietnam	2006	23 (20-26)
Burying/Incinerating				
Negro-Calduch (2013)	124	Egypt	2009-10	29.8 (22-39)
Neupane (2012)	96	Nepal	2009	95 (88-98)
Sultana (2012b)	40	Bangladesh	2008	12 (4-27)
Rimi (2014)	30	Bangladesh	2009	10 (2-27)
Khan (2012)	300	Bangladesh	2011	1.7 (1-4)
Khun (2012)	246	Cambodia	2009	71.5 (65-77)
Peng (2014)	127	China	2007	38 (29-47)
Negro-Calduch (2013)	102	Egypt	2009-10	18.6 (12-28)
Radwan (2011)	127	Egypt	2011	15.7 (10-23)
Santhia (2009)	291	Indonesia	2005	80 (75-85)
Barennes (2007)	399	Lao	2006	77.7 (73-82)
Barennes (2010)	1098	Lao	2007	87.1 (85-89)
Liao (2014)	907	Thailand	2006	95 (93-96)
Liao (2014)	994	Vietnam	2006	79 (76-81)
Manabe (2011)	418	Vietnam	2009	75.6 (71-80)



HH — Rural HH — Semi-urban HH — Urban HH — Farm — Premise — LBM

Supplementary Figure 5