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Risk factors for transmission of foodborne illness in restaurants and street vendors in Jakarta, Indonesia

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SUMMARY

In a previous risk factor study in Jakarta we identified purchasing street food as an independent risk factor for paratyphoid. Eating from restaurants, however, was not associated with disease. To explain these findings we compared 128 street food-vendors with 74 food handlers from restaurants in a cross-sectional study in the same study area. Poor hand-washing hygiene and direct hand contact with foods, male sex and low educational level were independent characteristics of street vendors in a logistic regression analysis. Faecal contamination of drinking water (in 65% of samples), dishwater (in 91%) and ice cubes (in 100%) was frequent. Directly transmittable pathogens including *S. typhi* ($n=1$) and non-typhoidal *Salmonella* spp. ($n=6$) were isolated in faecal samples in 13 (7%) vendors; the groups did not differ, however, in contamination rates of drinking water and *Salmonella* isolation rates in stools. Poor hygiene of street vendors compared to restaurant vendors, in combination with faecal carriage of enteric pathogens including *S. typhi*, may help explain the association found between purchasing street food and foodborne illness, in particular *Salmonella* infections. Public health interventions to reduce transmission of foodborne illness should focus on general hygienic measures in street food trade, i.e. hand washing with soap, adequate food-handling hygiene, and frequent renewal of dishwater.

INTRODUCTION

In a previous case-control study in Jakarta, Indonesia, we identified purchasing foods from street vendors as an independent risk factor for paratyphoid or typhoid fever, whereas no such association was found with eating in restaurants [1]. Similarly, in other studies in Indonesia street food was associated with typhoid fever [2, 3]. Several factors may explain this association of street food and paratyphoid or typhoid fever, a systemic febrile illness caused by *Salmonella typhi* and *S. paratyphi* A, B or C that only affects humans. For instance, personal hygiene and knowledge of hygienic food preparation [4–6], faecal contamination of basic ingredients or water used for food preparation [7] and/or isolation rates of enteric

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pathogens [8], may differ between street food-vendors and vendors in restaurants. Although the possible transmission routes of enteric pathogens like *Salmonella* are well known, the relative importance of the various factors, i.e. the weak link in the transmission chain, is uncertain but of great importance to help focus the most relevant health intervention.

We therefore examined determinants for transmission of enteric pathogens in commercial food handling in a cross-sectional study in Jakarta. Because of our previous findings in the same area we compared street vendors with vendors from restaurants. In both groups of food handlers we determined faecal isolation rates of enteric pathogens including *Salmonella* spp., assessed the hygiene practices and knowledge about safe food preparation and examined water reservoirs and ice cubes used for consumption. Our findings should be helpful to health authorities for the development of effective methods for the containment of foodborne diseases in commercial food handling especially in food stalls and pushcarts.

MATERIAL AND METHODS

Study population

From 17 February until 21 May 2003 all food vendors working in the Bidara Cina subdistrict in East Jakarta were approached by graduate medical-school students. During the study period the study area was visited daily, during daytime and evenings, until all present food vendors were interviewed. This area of 126 hectares houses 43 829 inhabitants (December 2002) and has been subject to a typhoid fever risk factor study as described elsewhere [1]. Ethical clearance was obtained from the Indonesian National Institute of Health Research and Development (*Litbangkes*) and the local provincial authorities. Written informed consent was obtained from all food vendors.

A study subject was defined as an individual working as a vendor of foods or drinks in the study area who was physically involved in the preparation or handling of the foods. All types of units were eligible for inclusion: restaurants, food stalls and pushcarts. Some restaurants and *warung* (i.e. small-scale restaurants often connected to the household of the owner) are subject to six-monthly visits by local health authorities for inspection and education on food hygiene, but food hawkers are not visited. Food stalls are stationary roadside facilities with or without seats. Pushcarts are mobile units that lack seating facilities.

Questionnaires

A standardized questionnaire was used to obtain data on demographic and socioeconomic characteristics of the food vendors, recent disease history, hygiene practice, and water sources in the units. Measures of hygiene that were assessed were: defecation during working hours, hand washing before food preparation and after defecation, the use of soap for hand washing, direct hand contact with food items, available water sources for hand washing and dishwashing, the use of soap for dishwashing and the frequency of renewal of dishwater, and the presence of flies on food items. Diarrhoea was defined as three or more loose stools per day. During and following the interview (i.e. a total period of 30 min) the interviewers observed the hand-washing hygiene and food handling of the vendors to compare the given answers with the actual practice. Any reported use of soap was verified by screening for the presence of soap in the unit. Knowledge about safe food preparation was tested by a scoring system. Eight diseases were mentioned: diarrhoea, typhoid fever, jaundice, worm infections, pneumonia, skin infections, AIDS, and tuberculosis. Vendors were asked whether these illnesses could be transmitted by food. Also knowledge about vehicles for disease transmission in food processing was tested, i.e. flies, dirty hands, polluted water, cutting boards, traffic fumes, and ill food handlers. For every correct answer one point was given, no point if the answer was not known, and one point subtracted for an incorrect answer.

Sample collection

At every location 150-ml samples were collected from the water source or container with drinking water and dishwater. If piped water was sampled, the bactericidal effect of chlorine during transport was neutralized by addition of 0·1 ml 10% sodium-thiosulphate. Ice cubes (150 ml) were collected from cool boxes into sterile bottles. Two stool samples were collected: 2 g faeces into a vial with Cary Blair transport medium for bacteriological examination and 10 g fresh stool for parasitological examination.

Water examination

The samples were transported on ice, processed within 6 h of collection and examined for total and faecal coliform counts by use of the most probable number (MPN) method [9]. Serially diluted water samples were incubated in Endolactose broth and Brilliant Green to detect specific colour changes and gas formation. Presence of faecal coliforms ($\geqslant$1 MPN Index/100 ml) was defined as faecal contamination [9]. The upper detection limit was 1600/100 ml.

Stool cultures

Stool samples were cultured in the central reference laboratory using Selenite enrichment broth (Oxoid Ltd, Hampshire, UK). Colonies were plated on xylose-lysine-desoxycholate, *Salmonella–Shigella* agar, and on triple sugar iron agar, SIM medium (sulphide and indole production and motility) and Simmons citrate (Oxoid). *Salmonella* bacteria were identified using agglutination anti-sera (Polyvalent, O-9, Vi, h, paratyphi A; Murex Biotech Ltd, Dartford, UK) and biochemical tests (Microbact, Medvet Diagnostics, Adelaide, Australia).

Parasitological stool examination

The second stool sample was processed within 24 h after collection and microscopically examined after Lugol staining, Kato–Katz technique and Harada–Mori method for the detection of hookworms.

Feedback

Food vendors were informed about their water quality, instructed on safe food preparation methods, and if necessary treated (worm infections: mebendazole, *Giardia lamblia*: metronidazole). When *Salmonella* was isolated in stool cultures, vendors were subject to follow-up and treatment was administered in case of repeated positive stool cultures.

Statistical methods

Data were entered twice in Epi-Info 6·04 (CDC, Atlanta, GA, USA), validated and imported in SPSS (SPSS Inc., Chicago, IL, USA) for analysis. *t* tests were used for evaluation of normally distributed numerical variables and Mann–Whitney *U* tests for abnormally distributed numerical variables. Proportions within the group of street food-vendors and within the group of vendors from restaurants or *warung* were compared using χ^2 tests. Measures for association were expressed as odds ratios (ORs) with their respective confidence intervals (CIs) for categorical exposures. To control for confounding a multivariate analysis was performed on the significantly associated risk factors from the bivariate analysis in a logistic regression model by forward-likelihood ratio test. For the comparison of hygiene parameters between the two groups we depended on the self-reported methods of hand-washing hygiene after defecation, but not all food vendors reported defecating during working hours (e.g. due to non-availability of facilities, limited working hours per day, or to business activity). Hygiene parameters were consequently evaluated by multivariate analysis for all food vendors, and additionally in the subgroup of subjects who reported defecating during working hours to confirm overall trends. Significance levels were P values $<0{\cdot}05$.

RESULTS

Study population

In total 238 food vendors were found to be working in the study area. From these, 202 food vendors (85%) were interviewed. Thirty-six food vendors refused to participate: 6 worked in restaurants, 13 worked in *warung*, and 17 worked in roadside stalls or pushcarts. Stool specimens could be collected from 175 of the 202 vendors; 27 (13%) refused a sample. We also collected 139 drinking water samples from the 149 vendors who offered drinking water to customers, and 172 dishwater samples. The age of food vendors ranged from 18 to 68 years, no significant difference in age between vendors from the four units was found ($P=0{\cdot}11$, ANOVA). Vendors in *warung* were significantly more often female ($P<0{\cdot}001$, χ^2) (Table 1). Education level of the group of vendors from stalls and pushcarts was lower than that of vendors in restaurants and *warung* ($P=0{\cdot}03$, χ^2) (Table 1). For 95% of the respondents food vending was a full-time economic activity during 6 or 7 days a week. Mobile vendors proportionally served most customers per day: 72% served more than 50 customers a day. The small-scale entrepreneurs in food stalls and pushcarts tend to specialize in food items which limits their supply to a few or single items (Table 2).

Hygiene in the grouped units

Seventy (55%) of the vendors from food stalls and pushcarts did not wash their hands before food preparation compared with 21 (28%) of the vendors in restaurants/*warung* ($P<0{\cdot}001$) (Table 3). Non-use of soap for hand washing before food preparation was reported in 79% *vs.* 51% respectively ($P=0{\cdot}002$).

Table 1. *Characteristics of food vendors*

Variables	Selling unit			
	Restaurant	*Warung*	Food stall	Pushcart
n	11	63	110	18
Sex				
Male	10 (91%)	15 (24%)	76 (69%)	18 (100%)
Female	1 (9%)	48 (76%)	34 (31%)	0
Age: median years (IQR)	30 (24–37)	40 (35–47)	39 (30–44)	34 (30–46)
Finished education				
Primary school or less	4 (36%)	33 (52%)	70 (64%)	14 (78%)
Secondary school	7 (64%)	30 (48%)	40 (36%)	4 (22%)
Time working as food vendor				
Median years (IQR)	6 (0–18)	5 (2–8)	5 (1–13)	9 (5–20)
Number of customers/day				
⩽50 customers	9 (82%)	48 (76%)	70 (64%)	5 (28%)
>50 customers	2 (18%)	15 (24%)	40 (36%)	13 (72%)
Ownership of the unit				
Self-owned by respondent	2 (18%)	46 (73%)	93 (85%)	13 (72%)
Family, rented or employee	9 (82%)	17 (27%)	18 (15%)	5 (28%)
Daily sales*				
⩽100 000 Rp	1 (10%)	33 (53%)	65 (59%)	12 (67%)
>100 000 Rp	9 (90%)	29 (47%)	45 (41%)	6 (33%)

* Missing data: one food vendor from a restaurant and one from a *warung*, Exchange rate: 9400 Rupiah = US$1 (March 2004).
IQR, Interquartile range.

Table 2. *Food supply*

Variables	Selling unit			
	Restaurant	*Warung*	Food stall	Pushcart
n	11	63	110	18
Number of sold items	2–87	1–35	1–10	1
Sold foods and drinks				
Rice dishes	7 (64%)	46 (73%)	42 (38%)	—
Noodle dishes	5 (46%)	13 (21%)	14 (13%)	5 (28%)
Meat dishes	10 (91%)	41 (65%)	52 (47%)	1 (6%)
Seafood and fish	4 (36%)	35 (56%)	24 (22%)	1 (6%)
Boiled and fresh vegetables	5 (46%)	48 (76%)	27 (25%)	2 (11%)
Fried snacks	—	6 (10%)	17 (16%)	2 (11%)
Fruit juices	7 (64%)	15 (24%)	14 (13%)	—
Es cendol or *es cincau**	3 (27%)	1 (2%)	6 (6%)	4 (22%)

* Iced flavoured coconut milk with insoluble flour particles or leaf extracts.

Although all vendors reported washing their hands after defecation during working hours, non-use of soap occurred significantly more frequent in stalls and pushcarts than in restaurants/*warung* (37% *vs.* 10%, $P<0{\cdot}001$). Direct hand contact with ready-to-eat foods occurred more often in food stalls and pushcarts (63% *vs.* 36%, $P<0{\cdot}001$). The limited facilities for hand washing and dishwashing were demonstrated for 86% of the pushcarts and food stalls and 58% of the *warung* and restaurants, because the same water reservoir was used for both purposes ($P=0{\cdot}01$). Vendors reported renewing the dishwater in buckets 0–20 times during working hours with the lowest mean frequency in the food stalls and pushcarts

Table 3. *Comparison of hygiene parameters between two groups of food vendors: bivariate analysis*

Variable*	Food stalls and pushcarts	Restaurants and *warung*	OR (95% CI)	P
n (202)	128	74		
Hand-washing hygiene				
No use of soap for hand washing after defecation ($n=74$ *vs.* 63)†	27 (37%)	6 (10%)	5·46 (2·08–14·33)	$<0·001$
Not washing hands before food preparation ($n=128$ *vs.* 74)	70 (55%)	21 (28%)	3·05 (1·65–5·63)	$<0·001$
No use of soap if washing hands before food preparation ($n=58$ *vs.* 53)	46 (79%)	27 (51%)	3·69 (1·61–8·49)	0·002
Direct hand contact with ready-to-eat food ($n=128$ *vs.* 74)	80 (63%)	27 (36%)	2·90 (1·60–5·25)	$<0·001$
Dishwater				
Dishwater is used for washing hands ($n=36$ *vs.* 31)‡	31 (86%)	18 (58%)	4·48 (1·37–14·63)	0·01
Mean number of times dishwater is renewed per day (range)	3·1 (0–15)	6·2 (1–20)		$<0·001$
Other factors				
Use of ice cubes ($n=128$ *vs.* 74)	62 (48%)	63 (85%)	0·16 (0·08–0·34)	$<0·001$
Flies on food items ($n=127$ *vs.* 73)	7 (6%)	12 (16%)	0·30 (0·11–0·79)	0·01
Diarrhoea last 3 months ($n=128$ *vs.* 74)	26 (20%)	21 (28%)	0·64 (0·33–1·25)	0·19

* Number of vendors from stalls/pushcarts *vs.* restaurants/*warung* available for analysis.
† $n=137$; only those vendors who reported defecating during working hours.
‡ $n=67$; only those vendors who washed utensils/dishes and/or hands before food preparation in buckets.

(3·1 *vs.* 6·2, $P<0·001$). In restaurants/*warung*, flies on ready-to-eat foods were observed more often ($P=0·01$) and ice cubes were used more often ($P<0·001$). Refrigerators for storage of ready-to-eat foods were lacking in 99% of the *warung*, food stalls and pushcarts, and 54% of the restaurants.

Knowledge of safe food preparation and recent illness

The score for the knowledge of safe food preparation (maximum score: 14) was not significantly different between the two groups of units (mean score: 5·0 and 5·5 for food stalls/pushcarts and restaurants/*warung* respectively; $P=0·15$, t test). Vendors most frequently indicated diarrhoea (89% of the vendors) and least frequently AIDS (6%) as foodborne illness. A total of 91% of the vendors from food stalls and pushcarts and 93% from restaurants and *warung* were aware that diarrhoeal diseases could be transmitted by hand ($P=0·52$, χ^2). In the 30 days prior to the interview 24% of the vendors reported to have suffered from fever, and 23% of the vendors reported experiencing at least one diarrhoeal episode in the preceding 3 months. The isolation rate of enteric pathogens and occurrence of diarrhoea in the preceding 3 months was not correlated ($P=0·35$, χ^2). The reported occurrence of diarrhoea did not differ between the two groups ($P=0·19$) (OR 0·64, 95% CI 0·33–1·25) (Table 3).

Examination of drinking water

Drinking water sources were bottled water (2), piped water (49), and groundwater extracted by pumps (98). Fifty-three food handlers did not serve drinking water. All respondents reportedly boiled drinking water before storage and serving. The majority of vendors (129, 88%) kept the boiled water in closed plastic jars, jerry-cans or kettles, while 18 vendors (12%) kept it in open containers such as buckets or pans. In the latter case utensils had to be immersed to collect the water from the reservoirs. Of the 139 samples examined, 90 (65%) contained faecal coliforms with a median of 39/100 ml [interquartile range (IQR) 17–450] in the contaminated samples. The location ($P=0·23$, χ^2), the storage method (i.e. closed or open container) ($P=0·82$), or the source (pump or piped water) ($P=0·39$) did not significantly influence the contamination rate. No significant differences were found in the number of faecal coliforms in the contaminated samples for the two groups of units ($P=0·12$, Mann–Whitney U test) (Table 4). Also, the bacterial numbers in tap water or groundwater samples from either closed or

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Table 4. *Comparison of water examination results between two groups of food vendors: bivariate analysis*

Variable*	Food stalls and pushcarts	Restaurants and *warung*	OR (95% CI)	*P*
Water examination				
Faecal contamination of sampled drinking water (*n*=67 *vs*. 72)	40 (60%)	50 (69%)	0·65 (0·32–1·31)	0·23
Median faecal coliform count in drinking water† (*n*=40 *vs*. 50)	34 (13–105)	46 (19–1075)		0·12
Faecal contamination of sampled dishwater (*n*=102 *vs*. 70)	95 (93%)	62 (89%)	1·75 (0·60–5·07)	0·30
Median faecal coliform count in dishwater† (*n*=95 *vs*. 62)	425 (33–1600)	39 (20–900)		0·006

* Number of vendors from stalls/pushcarts *vs*. restaurants/*warung* available for analysis.
† Median (interquartile range) MPN index/100 ml, comparison of numbers by Mann–Whitney *U* test.

open containers did not differ significantly (*P*=0·64, Kruskal–Wallis test).

Examination of dishwater

In 172 units (i.e. 102 street vendors and 70 restaurants/*warung*) dishwater was present at the vending location and this was consequently examined; 157 (91%) of the 172 dishwater samples were contaminated with a median faecal coliform count of 140/100 ml (IQR 23–1600) in the contaminated samples. Of the 172 dishwater samples, 157 samples (91%) were contaminated. The median faecal coliform count was 140/100 ml (IQR 23–1600) in the contaminated samples. The faecal coliform counts in dishwater from food stalls and pushcarts were higher than that from the restaurants and *warung* (*P*=0·01, Mann–Whitney *U* test) (Table 4). The median faecal coliform count in 46 buckets used both for washing hands and dishes was higher than in the 17 buckets only used for dishwashing [323/100 ml (IQR 28–1600) *vs*. 20/100 ml (IQR 15–1600)] (*P*=0·06, Mann–Whitney *U* test). The presence of detergent significantly decreased the number of faecal coliforms in dishwater [median 40/100 ml (IQR 17–1600) *vs*. 900/100 ml (IQR 34–1600)] where soap was absent (*P*=0·005, Mann–Whitney *U* test).

Examination of ice cubes

Ice cubes were used in drinks by 125 (62%) of the vendors. We collected 23 ice samples from 3 pushcarts, 14 food stalls, 4 *warung* (2 samples at one location) and 1 restaurant. All ice cubes were contaminated, with a median faecal coliform count of 500/100 ml (IQR 170–1600). Most of the ice cubes had been purchased from ice vendors (70%), but no significant differences in faecal coliform numbers between purchased or self-made ice cubes were observed (*P*=0·15, Mann–Whitney *U* test). Fifteen food vendors (68%) collected ice cubes with their hands and seven used tools in cool boxes, but faecal coliform counts did not differ significantly by either method of handling (*P*=0·25, Mann–Whitney *U* test).

Stool examination

In 86 vendors (49%) pathogens were detected. Directly transmittable pathogens (i.e. *Salmonella* spp., *Giardia* and *Entamoeba*) were isolated in 13 (7%) (Table 5). *S. typhi* was isolated in the stool from a 25-year-old male mobile vendor selling iced flavoured drinks. Two repeated stool cultures in 3-week intervals were negative. He reported not having suffered from prolonged fever in the preceding 6 months or from previous typhoid fever. Both *Salmonella* spp. and hookworms were detected in the stools from two food vendors. Faecal carriage of non-typhoidal *Salmonellae* was equally frequent in both groups (*P*=0·33) (OR 1·19, 95% CI 0·18–9·65).

Parasitology

Single parasite infestations were detected in the stools of 63 vendors (36%), and dual infestations in 18 vendors (10%) (Table 5). The most frequent combination was hookworm infection with *Trichiuris trichura* (*n*=12) or *Ascaris* (*n*=3). Two other combinations were *Ascaris* or *Giardia* with hookworms and *Trichiuris* with *Giardia*. Infestation rates of street food-vendors (49%) and restaurant/*warung* employees (42%) were non-significantly different (*P*=0·63) (OR 1·36, 95% CI 0·73–2·52).

Table 5. *Results of the stool examination* ($n = 175$)

Enteric pathogen	Food stalls and pushcarts ($n = 110$)	Restaurants or *warung* ($n = 65$)	Total
Non-typhoidal *Salmonellae*	4 (4%)	2 (3%)	6 (3%)
Salmonella typhi	1 (1%)	0	1 (0·6%)
Hookworms	32 (29%)	14 (22%)	46 (26%)
Trichuris trichiura	26 (24%)	13 (20%)	39 (22%)
Ascaris lumbricoides	3 (3%)	5 (8%)	8 (5%)
Giardia lamblia	2 (2%)	1 (2%)	4 (2%)
Entamoeba histolytica/dispar	2 (2%)	0	2 (1%)

Pathogens were isolated in 86 individuals.

Differences in hygiene parameters between restaurants/*warung* and food stalls/pushcarts

All study findings were summarized to compare hygiene parameters of the two groups by bivariate analysis (Tables 3 and 4). Significantly different features in food stalls and pushcarts were poor hand-washing hygiene, including less use of soap, direct hand contact with food items, and poor standards of dishwashing with higher median faecal coliform counts in dishwater. In restaurants and *warung* ice cubes were used more often because of the available cooling facilities and/or more frequent supply of drinks, and flies were observed more often on ready-to-eat foods. In a multivariate analysis including only the subjects who reported defecating during working hours ($n = 137$), independently associated features of food vendors from food stalls and pushcarts were not washing hands before food preparation (OR 7·51, 95% CI 2·44–23·05), direct hand contact with foods (OR 2·76, 95% CI 1·04–7·33), and male sex (OR 7·81, 95% CI 2·79–21·83). Also the numerical variable 'frequency of renewal of dishwater' was independently associated with food stalls and pushcarts (OR 0·77, 95% CI 0·65–0·91), which means that the lowest frequencies of renewal occurred significantly more often in the latter group. In a multivariate analysis for all vendors (i.e. without the variable of hand-washing hygiene after defecation and without the dishwater examination results, which reduced the number of vendors available for analysis) poor hand-washing before food preparation (OR 4·20, 95% CI 1·97–8·93), direct hand contact with foods (OR 2·54, 95% CI 1·22–5·29), and male sex (OR 5·45, 95% CI 2·59–11·48) remained independently associated, however, less use of ice cubes (OR 0·25, 95% CI 0·11–0·57) and lower educational level (OR 2·35, 95% CI 1·13–4·88) were also independently associated with food stalls and pushcarts (Table 6).

Table 6. *Multivariate comparison of vendors from food stalls/pushcarts and vendors from restaurants/*warung *using logistic regression analysis*

Variable	Odds ratio (95% CI)
No hand-washing before food preparation	4·20 (1·97–8·93)
Direct hand contact with foods	2·54 (1·22–5·29)
Use of ice cubes	0·25 (0·11–0·57)
Male sex	5·45 (2·59–11·48)
Low educational level	2·35 (1·13–4·88)

DISCUSSION

This cross-sectional study in Jakarta compared street food-vendors with vendors from restaurants to identify specific risk factors for the transmission of foodborne illness, in particular paratyphoid or typhoid fever, in pushcarts and food stalls that could explain the association of street food and paratyphoid or typhoid fever observed in a previous study. The main findings are that 1 in every 25 food vendors excreted *Salmonella* spp. including one *S. typhi* in their faeces, but that isolation rates did not differ between the two groups. Similarly, reported diarrhoeal episodes occurred with equal frequency in both groups and drinking water of poor quality was found in all units. Consequently, as possible pathogens are equally prevalent in both groups, other determinants of transmission, such as hygiene, should determine the association of paratyphoid or typhoid fever and street food. We demonstrated that infrequent hand washing, non-use of soap, direct hand contact with foods and inadequate dishwashing hygiene in food stalls and pushcarts – all characteristics that are likely to result in bacterial contamination of street food – may help explain the above-mentioned association. In addition, the street food-vendors had a lower educational level than the other vendors, yet were equally aware of transmission factors. However, that knowledge was not applied to food-handling practice. One reason is that most street vendors are small-scale entrepreneurs with limited (washing) facilities and limited financial resources who tend to compromise food safety for financial reasons [4].

These conclusions depend on the validity of our study design and in this respect some issues should be raised. First, we included all present food vendors in the study area by active search during daytime and evenings until all food vendors were approached. This method of inclusion and the variety of included units in terms of the food items sold provide a reliable representation of food-vending units and the Indonesian cuisine. Since the offered food items are prepared in characteristic ways to guarantee an universal taste of specific dishes all over Indonesia, and the preparation occurs in similar conditions (i.e. the same limitations as found in the food stalls and pushcarts), we assume that our findings are representative for food preparation procedures in Indonesia, especially in urban districts of lower socioeconomic standards. Secondly, the prevalence of faecal excretion of *Salmonella* bacteria of 4% is probably an underestimation, because we cultured a single stool sample from every vendor. Multiple stool cultures are advocated to establish carrier rates more definitively, because of the intermittent excretion of pathogenic bacteria in faeces [10]. Indeed, an earlier cross-sectional study in Jakarta found a prevalence of *Salmonella* spp. carriers of 8·4% [11]. The identification of 1 typhoid carrier in 175 individuals (0·6%) from our study is in line with that observed in other regions of endemicity, e.g. in Chile (0·69%) [12]. However, the essential issue here is not the exact rate of faecal carriage *per se* but the finding that the prevalence of faecal carriage was equal in both groups.

Thirdly, we were unable to examine direct health risk for consumers of street food, since bacterial contamination of the foods and drinks or basic ingredients was not examined. However, a previous study in Jakarta had demonstrated that beverages and meals are frequently contaminated with faecal coliforms, *Salmonella–Shigella* spp., and *Vibrio cholerae* [13]. As a consequence, we focused on the role of food handlers in the transmission of foodborne illness.

Finally, the more frequent use of ice cubes and observation of flies on foods in restaurants and *warung* could certainly contribute to transmission of foodborne diseases by this group as well. Enteric pathogens can survive freezing [14] and flies have been implicated as vehicles for transmission of foodborne diseases [15–17]. The contamination level of ice cubes was not influenced by unhygienic handling in the units, suggesting that contamination may also originate from the production or transport of the ice cubes by the ice distributors. Although these two risk factors for foodborne illness were more prominent in the restaurants and *warung*, the poor hand-washing hygiene and direct contact with foods in food stalls and pushcarts probably outweigh these two other transmission routes of foodborne illness because of a greater probability of a high inoculation size.

From the literature it is evident that proper hand washing is one of the most effective measures to control the spread of pathogens in food handling [18]. Greater priority for hand washing with soap should be given, considering the high isolation rates of enteric pathogens and also the poor sanitary conditions in Jakarta. The latter could be concluded from the high prevalence of trichiuriasis and hookworm infections, which is an indirect indicator of unhygienic human waste disposal. Also, in Jakarta bacterial gastrointestinal diseases such as paratyphoid or typhoid fever, Shigellosis and Campylobacter infections are endemic [19]. These data imply frequent faecal–oral transmission, probably by inadequate hand-washing hygiene. Bacteria can multiply rapidly, particularly when food items are stored in stalls and pushcarts that lack cooling facilities. Therefore, initial contamination of food with low numbers of bacteria as a consequence of improperly washed hands can result in sufficient numbers to cause disease in customers. Food can also be contaminated on soiled dishes or kitchen surfaces, because Gram-negative bacteria can survive on hands, dishes, washing-up sponges, and kitchen surfaces and be transmitted in sufficient numbers to foods [20–23]. The immersion of soiled hands in dishwater, the infrequent use of detergent, and the infrequent refilling of buckets were three factors that generated favourable conditions for survival of pathogens in dishwater and on dishes. Our study also demonstrated that the use of detergent was effective in reducing the bacterial numbers in dishwater.

Next to food as a vehicle for transmission of paratyphoid or typhoid fever drinking water might also play a role in Jakarta. More than half of the water samples were faecally contaminated which implies that drinking-water sources and human excreta disposal are not fully separated. However, contamination rates and levels in the two groups of food vendors did not differ. We are uncertain whether all vendors boiled their drinking water, but boiling water before consumption is not the ultimate safeguard against waterborne diseases, if storage methods and handling are insufficient to prevent contamination [7, 24]. However, no recommendations on safe drinking-water sources or storage methods could be made on the basis of our data.

Our report should not be interpreted as a plea to stop the street-food trade. Street-vended foods are an essential part of the daily diet for low-income groups in Indonesia and its variety allows the uptake of most essential nutrients. Food vending is also an essential economic activity for many low-educated residents. Rather, practical modifications should be introduced to reduce the risk of bacterial contamination of foods and spread of foodborne diseases in Jakarta, while nutritional and economic benefits are preserved [25]. First, the presence of carriers among food vendors gives cause for close monitoring of newly diagnosed cases of typhoid and paratyphoid fever among food handlers. Public health authorities should incorporate food stalls and pushcarts in their inspection and education programmes to monitor hygienic food preparation and hand-washing hygiene. In this respect, the distribution of soap, detergent or hypochlorite can be considered as an effective intervention method for the reduction of foodborne illness [7, 26]. Secondly, street food-vendors should be stimulated to use public pumps or taps from local health centres for the frequent renewal of dishwater. Thirdly, the production, transport and handling of ice cubes merit the attention of public health authorities. Finally, the protection of foods from flies in restaurants and *warung* should be promoted.

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