EcoHealth 14, 501–517, 2017
DOI: 10.1007/s10393-017-1267-4

EcoHealth

Original Contribution

A Controlled Trial to Reduce the Risk of Human Nipah Virus Exposure in Bangladesh

Nazmun Nahar,[1,2,3] Repon C. Paul,[1] Rebeca Sultana,[1] Shariful Amin Sumon,[1] Kajal Chandra Banik,[1] Jaynal Abedin,[1] Mohammad Asaduzzaman,[1] Fernando Garcia,[4] Susan Zimicki,[4] Mahmudur Rahman,[5] Emily S. Gurley,[1] and Stephen P. Luby[6]

[1]*icddr,b, 68, Shaheed Tajuddin Ahmed Sharani, Mohakhali, Dhaka 1212, Bangladesh*
[2]*Swiss Tropical and Public Health Institute, Basel, Switzerland*
[3]*University of Basel, Basel, Switzerland*
[4]*FHI 360, 1825 Connecticut Avenue NW, Washington, DC 20009*
[5]*Institute of Epidemiology, Disease Control and Research (IEDCR), Dhaka, Bangladesh*
[6]*Infectious Diseases and Geographic Medicine, Stanford University, Stanford, CA*

Abstract: Human Nipah virus (NiV) infection, often fatal in Bangladesh, is primarily transmitted by drinking raw date palm sap contaminated by *Pteropus* bats. We assessed the impact of a behavior change communication intervention on reducing consumption of potentially NiV-contaminated raw sap. During the 2012–2014 sap harvesting seasons, we implemented interventions in two areas and compared results with a control area. In one area, we disseminated a ''do not drink raw sap'' message and, in the other area, encouraged only drinking sap if it had been protected from bat contamination by a barrier (''only safe sap''). Post-intervention, 40% more respondents in both intervention areas reported knowing about a disease contracted through raw sap consumption compared with control. Reported raw sap consumption decreased in all areas. The reductions in the intervention areas were not significantly greater compared to the control. Respondents directly exposed to the ''only safe sap'' message were more likely to report consuming raw sap from a protected source than those with no exposure (25 vs. 15%, OR 2.0, 95% CI 1.5–2.6, $P < 0.001$). While the intervention increased knowledge in both intervention areas, the ''only safe sap'' intervention reduced exposure to potentially NiV-contaminated sap and should be considered for future dissemination.

Keywords: Nipah virus, Behavior change communication intervention, Date palm sap, Bangladesh

Introduction

Zoonotic infections can kill people, spread globally and have a devastating social and economic impact on affected regions (Dawood et al. 2012; WHO 2016). Intervention strategies aimed at interrupting spillover of zoonotic infections could reduce the risk of disease occurrence and its consequences.

Nipah virus (NiV) infection, a zoonotic disease transmitted from infected *Pteropus* bats to humans, is often fatal and can cause neurological sequelae among survivors (Chua et al. 1999; Reynes et al. 2005; Wacharapluesadee

Published online: September 13, 2017

Correspondence to: Nazmun Nahar, e-mail: nahar.nazmun@yahoo.com

et al. 2005; Sejvar et al. 2007). Since 2001, NiV outbreaks have been identified almost every year in Bangladesh (Luby 2013). People in Bangladesh most commonly acquire NiV from drinking bat-contaminated raw date palm sap (Luby et al. 2006; Rahman et al. 2012; Hegde et al. 2016). Once a person is infected with NiV, they can transmit it to other people (Gurley et al. 2007; Homaira et al. 2010; Sazzad et al. 2013).

In Bangladesh, date palm sap harvesters, locally called *gachhis*, collect raw sap during cold months, from November to March, by shaving the bark of the tree and hanging a pot to collect sap overnight (Nahar et al. 2010). In 2009, the Government of Bangladesh began discouraging people from drinking raw sap to prevent NiV.

Traditionally, *gachhis* occasionally used skirt-like barriers called *banas* to cover the shaved area, the sap flow and the collection pot to stop bats, rodents, birds and insects from accessing the sap (Nahar et al. 2010). *Banas* can interrupt bats' access to the sap, potentially preventing NiV spillover, and were acceptable to *gachhis* when promoted (Khan et al. 2012; Nahar et al. 2013, 2014). Some people reported stopping drinking raw sap after they learned about NiV (Sultana et al. 2013). To reduce the risk of NiV transmission, we implemented a behavior change intervention in two areas, promoting not drinking raw sap in one area and encouraging drinking only *bana*-protected sap in the second area. This study assessed the impact of these interventions.

Methods

Study Sites

We selected three NiV-affected districts—Rajbari and Faridpur for the interventions and Kushtia as a control. These three neighboring districts have similar population density, household size and literacy rate (Table 1) (BBS 2012). Date palm sap is harvested and consumed raw in these districts. From each district, we selected two adjacent sub-districts that did not share borders with the other intervention and control districts (Nahar et al. 2015). From Faridpur, we excluded 145 hard to reach villages located in river islands because they had no *gachhis* and no electricity, and could not run TV public service announcements, an important component of our intervention. Our study sub-districts included 342 villages in Rajbari, 381 in Faridpur and 276 in Kushtia. The approximate population of these sub-districts were 361,000 in Rajbari, 335,000 in Faridpur and 530,000 in Kushtia (BBS 2012).

Study Design

We assessed two different community-based behavior change communication messages to improve knowledge about NiV and ultimately change behavior. In Rajbari district, we disseminated a "no raw sap" message for two seasons, discouraging community residents from drinking raw date palm sap (Fig. 1). Because we were delayed in securing Government of Bangladesh approval, in Faridpur district we disseminated an "only safe sap" message for only the second season. This message targeted community residents and *gachhis*, discouraging drinking raw sap but offering the option of drinking *bana*-protected sap. In both areas, local non-governmental organizations (NGOs) implemented the intervention by convening meetings and placing posters with key messages in public places with heavy traffic of people (Table 2). We broadcast televised public service announcements on closed-circuit local television, reaching both intervention areas exclusively, about five times daily, during the intervention period. Residents

Table 1. Demographic Characteristics of the "No Raw Sap" and the "Only Safe Sap" Intervention and Control Areas

	Rajbari district	Faridpur district	Kushtia district
Sub-districts	Pangsha and Kalukhali	Nagarkanda and Sadarpur	Mirpur and Bheramara
Area	"No raw sap"	"Only safe sap"	Control
Population density (sq. km)	945	871	1192
Sex ratio			
Men	50%	49%	50%
Women	50%	51%	50%
Average household size	4.3	4.6	4.1
Literacy rate	49.8%	44.7%	45.3%

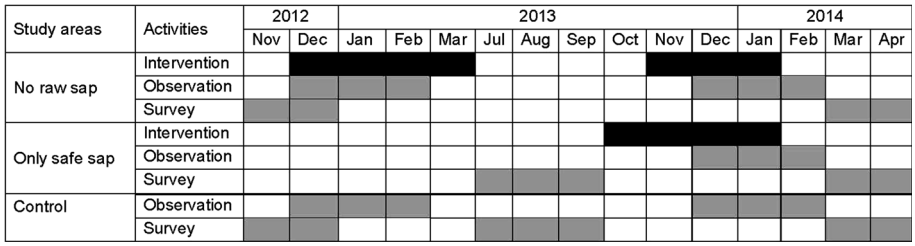

Figure 1. Study activities in the "no raw sap" "only safe sap" and control areas between 2012 and 2014 in Bangladesh

Table 2. Audience, Key Messages and Targeted Behaviors for the "No Raw Sap" and "Only Safe Sap" Intervention Areas, Implemented During 2012–2014 in Bangladesh

Area	Audience	Key message	Behavior
No raw sap	Community	To avoid Nipah disease stop drinking raw date palm sap	Stop drinking raw date palm sap
Only safe sap	Community	To avoid Nipah disease stop drinking raw date palm sap	Stop drinking raw date palm sap
		If you want to drink raw sap drink only *bana*-protected sap	Drink only *bana*-protected sap
		If you consume raw sap, ask if it is *bana*-protected sap	Make sure the sap you consume is *bana*-protected
	Gachhis	Protecting palm sap trees with *banas* protects your community from the deadly Nipah disease	Use *banas* on those trees used for raw sap consumption

in both intervention areas had similar access to television and other communication channels used to disseminate the campaign messages (Nahar et al. 2017).

To assess the effect of the intervention, we conducted baseline and endline surveys using pretested standardized questionnaires for face-to-face-interviews and observed *gachhis* collecting sap and sap selling points (Fig. 1).

During the 2012–2013 sap harvesting season, the evaluation team collected baseline survey data which asked about consumption in the prior year from community residents in Rajbari, the "no raw sap" area, and Kushtia, the control area. After the survey, the intervention consisted of meetings with opinion leaders and community residents, posters and TV public service announcements, from December 26, 2012, to March 29, 2013. During the 2013–2014 sap harvesting season, we continued with a limited intervention, only broadcasting the public service announcement from mid-November 2013 to January 2014 reminding residents of the risk of drinking raw sap. The evaluation team observed *gachhis* collecting and selling raw sap in the "no raw sap" intervention and control areas, between December and February during the 2012–2013 and 2013–2014 seasons. We did not conduct a baseline with *gachhis* in the "no raw sap" area because the message did not target them.

Before the 2013–2014 sap harvesting season, the evaluation team collected baseline data among community residents and *gachhis* in Faridpur, the "only safe sap" area, and Kushtia, the control area (Fig. 1). After the survey, we implemented the intervention from October 2013 to January 2014 including opinion leaders' meetings, community residents' meetings, posters and public service announcements. NGO workers also trained *gachhis* on making *banas*, encouraging their use on trees which sap was collected for raw consumption, provided stickers that *gachhis* could use to identify *bana*-protected sap pots, and offered sweatshirts as an incentive to use *banas*. Between December 2013 and February 2014, the evaluation team visited *gachhis* to observe them collecting and selling sap and to assess *bana* usage.

After the interventions ended in both areas, from March 31 to April 21, 2014, the evaluation team conducted endline surveys among community residents and *gachhis* from the intervention and control areas (Fig. 1).

During baseline and endline surveys, the evaluation team interviewed separate samples of adult men and wo-

men (Nahar et al. 2015). They collected data on respondents' sap consumption behavior during the previous sap collection season, their exposure to the intervention communication channels and message recall from elements of the intervention. They interviewed *gachhis* on their NiV knowledge, number of trees harvested, use of *banas* and raw sap selling practices.

Sample Size Calculation

Based on our previous studies (Sultana et al. 2013) (Stephen P Luby, unpublished data), our intervention aimed for a 15% absolute reduction in proportion of people reporting raw sap consumption in the intervention areas, compared to the control area. For a difference in difference analysis, we calculated the desired sample size as 372 men and 372 women from 75 villages per area, per survey. We followed a probability proportionate to size sampling procedure, using 2011 census information on total population per village, to select villages from each area. From each village, we selected independent samples of men from six households and women from six other households, targeting 450 households per gender per area, allowing for a 15% refusal rate. We followed the same procedure for baseline and endline sampling.

To measure changes in *gachhi* behavior, targeting a 15% absolute increase in reported *bana* usage between the intervention and control groups in a difference in difference analysis, we calculated the desired sample size as 53 *gachhis* (from 27 villages) in the intervention and control areas. Since the evaluation team would have already visited 75 villages during the community surveys, we increased the sample to 150, two *gachhis* per village, per area per year.

The evaluation team asked community respondents to identify *gachhis* in their village and listed their names, phone numbers and household locations. The evaluation team used a Kish grid (Kish 1949), to select *gachhis* at random for interviews.

Observational Data Collection

Every two weeks, the evaluation team conducted observations in at least five different sites in the intervention and control areas, randomly selecting 10 *gachhis* per area, from the initial *gachhi* list. They observed their activity between 5:25 and 9:45 am, when they collected and sold raw sap, stopping when *gachhis* sold all their sap or started making molasses. They observed and recorded the number of trees harvested, trees covered by *banas*, amount of raw sap collected and consumed and the number of persons who consumed or purchased raw sap to take home. They estimated the amount of sap collected and consumed by observing the size of the pots and consulting with the *gachhis*.

Data Analysis

We compared respondents' knowledge about NiV and sap harvesting and consumption practices between baseline and endline surveys. We assessed the relationship between intervention exposure and behavioral outcomes using a logistic regression model calculating odds ratios (OR). We adjusted for clustering within villages when calculating 95% confidence limits and *P* values. We used difference in difference analysis to compare changes from baseline to endline between the control and intervention groups.

Using the observation data, we calculated the median amount of raw sap collected and consumed; the mean number of people who consumed and purchased raw sap; and the proportion of observations during which at least one person consumed raw sap. We used difference in difference analysis to understand the changes in observed behavior among the control and the "no raw sap" intervention groups, from the 2012–2013 to the 2013–2014 sap season. We calculated the proportion of *gachhis* using *banas* and selling *bana*-protected sap for raw consumption, to understand the effect of the "only safe sap" intervention on *bana* usage.

Results

The evaluation team interviewed a total of 6220 community residents and 665 *gachhis* during baseline and endline surveys.

Knowledge About the Disease

Post-intervention 40% more respondents in both intervention areas reported knowing about a disease contracted through raw sap consumption compared with control. This increase was markedly higher in the intervention areas than in the control area. A larger proportion of *gachhis* reported knowing about NiV than community residents, both at baseline and endline (Table 3).

Table 3. Reported Community's and *gachhis* Knowledge of Nipah, at Baseline and Endline, from the "No Raw Sap" and "Only Safe Sap" Intervention and Control Areas, Bangladesh 2012–2014

Heard about a disease associated with date palm sap consumption and bats	Intervention area		Control area		Difference in difference analysis [95% CI]
	n (%)	*n* (%)	*n* (%)	*n* (%)	
"No raw sap" intervention and control areas, community					
	Baseline 2012[¶]	Endline 2014	Baseline 2012[¶]	Endline 2014	
	N = 892	*N* = 897	*N* = 885	*N* = 896	
A disease that people can get from drinking raw date palm sap	322 (36)	688 (77)[†††]	339 (38)	279 (31)[†]	(48)[†††] [38, 57]
A disease that can be transmitted from bats to people	176 (20)	541 (60)[†††]	133 (15)	181 (20)[†]	(35)[†††] [27, 43]
Heard of Nipah disease	47 (5)	276 (31)[†††]	42 (5)	58 (6)	(24)[†††] [19, 28]
"Only safe sap" intervention and control areas, community					
	Baseline 2013[#]	Endline 2014	Baseline 2013[#]	Endline 2014	
	N = 879	*N* = 879	*N* = 892	*N* = 896	
A disease that people can get from drinking raw date palm sap	405 (46)	667 (76)[†††]	371 (42)	279 (31)[†]	(40)[†††] [30, 49]
A disease that can be transmitted from bats to people	338 (39)	620 (71)[†††]	217 (24)	181 (20)	(36)[†††] [26, 45]
Heard of Nipah disease	97 (11)	307 (35)[†††]	77 (9)	58 (6)	(26)[†††] [20, 31]
"Only safe sap" intervention and control areas, *gachhis*					
	Baseline 2013[#]	Endline 2014	Baseline 2013[#]	Endline 2014	
	N = 110	*N* = 150	*N* = 105	*N* = 150	
A disease that people can get from drinking raw date palm sap	57 (52)	135 (90)[†††]	56 (53)	61 (41)	(50)[†††] [35, 66]
A disease that can be transmitted from bats to people	50 (45)	135 (90)[†††]	50 (48)	67 (45)	(47)[†††] [31, 63]
Heard of Nipah disease	10 (9)	113 (75)[†††]	24 (23)	24 (16)	(73)[†††] [59, 86]

All *P* values were cluster adjusted

[¶] *P* value was calculated by comparing baseline 2012 data with endline 2014 data

[#] *P* value was calculated by comparing baseline 2013 data with endline 2014 data

[†] *P* value < 0.05, [††] *P* value < 0.01, [†††] *P* value < 0.001

Community Practices in the "No Raw Sap" Area

Reported raw sap consumption decreased markedly between the 2012 baseline and 2014 endline, from 43 to 18%, among residents of the "no raw sap" area, and from 57 to 40%, among residents of the control area (Table 4). The reduction in the intervention area was not significantly larger than in the control (−7%, 95% CI −15, 1%, $P = 0.07$). Reported raw sap purchasing from local *gachhis* and tree owners declined from 34 to 18% in the intervention area, a decline that was not significantly larger than in the control (−11%, 95% CI −22, 1%, $P = 0.07$). Reported collection of raw sap from one's own trees or purchasing from market or mobile vendors for raw consumption did not change significantly among any group.

Community Practices in the "Only Safe Sap" Area

Reported overall raw sap consumption decreased markedly, between the 2013 baseline and the 2014 endline, from 60 to 44% among residents of the intervention area, and from 49 to 40%, in the control area. This reduction was not significantly larger than the control (−7%, CI −14, 2%, $P = 0.12$). Re-

Table 4. Reported Community Raw Sap Consumption Behavior, at Baseline and Endline, from the ''No Raw Sap'' and ''Only Safe Sap'' Intervention and Control Areas, Bangladesh 2012–2014

Community sap consumption behavior	Intervention area community		Control area community		Difference in difference analysis [95% CI]
	n (%)	*n* (%)	*n* (%)	*n* (%)	
''No raw sap'' intervention and control areas, community					
	Baseline 2012[¶]	Endline 2014	Baseline 2012[¶]	Endline 2014	
	N = 892	*N* = 897	*N* = 885	*N* = 896	
Respondents' individual raw sap consumption during previous sap harvesting season					
Consumed raw sap	380 (43)	163 (18)[†††]	506 (57)	354(40)[†††]	(−7) [−15, 1]
Sources of raw sap among those who drank raw sap during previous sap harvesting season[‡]					
	N = 380	*N* = 163	*N* = 506	*N* = 358	
Purchased from local *gachhi*/ tree owner	130 (34)	30 (18)[†††]	151 (30)	89 (25)	(−11) [−22, 1]
Own household trees	99 (26)	40 (25)	87 (17)	55 (15)	0
Gift	91 (24)	73 (45)[†††]	102 (20)	126 (35)[†††]	(6)[†] [−4, 16]
Purchased in market/ mobile vendor	65 (17)	23 (14)	192 (37)	104 (29)	(4) [−5, 14]
''Only safe sap'' intervention and control areas, community					
	Baseline 2013[#]	Endline 2014	Baseline 2013[#]	Endline 2014	
	N = 879	*N* = 879	*N* = 892	*N* = 896	
Respondents' individual raw sap consumption during previous sap harvesting season					
Consumed raw sap	530 (60)	391 (44)[†††]	440 (49)	358 (40)[††]	(−7) [−14, 2]
Consumed unprotected raw sap	515 (59)	224 (26)[†††]	325 (36)	260 (29)[††]	(−26)[†††] [−33, −18]
Raw sap consumption behavior among those who drank raw sap during previous sap harvesting season[‡]					
	N = 530	*N* = 391	*N* = 440	*N* = 358	
Consumed *bana*-protected raw sap	15 (3)	167 (43)[†††]	115 (26)	98 (27)	(38)[†††] [29, 48]
Asked at least once about *bana* usage before sap purchase	35 (7)	148 (38)[†††]	119 (27)	73 (20)	(38)[†††] [26, 49]
Sources of raw sap among those who drank raw sap during previous sap harvesting season[‡]					
Purchased from local *gachhi*/tree owner	206 (39)	119 (30)[†]	169 (38)	89 (25)[†††]	(5) [−5, 15]
Own household trees	159 (30)	116 (30)	61 (14)	55 (15)	(−2) [−11, 8]
Gift	114 (22)	107 (27)[†]	110 (25)	126 (35)[††]	(−4) [−13, 5]
Purchased in market/ mobile vendor	97 (18)	62 (17)	124 (28)	104 (29)	(−3) [−14, 7]

Table 4. continued

Community sap consumption behavior	Intervention area community		Control area community		Difference in difference analysis [95% CI]
	n (%)	*n* (%)	*n* (%)	*n* (%)	
Sap purchasing behavior among those who consumed sap from *bana*-protected trees					
	N = 15	*N* = 167	*N* = 115	*N* = 98	
Purchased from local *gachhi*/ tree owner	2 (13)	52 (31)†††	41 (36)	26 (27)	(27)† [3, 50]

All *P* values were cluster adjusted
‡ Open-ended responses
¶ *P* value was calculated by comparing baseline 2012 data with endline 2014 data
$^{\#}$ *P* value was calculated by comparing baseline 2013 data with endline 2014 data
† *P* value < 0.05, †† *P* value < 0.01, ††† *P* value < 0.001

ported consumption of unprotected sap declined in the intervention area (59 to 26%) and the control (36 to 29%). This decline was significantly larger in the "only safe sap" area than in the control (−26%, 95% CI −33, −18%, $P < 0.001$) (Table 4).

Restricting the analysis to residents who consumed sap, reported consumption of *bana*-protected sap significantly increased in the "only safe sap" area (3 to 43%), while it hardly changed in the control (26 to 27%). In addition, reported inquiries about *bana* use before purchasing sap significantly increased in the intervention area but decreased in the control. Reported raw sap purchased from local *gachhis* significantly declined in the "only safe sap" intervention (39 to 30%) and control (38 to 25%) areas. However, reported buying sap from local *gachhis* increased among residents who reported consuming *bana*-protected sap (13 to 31%). This increase was significantly larger in the intervention area than in the control (27%, 95% CI 3, 50%, $P < 0.05$) (Table 4).

Gachhi-Reported Date Palm Tree Harvesting and *Bana* Use

In the "only safe sap" area, between the 2013 baseline and 2014 endline, the total number of trees harvested and those harvested for raw sap consumption significantly declined. In the control, there were fewer harvested trees than in the intervention area, but the number remained constant throughout the study. The 2014 endline data suggest a higher number of harvested trees in the "no raw sap" area than the control (Table 5).

In the "only safe sap" area, *gachhi*-reported *bana* usage increased from 11 to 90% between the 2013 baseline and 2014 endline. In the control, an unexpectedly high proportion of *gachhis* reported *bana* use during the 2013 baseline, though it decreased during the 2014 endline (66 to 57%). The increase in the intervention area was significantly higher than in the control (Table 5).

Observation of Protected and Unprotected Raw Sap Consumption and *Bana* Usage

Comparing the 2012–2013 and the 2013–2014 sap harvesting seasons, in the "no raw sap" area, the observed amount of raw sap collected increased (median 36 vs. 50 L), while it decreased in the control (median 48 vs. 14 L). The proportion of observations of at least one person consuming raw sap at the *gachhi's* place declined more in the "no raw sap" area (46 to 22%) than in the control (61 to 53%; difference in difference 95% CI −45, 14% and $P = 0.30$). During the 2013–2014 sap harvesting season, the evaluation team observed a higher number of harvested trees in the intervention area than the control. They observed a higher percentage of *gachhis* using *banas* in the control than in intervention villages (Table 6).

Association of Exposure to the Intervention with Raw Sap Consumption

During the 2014 endline, more respondents from the "only safe sap" area than from the "no raw sap" area reported direct exposure to any element of the intervention (41 vs. 30%) as well as more indirect exposure by learning from others (36 vs. 28%) ("Appendix" of Table 11).

In the "only safe sap" area, respondents with direct exposure to at least one intervention element were more

Table 5. Reporting of *gachhis* on Their Harvested Trees and *bana* Usage During Baseline and Endline Data Collection from the "No Raw Sap," "Only Safe Sap" and Control Areas, Bangladesh 2013–2014

Information on harvested trees and bana usage	"No raw sap" intervention[§]	"Only safe sap" intervention area, *gachhis*		Control area, *gachhis*		Difference in difference analysis "the "only safe sap" and control group [95% CI]	Difference of "only safe sap" endline and control endline 2014 [95% CI]	Difference of "no raw sap endline and control endline 2014 [95% CI]
	Endline 2014 $N = 150$ n (%)	Baseline 2013 $N = 110$ n (%)	Endline 2014 $N = 150$ n (%)	Baseline 2013 $N = 105$ n (%)	Endline 2014 $N = 150$ n (%)			
Number of trees harvested during previous sap harvesting season								
Median (IQR)	30 (8, 60)	65 (29, 100)	40 (19, 80)††	7 (4, 16)	6 (2, 15)	(−29)††	(34)††† [26, 42]	(24)††† [12, 36]
Harvested trees used for raw consumption during previous sap harvesting season								
Median (IQR)	10 (2, 40)	60 (25, 100)	19 (5, 40)†††	6 (3, 10)	5 (2, 10)	(−40)†††	(14)††† [8, 20]	(5)†† [0, 10]
Gachhis used *banas* during previous sap harvesting season								
Gachhis used *banas*	47 (31)	12 (11)	135 (90)†††	69 (66)	85 (57)	(88)††† [73, 102]	(33)††† [23, 43]	(−25)††† [−38, −12]
Mean proportion of harvested trees used for raw consumption, covered by banas, during previous sap harvesting season								
Trees always covered by *banas*	30%	7%	68%†††	60%	53%	(68)†††	(15)†††	(−23)†††

All P values were cluster adjusted

[§] No baseline with gachhis

[†] P value < 0.05, [††] P value < 0.01, [†††] P value < 0.001

Table 6. Observation of Date Palm Sap Harvesting, Consumption and Selling at *gachhis*' Households, from 5.25 to 9.45 am, Until *gachhis* Finished the Raw Sap Selling and/or Start Making Molasses, During the 2012–2013 and 2013–2014 Sap Harvesting Seasons

Observation findings	"No raw sap" intervention[¶]		"Only safe sap" intervention[#]	Control		Difference in difference analysis of the "no raw sap" and control group [95% CI]
	2012–2013 sap season $N = 46$	2013–2014 sap season $N = 46$	2013–2014 sap season $N = 48$	2012–2013 sap season $N = 36$	2013–2014 sap season $N = 38$	
Amount of sap (in liters) collected, median (IQR)	36 (20, 56)	50 (40, 80)	39 (27, 60)	48 (24, 105)	14 (8, 40)[†††¶, †††#]	49[†††] [25, 73]
Number of trees harvested (observed), median (IQR)[§]	–	16 (12, 27)	16 (11, 24)		7 (3, 13)[†††¶, †††#]	
Consumption and purchase of raw sap during observation						
At least one person consumed raw sap during observation	21 (46%)	10 (22%)	15 (31%)	22 (61%)	20 (53%)[††¶, †#]	−15 [−45, 14]
Gachhi who served sap for raw consumption used *bana*[‡§]	–	0	8 (53%)	–	12 (60%)[††¶]	
Mean number of persons that consumed raw sap[‡] (SD) (protected or unprotected)	3.14 (2.22)	3.20 (2.20)	3.00 (2.83)	5.45 (3.78)[¶†††]	2.95 (1.85)	1 [−0.5, 2.6]
Mean number of persons that purchased raw sap and took it home[‡‡] (SD)	1.85 (1.21)	1.56 (1.33)	1.65 (0.93)	3.77 (2.98)[¶††]	2.25 (2.00)	1.4[†] [0.3, 2.4]
Amount of raw sap (in liters) consumed by the people at *gachhi's* household, median (IQR) (people who purchased or did not purchased)	1(1, 2)	0.88 (0.5, 1.25)	1 (0.5, 2.75)	2(1, 4)	1 (0.5, 1.75)	0.5 [−0.3, 1.3]
Uses of *bana* on observation day						
Proportion of *gachhis* using *banas*[§]	_	2(4%)	15 (31%)	_	21(55%)[†††¶, ††#]	_
Proportion of trees with *banas*[§]	_	0%	7%	_	26%[†††¶ †††#]	_

[§] Items were not observed in 2012–2013 season

[¶] *P* value was calculated by comparing the "no raw sap" intervention area with the control area; [#] *P* value was calculated by comparing the "only safe sap" intervention area with the control area

[†] *P* value < 0.05, [††] *P* value < 0.01, [†††] *P* value < 0.001

[‡] Denominator was the *gachhis* household where raw sap consumption occurred, [‡‡] Denominator was the *gachhis* household where persons purchased raw sap and took away

likely to report consuming raw sap from a protected source than those with no exposure (25 vs. 15%, OR 2.0, 95% CI 1.5–2.6, $P < 0.001$) (Table 7). Similarly, there were noticeable differences among respondents exposed to an individual element and those with no exposure. Respondents who attended community meetings were more likely to report consuming raw sap (54 vs. 43% OR 1.5, 95% CI 1.0–2.3, $P = 0.02$) than those who did not. They were also more likely to report consuming raw sap from a protected source than those who did not attend community meetings (38 vs. 16%, OR 3.1, 95% CI 2.1–4.6, $P < 0.001$). In addition, respondents who saw a poster were more likely to report consuming raw sap from a protected source than those who did not (26 vs. 16%, OR 1.8, 95% CI 1.3–2.5, $P < 0.001$). Respondents who watched the public service announcements were more likely to report consuming raw sap from a protected source than those who did not (27 vs. 18%, OR 1.7, 95% CI 1.0–2.7, $P < 0.05$) (Table 7). By

Table 7. Association of Exposure to Interventions with Reported Consumption of Raw Date Palm Sap During Previous Sap Harvesting Season in the Intervention Areas—Endline 2014

Exposure to intervention	"No raw sap" intervention area $N = 897$			"Only safe sap" intervention area $N = 879$								
				Raw sap			Unprotected raw sap			Protected raw sap		
	Consumption of raw sap *n* (%)	Odds ratio (95% Cl)	*P**	Consumption of raw sap *n* (%)	Odds ratio (95% Cl)	*P**	Consumption of raw sap from unprotected source *n* (%)	Odds ratio (95% Cl)	*P**	Consumption of raw sap from protected source *n* (%)	Odds ratio (95% Cl)	*P**
Attended community meeting												
No	147/807 (18)	Ref		334/774 (43)	Ref		215/774 (28)	Ref		127/774 (16)	Ref	
Yes	16/90 (18)	0.97 (0.6–1.7)	0.916	57/105 (54)	1.56 (1.1–2.3)	0.025	17/105 (16)	0.50 (0.3–0.8)	0.010	40/105 (38)	3.1 (2.1–4.6)	0.000
Saw a poster												
No	130/707 (18)	Ref		264/607 (43)	Ref		173/607 (28)	Ref		97/607 (16)	Ref	
Yes	33/190 (17)	0.93 (0.6–1.4)	0.753	127/272 (47)	1.14 (0.8–1.5)	0.402	59/272 (22)	0.70 (0.5–1.0)	0.061	70/272 (26)	1.8 (1.3–2.5)	0.000
Saw TV public service announcement												
No	150/798 (19)	Ref		339/770 (44)	Ref		207/770 (27)	Ref		138/770 (18)	Ref	
Yes	13/99 (13)	0.65 (0.4–1.2)	0.167	52/109 (48)	1.16 (0.8–1.7)	0.442	25/109 (23)	0.81 (0.5–13)	0.362	29/109 (27)	1.7 (1.0–2.7)	0.048
Directly exposed to any communication channel (community meeting or poster or TV public service announcement)												
No	114/629 (18)	Ref		224/518 (43)	Ref		153/518 (30)	Ref		76/518 (15)	Ref.	
Yes	49/268 (18)	1.01 (0.7–1.5)	0.959	167/361 (46)	1.13 (0.9–1.5)	0.346	79/361 (22)	0.67 (0.5–0.9)	0.013	91/361 (25)	2.0 (1.5–2.6)	0.000
Indirectly exposed to the new information through word of the mouth (no direct exposure to community meeting or poster or TV public service announcement												
No	111/649 (17)	Ref		250/558 (45)			145/558 (26)			111/558 (20)	Ref.	
Yes	52/248 (22)	1.29 (0.8–2.0)	0.259	141/321 (44)	0.97 (0.7–1.2)	0.783	87/321 (27)	1.1 (0.8–1.5)	0.729	56/321 (17)	0.9 (0.6–1.2)	0.314

* Cluster adjusted

contrast, exposure to individual elements of the ''no raw sap'' intervention was not associated with reported avoidance of raw sap consumption.

Discussion

Respondents' knowledge of NiV transmission in both intervention areas markedly improved, while there was no significant change among controls. Reported raw sap consumption declined in both intervention and control areas. Reported *bana* usage and consumption of *bana*-protected sap increased in the ''only safe sap'' area. Direct exposure to the intervention was significantly associated with drinking sap from a protected source in the ''only safe sap'' area.

The primary objective of the ''no raw sap'' intervention area was to reduce raw sap consumption. We expected a 15% absolute reduction in the proportion of people reporting raw sap consumption in the intervention area and observed a 25% absolute reduction, but we also observed an unexpected 17% reduction in the control; thus, the reduction in the intervention area was not significantly different than in the control. Our observational data found no change in the mean number of persons consuming raw sap at the *gachhis* place nor in the amount consumed, suggesting that the decrease in the number of people reporting sap consumption may have been due to social desirability bias (Wood et al. 2008). We also did not find any association between exposure to the intervention and decline in raw sap consumption. Overall, the evaluation does not provide compelling evidence that the ''no raw sap'' message markedly reduced raw sap consumption.

In the ''only safe sap'' area, there was no reported or observed reduction in raw sap consumption. However, reported consumption of *bana*-protected sap, inquiring about the use of *bana* prior to sap purchasing, and drinking *bana*-protected sap from the local *gachhi* significantly increased in comparison with the control. Direct exposure to the intervention was associated with increased consumption of raw sap, increased consumption of protected sap and reduced consumption of unprotected sap.

In the ''only safe sap'' area, reported *bana* usage significantly increased and exceeded the 15% absolute increase projection, though observed *bana* usage was much lower than that reported by *gachhis*. This higher reporting might be due to social desirability bias. However, in the ''only safe sap'' area, the observed proportion of *gachhis* using *banas* during the intervention period was about three times higher than the reported *bana* usage at baseline, suggesting that *bana* use increased because of the intervention.

The ''no raw sap'' message did not achieve the expected outcome. Exposure to community meetings and posters occurred one year prior to conducting the survey, probably affecting recall. Although we re-broadcast the public service announcement the second year, exposure to it, during two seasons, was not related to behavior change. This might be because a two-season intervention was not enough to eliminate an existing food behavior such as drinking raw sap. People acquire eating behaviors over a lifetime, and changing them requires alterations in habits with long-term interventions (Nestle et al. 1998). Although many respondents reported ceasing drinking raw sap, continuous intervention efforts may be required to ultimately modify raw sap consumption behavior. When raw sap is available, it might be difficult for people to abstain from drinking it (Nahar et al. 2015). Indeed, drinking raw sap from one's own household trees remained constant among intervention and control groups over time.

Even though the ''only safe sap'' message was disseminated for a single season, reported community and *gachhi* behaviors were in line with the expected outcomes. The intervention offered the option of continuing an existing food behavior rather than completely eliminating a preferred food item. The use of *bana* and drinking *bana*-protected sap was an already existing occasional practice among some *gachhis* (Nahar et al. 2010). The cultural environment and social interaction exerts a strong influence on perceptions about food, food choices eating behavior (Nestle et al. 1998; Shepherd and Shepherd 2002). Thus, having the option to drink safe sap might be more acceptable compared with completely stopping consumption.

The ''only safe sap'' message is a harm reduction approach that recognizes abstinence as an ideal outcome but accepts alternatives that reduce harm (Marlatt 1996). These approaches have proven useful for reducing other public health risks, such as HIV transmission through needle sharing among drug users (Aspinall et al. 2014). Harm reduction studies demonstrate that modest changes to behaviors are easier to achieve than more substantive changes (Luby et al. 2005; Plautz and Meekers 2007; Kirby 2008). We know that some people drink raw sap even after learning about the risk of NiV (Nahar et al. 2015). Asking them to drink only safe sap is less demanding than asking them to stop drinking sap altogether. It also targeted *gachhis* who are the source of sap and could be held responsible for NiV transmission, giving them a safe option

to provide sap. Thus, disseminating an ''only safe sap'' message may be a more pragmatic strategy to reduce the risk of NiV transmission.

Our study has limitations. Neither the community nor our evaluators were blinded to the intervention. Our primary outcome was measured through reported behavior. Although social desirability bias may have induced respondents to underreport their sap consumption practice and over-report *bana* usage (Wood et al. 2008), there is little reason to expect more social desirability bias in the ''only safe sap'' than in the ''no raw sap'' area. To interpret our reported data, we looked at changes in knowledge and observation data, though the number of observed outlets was small and the presence of our observer might have altered some behavior. Nevertheless, the association between exposure to specific elements of the intervention and reported safe sap behaviors suggests behavior change resulted from the ''only safe sap'' message but not from the ''no raw sap'' message.

Our intervention and control areas were not comparable in terms of number of date palm trees harvested and preexisting behaviors related to *bana* usage. The constraints of a mass media intervention trial requiring large units of intervention make balance more difficult to achieve than a trial with many smaller units of intervention that permits random assignment. Without any intervention, raw sap consumption decreased among community respondents in the control area, and this decline remains unexplained. There might be other characteristics specific to the districts that contributed to different practices in different years, rather than the intervention. Further research to better explicate year-to-year variability in sap consumption practices, which may be related to weather, sap harvest productivity, competing employment opportunities for *gachhis* or other factors, may help and guide future interventions and evaluations. Nevertheless, the changes in the ''only safe sap'' area likely resulted from the intervention, because of the association between exposure and behaviors and the significant changes identified in the difference in difference analysis between intervention and control groups on a number of outcomes. The control districts provided a useful counterfactual illustrating underlying variability and supporting a more conservative interpretation than a design that would have only looked at baseline and endline.

We did not fully understand why a high proportion of *gachhis* from the control area used *bana* at baseline and endline. Perhaps, since *gachhis* from the control area harvested a small number of trees, they have less work related to tree harvesting and more time to make *banas*. In our earlier work, even without intervention, some *gachhis* reported to occasionally using *banas* to collect more, cleaner sap (Nahar et al. 2010, 2014). Other *gachhis* recalled their previous experience seeing colleagues using *banas* more frequently when harvesting fewer trees (Nahar et al. 2010, 2014). In the ''only safe sap'' area, the proportion of *gachhis* that used *banas* increased, thus increasing their workload, which may have resulted in the significant decline in the number of harvested trees after the intervention. Better understanding of control area *gachhis*' motivation to use *banas* without any intervention might provide useful insights to support the expansion of this intervention strategy.

Our measurements were unable to confirm if people reporting drinking protected sap, actually consumed protected sap. Their ability to reliably assess whether the sap was *bana*-protected or not likely depends on how well they know the *gachhi*. Future studies could investigate the effect of the message to ask for *bana*-protected sap from local *gachhis* (Table 2) and to observe actual use of *banas*.

The ''only safe sap'' message resulted in changes in reported behavior that may reduce the risk of NiV spillovers; thus, this intervention could be further promoted and evaluated. Prospective efforts to track raw sap consumption practices, and explore year-to-year variation in Bangladesh, would be particularly useful to guide government policy.

Acknowledgements

Support for this study was provided by FHI 360 with funds from USAID Cooperative Agreement GHN-A-00-09-00002-00; this study was made possible by the generous support of the American people through the United States Agency for International Development (USAID). icddr,b acknowledges with gratitude the commitment of FHI 360 to the Centre's research efforts. icddr,b is thankful to the Governments of Bangladesh, Canada, Sweden and the UK for providing core/unrestricted support. We are grateful to all the study participants for their valuable time. We are thankful to the quantitative data collection team. We acknowledge the continuous support of Professor Marcel Tanner from Swiss Tropical and Public Health Institute.

Compliance with Ethical Standards

Conflict of interests

Authors have no conflict of interest.

Human and Animal Rights

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all individual participants included in the study. Human subject review committees at icddr,b and FHI 360 approved the study protocol. The study protocol was registered as a clinical trial on clinicaltrials.gov (NCT01811784).

Appendix

See Tables 8, 9, 10 and 11.

Table 8. Reported Community and *gachhi* Exposure to Information about NiV at Baseline and Endline from the "No Raw Sap" and "Only Safe Sap" Intervention and Control Areas, Bangladesh 2012 to 2014

Characteristics	Intervention area community		Control area community		Difference in difference analysis [95% CI]
	n (%)	*n* (%)	*n* (%)	*n* (%)	
"No raw sap" intervention and control areas community					
	Baseline 2012[¶]	Endline 2014	Baseline 2012[¶]	Endline 2014	
	N = 892	*N* = 897	*N* = 885	*N* = 896	
First time heard about a disease associated with date palm sap consumption and bats					
This year	22 (2)	74 (8)[†††]	13 (1)	61 (7)[†††]	0
One year back	102 (11)	237 (26)[†††]	149 (17)	94 (10)[††]	(21)[†††] [15, 28]
Two or more years back	247 (28)	418 (47)[†††]	219 (25)	193 (22)	(22)[†††] [14, 30]
"Only safe sap" intervention and control areas community					
	Baseline 2013[#]	Endline 2014	Baseline 2013[#]	Endline 2014	
	N = 879	*N* = 879	*N* = 892	*N* = 896	
First time heard about a disease associated with date palm sap consumption and bats					
This year	126 (14)	405 (46)[†††]	113 (13)	61 (7)[††]	(38)[†††] [30, 45]
One year back	140 (16)	182 (21)[†††]	145 (16)	94 (10)[††]	(10)[††] [4, 17]
Two or more years back	235 (27)	124 (14)[†††]	170 (19)	193 (22)	(−16)[†††] [−23, −8]
"Only safe sap" intervention and control areas gachhi					
	Baseline 2013[#]	Endline 2014	Baseline 2013[#]	Endline 2014	
	N = 110	*N* = 150	*N* = 105	*N* = 150	
This year	18 (16)	81 (54)[†††]	22 (21)	15 (10)[†]	(49)[†††] [34, 63]
One year back	10 (9)	38 (25)[†]	20 (19)	34 (23)	(12) [−1, 26]
Two or more years back	35 (32)	23 (15)[†]	26 (25)	42 (28)	(−19)[††] [−34, −4]

All *P* values were cluster adjusted

[¶] *P* value was calculated by comparing baseline 2012 data with endline 2014 data; [#] *P* value was calculated by comparing baseline 2013 data with endline 2014 data

[†] *P* value < 0.05, [††] *P* value < 0.01, [†††] *P* value < 0.001

Table 9. Reporting of *gachhis* on Receiving NiV Information and Behavior Related to Raw Sap, During Baseline and Endline Data Collection from the "No Raw Sap," "Only Safe Sap" and Control Areas, Bangladesh 2013 to 2014

Characteristics	"No raw sap" intervention	"Only safe sap" intervention area *gachhi*		Control area *gachhi*		Difference of ("Only safe sap" difference 2014–2013)—(control difference 2014–2013) [95% CI]	Difference of "only safe sap" endline and control endline 2014 [95% CI]	Difference of "no raw sap endline and control endline 2014 [95% CI]
	Endline 2014 $N = 150$ *n* (%)	Baseline 2013 $N = 110$ *n* (%)	Endline 2014 $N = 150$ *n* (%)	Baseline 2013 $N = 105$ *n* (%)	Endline 2014 $N = 150$ *n* (%)			
Frequency of bringing sap for raw consumption from harvested trees to household during previous sap harvesting season								
Very frequently	115 (77)	102 (93)	137 (91)	89 (85)	124 (83)	0	(9)† [0.1, 17]	(−6) [−16, 4]
Once a week	23 (15)	8 (7)	10 (7)	13 (12)	19 (13)	(−0) [−1, 9]	(−6) [−12, 1]	(2) [−6, 11]
Frequency of selling raw sap during previous sap harvesting season								
At least few times	102 (68)	90 (82)	109 (73)	64 (61)	81 (54)	(−2) [−18, 13]	(19)†† [6, 31]	(14)† [0.1, 27]
Learned about using *banas* from‡								
Family members	18 (12)	5 (5)	17 (11)†	35 (33)	34 (23)	(17) [4, 30]	(−11)† [−20, −2]	(−11)† [−20, −1]
Other *gachhis*	13 (9)	3 (3)	6 (4)	21 (20)	33 (22)	(−1) [−11, 10]	(−18)††† [−26, −10]	(−13)† [−22, −4]
NGO workers	5 (3)	0	89 (59)†††	1 (1)	1 (1)	(59)††† [50, 69]	(59)††† [50, 67]	(3) [−0.5, 5]
Community meetings	3 (2)	0	37 (25)†††	0	0	(25)††† [16, 33]	(24)††† [17, 33]	(2) [−0.2, 4]
Poster	2 (1)	0	6 (4)†††	0	0	(4) [0,, 8]	(4)† [0.3, 8]	(1) [−0.5, 3]

Table 9. continued

Characteristics	"No raw sap" intervention	"Only safe sap" intervention area *gachhi*		Control area *gachhi*		Difference of ("Only safe sap" difference 2014–2013)—(control difference 2014–2013) [95% CI]	Difference of "only safe sap" endline and control endline 2014 [95% CI]	Difference of "no raw sap endline and control endline 2014 [95% CI]
	Endline 2014 $N = 150$ *n* (%)	Baseline 2013 $N = 110$ *n* (%)	Endline 2014 $N = 150$ *n* (%)	Baseline 2013 $N = 105$ *n* (%)	Endline 2014 $N = 150$ *n* (%)			
Television	2 (1)	0	5 (3)†††	4 (4)	4 (3)	(4) [−1, 9]	0	(−1) [−5, 2]
Self-taught	7(5)	5(5)	3(2)	14(13)	18(12)	(−1) [−10, 8]	(−10)†† [−16, −4]	(−7)† [−14, −0.3]
Neighbor	1 (1)	1 (1)	2 (1)	2 (2)	6 (4)	(−2) [−7, 3]	(−2) [−6, 1]	(−3) [−6, 0.1]
Tree owners	2 (1)	0	5 (3)†††	5 (5)	1 (1)††	(7) [2, 12]	(2) [−1, 6]	(1) [−1, 3]

All *P* values were Cluster adjusted

‡ Open-ended responses with multiple answers allowed, † *P* value < 0.05, †† *P* value < 0.01, ††† *P* value < 0.001

Table 10. Observation of Date Palm Sap Harvesting, Consumption and Selling at *gachhis*' Households at 5.25–9.45 am Until *gachhis* Finished the Raw Sap Selling and/or Start Making Molasses During 2012–2013 and 2013–2014 Sap Harvesting Seasons

Observation findings	2012–2013 sap season		2013–2014 sap season		
	"No raw sap" intervention area $N = 46$	Control area $N = 36$	"No raw sap" intervention area[¶] $N = 46$	"Only safe sap" intervention area[#] $N = 48$	Control area $N = 38$
Amount of sap (in liters) used for molasses, median (IQR)	40 (32, 62)	23 (0, 71)	50 (37, 80)	32 (19, 53)	5 (0, 14)[†††¶, †††#]
Persons purchased raw sap and took it home for household use during observation					
At least one person purchased raw sap and took away to home	13 (28%)	22 (61%)[††]	9 (20%)	20 (42%)	12 (32%)
Gachhi who sold raw sap for household use used *bana*[§‡‡]			1 (11%)	10 (50%)	6 (50%)
Amount of raw sap (in liters) bought and brought home, median (IQR) (among who purchased raw sap)	15 (6, 16)	17 (8, 24)	10 (8, 10)	15 (9, 20)	10 (6, 14)

[§] Items were not observed in 2012–2013 season

[¶] P value was calculated by comparing the "no raw sap" intervention area with the control area; [#] P value was calculated by comparing the "only safe sap" intervention area with the control area

[†] P value < 0.05, [††] P value < 0.01, [†††] P value < 0.001

[‡‡] Denominator was the *gachhis* household where persons purchased raw sap and took away

Table 11. Endline Data on Community Respondents' Exposure to Nipah Prevention Intervention During 2012–2013 and 2013–2014 Sap Seasons from the "No Raw Sap" and the "Only Safe Sap" Intervention Area, Bangladesh

Exposure to interventions	Intervention community endline	
	No raw sap $N = 897$ n (%)	Only safe sap $N = 879$ n (%)
Attended community meeting	90 (10)	105 (12)
Saw a poster	190 (21)	272 (31)
Saw TV public service announcement	99 (11)	109 (12)
Directly exposed to any communication channel (community meeting or poster or TV public service announcement)	268 (30)	361 (41)
Indirectly exposed to the new information through word of the mouth (no direct exposure to community meeting or poster or TV public service announcement)	248(28)	321(37)

References

Aspinall EJ, Nambiar D, Goldberg DJ, Hickman M, Weir A, Van Velzen E, Palmateer N, Doyle JS, Hellard ME, Hutchinson SJ (2014) Are needle and syringe programmes associated with a reduction in HIV transmission among people who inject drugs: a systematic review and meta-analysis. *Int J Epidemiol* 43:235–248

BBS (2012) *Population and Housing Census 2011*, Dhaka, Bangladesh: Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division, Ministry of Planning

Chua KB, Goh KJ, Wong KT, Kamarulzaman A, Tan PS, Ksiazek TG, Zaki SR, Paul G, Lam SK, Tan CT (1999) Fatal encephalitis due to Nipah virus among pig-farmers in Malaysia. *Lancet* 354:1257–1259

Dawood FS, Iuliano AD, Reed C, Meltzer MI, Shay DK, Cheng PY, Bandaranayake D, Breiman RF, Brooks WA, Buchy P, Feikin DR, Fowler KB, Gordon A, Hien NT, Horby P, Huang QS, Katz MA, Krishnan A, Lal R, Montgomery JM, Molbak K, Pebody R, Presanis AM, Razuri H, Steens A, Tinoco YO, Wallinga J, Yu H, Vong S, Bresee J, Widdowson MA (2012) Estimated global mortality associated with the first 12 months of 2009 pandemic influenza A H1N1 virus circulation: a modelling study. *Lancet Infect Dis* 12:687–695

Gurley ES, Montgomery JM, Hossain MJ, Bell M, Azad AK, Islam MR, Molla MA, Carroll DS, Ksiazek TG, Rota PA, Lowe L, Comer JA, Rollin P, Czub M, Grolla A, Feldmann H, Luby SP, Woodward JL, Breiman RF (2007) Person-to-person transmission of Nipah virus in a Bangladeshi community. *Emerg Infect Dis* 13:1031–1037

Hegde ST, Sazzad HM, Hossain MJ, Alam MU, Kenah E, Daszak P, Rollin P, Rahman M, Luby SP, Gurley ES (2016) Investigating Rare Risk Factors for Nipah Virus in Bangladesh: 2001–2012. *EcoHealth* 13:720–728

Homaira N, Rahman M, Hossain MJ, Epstein JH, Sultana R, Khan MS, Podder G, Nahar K, Ahmed B, Gurley ES, Daszak P, Lipkin WI, Rollin PE, Comer JA, Ksiazek TG, Luby SP (2010) Nipah virus outbreak with person-to-person transmission in a district of Bangladesh, 2007. *Epidemiol Infect* 138:1630–1636

Khan SU, Gurley ES, Hossain MJ, Nahar N, Sharker MA, Luby SP (2012) A randomized controlled trial of interventions to impede date palm sap contamination by bats to prevent nipah virus transmission in Bangladesh. *PLoS One* 7:e42689

Kirby DB (2008) The Impact of Abstinence and Comprehensive Sex and STD/HIV Education Programs on Adolescent Sexual Behavior. *SR & SP* 5:18–27

Kish L (1949) A procedure for objective respondent selection within the household. *J Am Stat Assoc* 44:380–387

Luby S, Hoodbhoy F, Jan A, Shah A, Hutin Y (2005) Long-term improvement in unsafe injection practices following community intervention. *Int J Infect Dis* 9:52–59

Luby SP (2013) The pandemic potential of Nipah virus. *Antiviral Res* 100:38–43

Luby SP, Rahman M, Hossain MJ, Blum LS, Husain MM, Gurley E, Khan R, Ahmed BN, Rahman S, Nahar N, Kenah E, Comer JA, Ksiazek TG (2006) Foodborne transmission of Nipah virus, Bangladesh. *Emerg Infect Dis* 12:1888–1894

Marlatt GA (1996) Harm reduction: come as you are. *Addict Behav* 21:779–788

Nahar N, Asaduzzaman M, Sultana R, Garcia F, Paul RC, Abedin J, Sazzad HMS, Rahman M, Gurley ES, Luby SP (2017) A large-scale behavior change intervention to prevent Nipah transmission in Bangladesh: components and costs. BMC Res Notes 10:225.

Nahar N, Mondal UK, Hossain MJ, Khan MS, Sultana R, Gurley ES, Luby SP (2014) Piloting the promotion of bamboo skirt barriers to prevent Nipah virus transmission through date palm sap in Bangladesh. *Glob Health Promot* 21:7–15

Nahar N, Mondal UK, Sultana R, Hossain MJ, Khan MS, Gurley ES, Oliveras E, Luby SP (2013) Piloting the use of indigenous methods to prevent Nipah virus infection by interrupting bats' access to date palm sap in Bangladesh. *Health Promot Int* 28:378–386

Nahar N, Paul RC, Sultana R, Gurley ES, Garcia F, Abedin J, Sumon SA, Banik KC, Asaduzzaman M, Rimi NA, Rahman M, Luby SP (2015) Raw sap consumption habits and Its association with knowledge of Nipah virus in two endemic districts in Bangladesh. *PLoS One* 10:e0142292

Nahar N, Sultana R, Gurley ES, Hossain MJ, Luby SP (2010) Date palm sap collection: exploring opportunities to prevent Nipah transmission. *EcoHealth* 7:196–203

Nestle M, Wing R, Birch L, DiSogra L, Drewnowski A, Middleton S, Sigman-Grant M, Sobal J, Winston M, Economos C (1998) Behavioral and social influences on food choice. *Nutr Rev* 56:S50–64; discussion S64–74.

Plautz A, Meekers D (2007) Evaluation of the reach and impact of the 100% Jeune youth social marketing program in Cameroon: findings from three cross-sectional surveys. *Reprod Health* 4:1

Rahman MA, Hossain MJ, Sultana S, Homaira N, Khan SU, Rahman M, Gurley ES, Rollin PE, Lo MK, Comer JA, Lowe L, Rota PA, Ksiazek TG, Kenah E, Sharker Y, Luby SP (2012) Date palm sap linked to Nipah virus outbreak in Bangladesh, 2008. *Vector Borne Zoonotic Dis* 12:65–72

Reynes JM, Counor D, Ong S, Faure C, Seng V, Molia S, Walston J, Georges-Courbot MC, Deubel V, Sarthou JL (2005) Nipah virus in Lyle's flying foxes, Cambodia. *Emerg Infect Dis* 11:1042–1047

Sazzad HM, Hossain MJ, Gurley ES, Ameen KM, Parveen S, Islam MS, Faruque LI, Podder G, Banu SS, Lo MK, Rollin PE, Rota PA, Daszak P, Rahman M, Luby SP (2013) Nipah virus infection outbreak with nosocomial and corpse-to-human transmission, Bangladesh. *Emerg Infect Dis* 19:210–217

Sejvar JJ, Hossain J, Saha SK, Gurley ES, Banu S, Hamadani JD, Faiz MA, Siddiqui FM, Mohammad QD, Mollah AH, Uddin R, Alam R, Rahman R, Tan CT, Bellini W, Rota P, Breiman RF, Luby SP (2007) Long-term neurological and functional outcome in Nipah virus infection. *Ann Neurol* 62:235–242

Shepherd R, Shepherd R (2002) Resistance to changes in diet. *Proc Nutr Soc* 61:267–272

Sultana R, Mondal UK, Abedin J, Hossain MJ, Sharkar MAY, Rimi NA, Gurley ES, Nahar N, Luby SP (2013) Evaluating long-term behavior change resulting from an intervention to prevent Nipah virus transmission from bats to humans in Bangladesh. Page p. 05.001 *in* International Meeting on Emerging Diseases and Surveillance, Vienna, Austria

Wacharapluesadee S, Lumlertdacha B, Boongird K, Wanghongsa S, Chanhome L, Rollin P, Stockton P, Rupprecht CE, Ksiazek TG, Hemachudha T (2005) Bat Nipah virus, Thailand. *Emerg Infect Dis* 11:1949–1951

WHO (2016) *Ebola situation report*, World Health Organization

Wood L, Egger M, Gluud LL, Schulz KF, Juni P, Altman DG, Gluud C, Martin RM, Wood AJ, Sterne JA (2008) Empirical evidence of bias in treatment effect estimates in controlled trials with different interventions and outcomes: meta-epidemiological study. *BMJ* 336:601–605