Reduce Rice Consumption to Mitigate Inorganic Arsenic Exposure: Development and Evaluation of A Risk-Communication Intervention in College Rice Consumers

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1. Abstract

Background: Rice intake is a major route of chronic, oral exposure to inorganic arsenic (iAs), a known human carcinogen. Regular rice consumers are under an elevated risk of lung and bladder cancers associated with exposure to iAs via daily rice intake. The feasibility of reducing rice consumption as a potential mean to mitigate iAs-related health risk has not been adequately studied.

Objective: This paper aims to i) identify social-behavioral determinants of rice consumption in rice consumers; and ii) explore the feasibility of the altering the risk perceptions and behavior of rice consumption through the communication of risk information.

Methods: Rice consumers were recruited on the campus of Indiana University Bloomington (IUB). The social-behavioral determinants of consumption in rice consumers were identified using a psychometrical questionnaire, which was constructed by the formula of Health Belief Model. Theoretical framework of rice consumption behavior was devised based on identified determinants. An educational material was designed by organizing risk information related to the exposure of iAs through rice consumption by the proposed framework, with highlights on the identified determinants. The impact and effectiveness of the material was evaluated using a randomized controlled trial (n=136) that subjects were randomly assigned to treatment (n=67) and control groups (n=69), while only the treatment received the educational material as intervention. Psychometrical measurements were conducted after the intervention to compare the differences in risk perceptions and behavior related to rice consumption between the treatment and control groups.

Results: Risks of lung and bladder cancers in our sample of college rice consumers are five times greater than the general U.S. population. Perceived risk is a strong predictor of changes in rice consumption behavior, while perceived barrier might also have substantial influences. Our risk communication intervention improved the perception of susceptibility and seriousness, while had not direct impact on short-term rice consumption.

Keywords: rice, arsenic, randomized controlled trial, intervention, health belief model

2. Background

2.1 Elevated Exposure to Inorganic Arsenic and Health Risks in Rice Consumers

Inorganic arsenic is a naturally occurring element that widely exists in the earth's crust. Inorganic arsenic has been long known for its toxicity. Inorganic arsenic (iAs) is a group 1 human carcinogen (International Agency for Research on Cancer [IARC], 2012). Acute exposure to large doses of iAs causes severe symptoms such as vomiting, muscle cramping and even death in extreme cases (Agency for Toxic Substances and Disease Registry [ATSDR], 2007). Chronic exposure to low dose of iAs can impose serious health burdens as well, such as skin lesions, cardiovascular diseases, developmental neurological disorders and cancers at skin, lung and bladder (Gomez-Caminero et al., 2001; ATSDR, 2007; ATSDR, 2016). Drinking water and diet are the primary pathways of exposure in the non-occupationally exposed population.

Among all varieties of food items, rice is the biggest contributor to dietary exposure of iAs due to rice's ability to accumulate arsenic and magnitude of consumption (U.S. FDA, 2016). Rice, as a semi-aquatic food crop that grows in flooded fields, can take up and accumulate arsenic more efficiently from surrounding soil and water than barley and wheat (Su et al., 2010). Indeed, elevated concentrations of iAs have been found in rice samples from around the world (Zhu et al., 2008; European Food Safety Authority [EFSA], 2009; Joint FAO/WHO Expert Committee on Food Additives [JECFA], 2011; U.S. Food and Drug Administration [U.S. FDA], 2013). Furthermore, rice is a widely accessible and popular staple food that feeds billions of people around the world.

Quantitative studies of the exposure to iAs via rice intake demonstrate that the exposure displays distinctive patterns of distributions across the U.S. population, while some subpopulations are found to have an alarming level of exposure. The entire population has a low average exposure of 31.9 ng iAs/ kg body weight/ day (U.S. FDA, 2016). However, since the exposure climbs proportionally to the rate of rice intake, subpopulations that consume considerably higher amount of rice are at elevated level of exposure to iAs through daily rice consumption. Mantha et al. (2017) reports that the estimated daily iAs in Tribal, Asian and Pacific American ($\bar{x}$ = 2.8 µg iAs/day) is about three times greater than that in the entire population ($\bar{x}$ = 1.1 µg/day). In addition to Asian Americans, multiracial groups, Mexican Americans and 22% of Caucasian population have up to ten times larger rates of rice consumption in their regular diet (U.S. FDA, 2016). The elevated exposure to iAs in the high-consumption population is not well represented in the weighted average level of exposure in the entire U.S. population, due to the small population size of these subpopulations (< 3.4% of total U.S. population).

Health risks associated with the exposure to iAs via rice intake in U.S. rice consumers are of great concern. Elevated exposure in rice consumers leads to escalation in associated health risks. A total of 39 lifetime cases of lung and bladder cancers (best studied cancer endpoints) per million population was estimated in the entire U.S. population (U.S. FDA). As a comparison, predicted lifetime cases of lung and bladder cancers in the high-consumption subpopulations can reach almost ten times higher than that in the general population, which consists of a large proportion of non-consumers of rice.

2.2 Risk Mitigation by Reducing Rice Consumption

The excessive health risks associated with iAs exposure via rice intake in the aforementioned subpopulations are not currently addressed by regulatory actions. U.S. FDA (2016) concluded that the estimated lung and bladder cancer cases caused by iAs exposure via rice (39 cases per million) in the U.S. general population is a small proportion relative to cases lung and bladder cancers of all causes (90,000 cases per million). In addition, imposing limits on the iAs concentrations in rice would significantly damage the U.S. rice supply on the market. For example, a 100 ppb limit of iAs concentration on rice and rice products would exclude 93% of existing brown rice market since U.S. FDA (2016) found only 7% of brown rice and rice products have iAs concentrations lower than 100 ppb. Cutting the limit to 75 ppb would further eliminate all existing brown rice supply from the market.

Strategies to mitigate health risks related to iAs exposure via rice intake other than regulatory limit have been intensively discussed, targeting various phases from industrial stages such as agronomic production and processing of rice to individual stages such as cooking practice and consumer preference of rice (Nachman et al., 2018). However, little attention has been paid to the approach of mitigating exposure by directly reducing rice consumption. As mentioned in section 1.1, amount of rice consumption is a key determining factor of iAs exposure through rice that level of exposure escalates proportionally to the rate of rice intake. Lowering the rate of rice consumption from three occasions per day to one occasion per day can effectively reduce the estimated lifetime cases of lung and bladder cancers from 408 to 136 per million population (U.S. FDA, 2016). Yet, the feasibility and practicability of modifying individual rate of rice consumption has not been adequately explored.

2.3 Using Health Belief Model in Assist of Risk Communication to Reduce Rice Consumption

Risk communication is a practice to communicate risk information to the target audience that has been widely applied in public health and risk management. According to Gerrard et al. (1999), the fundamental assumption of risk communication is that being more knowledgeable about consequences of risk behavior can enhance the individuals' ability to make decisions on precautionary/ preventative or risk behavior. Risk communication promotes risk-related decision-making capability in a way that being informed about the consequences of risk behavior influences individuals' risk perceptions and invokes subsequent behavioral changes (Gerrard et al., 1999). Having rice consumers aware of the iAs exposure and its associated health risks might modify rice consumers' perceptions regarding the negative outcomes of rice consumption, which might further induce changes in rice consumption.

The framework of Health Belief Model (HBM) is used to identify social-behavioral determinants of rice consumption other than the risk perception. HBM has been demonstrated to be a powerful explanatory tool to predict preventative behavior (Champion & Skinner, 2008) and a successful guidance for the development of communication intervention (Carpenter, 2010). The evolved HBM framework posits five core constructs (Champion & Skinner, 2008): i) perceived threat from the risk behavior, ii) perceived benefit of the precautionary/ preventative action, iii) perceived barrier in executing the preventative action, iv) cues to action such as "how to" instructions and v) self-efficacy as individual's expectancy to successfully take the preventative action. The construct perceived threat is similar but not equal to risk perception. Perceived threat be further unfolded as perceived susceptibility and perceived seriousness, while perceived risk is the product of likelihood and hazard. Although the equivalency can be assumed between likelihood and susceptibility and between hazard and seriousness, the multiplicative relationship between susceptibility and seriousness is not included in perceived threat. Therefore, a modified version of HBM, replacing perceived risks for perceived threats, is used in this study. Structure of the modified HBM is shown in figure 1. The application of HBM requires construct definitions to be consistent with the original theory and specific to the context of application as well. The variability in construct measurements also requires the construct validity and reliability to be examined with each study.

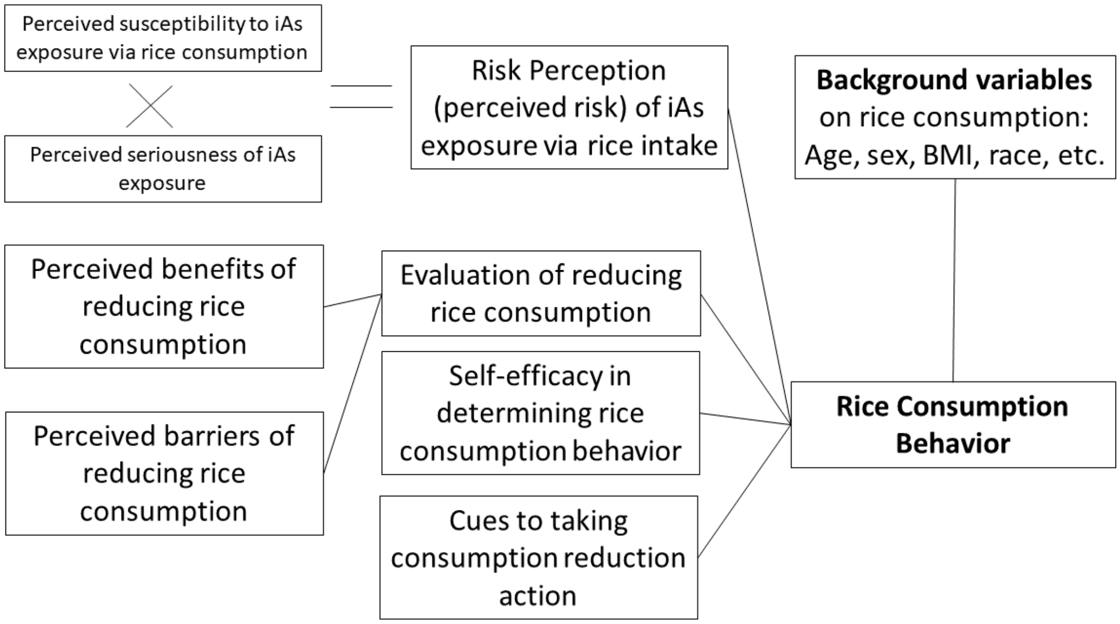

Figure 1 Structure of Health Belief Model of Predictors on Rice Consumption Behavior

The objective of this study is to i) identify social-behavioral determinants of rice consumption behavior in rice consumers and ii) evaluate the feasibility of altering the risk perception and behavior of rice consumption through risk communication. This paper is structured to answer the following questions: 1) Is our psychometrical measurement designed under HBM able to identify and capture the social-behavioral determinants of consumption reduction behavior in rice consumers? 2) Is risk perception one of the determinants of the consumption reduction behavior, or in other words whether changes in risk perception relates to the consumption reduction behavior? 3) Can our communication material cause any changes in risk perceptions? 4) Finally, can our communication material cause any direct changes in reduction behavior?

3. Methods

3.1 Subject Recruitment and Inclusion

A total of 360 adult participants from the campus of Indiana University Bloomington (IUB) voluntarily enrolled through April to November of 2019. A flyer was designed for recruitment purpose to include title, investigator, contact information, eligibility of participation. This study was described as “staple food” study instead of “rice” on the flyer to reduce potential interview bias. Consequently, there were two eligibility criterion that the participant must be adult and a regular consumer of any type of staple food (e.g. wheat, potato and rice). Flyers were distributed in buildings, facilities and dorms across IUB campus. Our study was entire constructed online that voluntary participants were directly by a link and a QR code on the flyer to our study webpage, where they can read the informed consent of this study. After granting their consent, participants were asked to take a short, preliminary online questionnaire survey on Qualtrics in which socio-demographic variables, baseline consumption behavior of wheat, potato and rice and baseline risk perceptions were asked. Data of rice consumption were analysed to identify regular rice consumers who eat more than half serving (50g cooked weight) of rice per day. A total of 192 identified rice consumers were included in the randomized controlled trial.

3.2 Randomized Controlled Trial

Flow diagram of this study is shown in figure 2. A simple randomization design was applied that 192 subjects were randomly assigned to either treatment or control group (n=96 each). The intervention program, an online video presentation, was administered to only subjects in the treatment group through email. 82% of subjects in the treatment group actually finished the intervention program. One month after the completion of intervention, all subjects in both groups were asked to take a final survey that is an online questionnaire on Qualtrics, in which both behavior and risk perceptions were investigated. Given the interval between intervention and the final survey, the survey reflects only short-term outcomes. A total of 136 responses (treatment n=67, control n=69) were received with balanced attrition rate (28%) in the two groups. Monetary incentives were provided for the completion of the study.

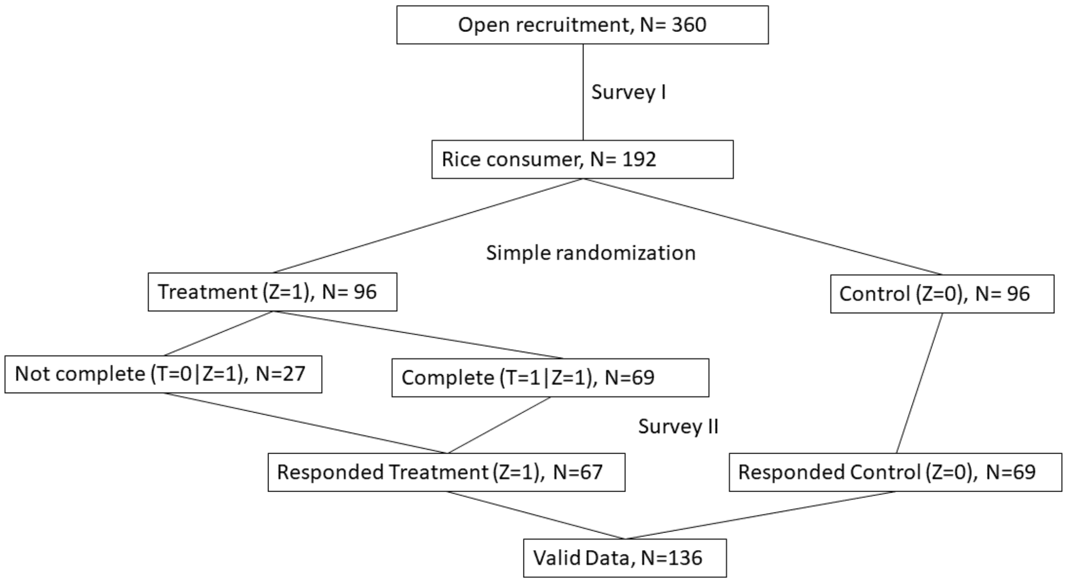

Figure 2 Flow Diagram of This Study

3.3 Instrument

As explained in section 1.4, both dietary behavior and social-behavioral determinants were surveyed for wheat, potato and rice in order to reduce interview bias. Questions in each section were first determined for rice as a template, then adjusted correspondingly for wheat and potato.

The dietary questionnaire used in both the preliminary survey and final survey was designed based on the instrument used in What We Eat in America 2015-2016 (U.S. Department of Agriculture [USDA], 2015). Our adopted dietary questionnaire has also been validated in a previous study (Zhou et al., 2020). Rice consumption behavior is investigated through the measurement of the amount consumed per serving (i.e. serving size is not necessarily the same across individual), number of servings consumed each day during the last two days of survey, weekly average servings consumed, type of rice consumed and cooking methods. Daily intake rate is calculated separately from two-day average and from weekly average. An adjusted daily intake rate is estimated by taking the mean of the two intake rates.

As described in section 1.3, our questions were designed based on HBM constructs to identify determinants of rice consumption and change in consumption behavior. A seven-level Likert scale format is used that subjects choose from strongly disagree to strongly agree. Questions (called as "items" in HBM) are consistent to the concept of HBM constructs and also specific to the risk perceptions and health beliefs associated with the consumption of each staple food in our study. 20 items were initially drafted and reviewed by an advisory board, consisting of both HBM specialists and actually consumers of the three staple food. Items related to the benefits and barriers of changing consumption behavior were modified according to suggestions from the advisory board. The final version retains 16 items, representing the five core HBM constructs (4 for perceived risk, 2 for perceived benefits, 4 for perceived barriers, 3 for cues to action and 3 for self-efficacy). Items are examined for construct validity, reliability and predictive validity.

Construct validity is tested using exploratory factor analysis to determine the structure of interrelations between items (Nunnally 1994). A principal component analysis (PCA) method is used to identify factors with eigenvalue greater than 1. Items are expected to be factored into five independent scales, correspond to the five constructs. Varimax rotation is used to organize the component matrix. The relationship between item and factor is identified if the loading of the item is greater than 0.4 on the factor and lower than 0.4 for all other factors (Wardle et al., 2003).

Reliability is tested for items retained with enough construct validity from two aspects: internal consistency and test-retest reliability. Internal consistency of items in one factor, or in other words associated with one construct, is confirmed if the Cronbach's alpha value is greater than 0.6. Score of individual scale is calculated as the sum of scores of items under the scale. Test-retest reliability is calculated as the correlation of scales between the preliminary test and the final test, using data only from the control group as changes of scales are expected caused by our intervention in the treatment group. Predictive validity was examined on how good the scales predict the outcome variables, i.e. reduction in consumption in this study using multiple regression.

Both dietary and psychometrical questionnaire can be found in the supplementary material.

3.4 Intervention Material

Successful risk communication requires the dissemination of accurate risk information to the target audience in a comprehensible way. The risk-communication based intervention is to deliver general information pertaining to the risk of iAs exposure through rice intake. Emphases are made on the following facts regarding risk perception according to HBM: 1) chronic exposure to iAs, even at low dose, can cause severe adverse health effects, 2) rice consumption is the biggest source of dietary exposure to iAs and 3) rice consumers are indeed under greater risks of lung and bladder cancers. The three statements reflect the two critical components of risk perception, susceptibility and seriousness, of iAs exposure in rice consumers. Facts are based on data from peer-reviewed journal articles and other credible sources such as U.S. FDA (2016) and Dartmouth Toxic Metals Superfund Research Program (2017). Language of eighth grade is used to ensure comprehensibility. Given our target audience of college population (mostly students), information was eventually organized into an online presentation on Qualtrics, which can be accessed by individual at any time during the intervention stage through a personal link. Progress and completion of the presentation is recorded by Qualtrics automatically. Script of the presentation is available in the supplementary material.

3.5 Models for Intervention Evaluation

The impact of our intervention on rice consumption and risk perception is evaluated using a two-stage casual linear model. The average Treatment on the Treated (TOT), or in other term the impact of receiving the intervention is represented by a Wald estimator as equation 1:

$$TOT = \frac{ITT}{Compliance\ Rate} \qquad \text{eq.1}$$

Where $Intent\ to\ Treat\ (ITT) = E(Y|Z=1) - E(Y|Z=0)$, compliance rate= $E(T|Z=1) - E(T|Z=0)$. Since intervention material can only be accessed through a personal link by subjects in the treatment group, no subject in the control group could access the intervention that E(T|Z=0)=0. Therefore, compliance rate can be simplified as $E(T|Z=1)$= 1-28%= 72%. The equation of TOT can be written as TOT= ITT / 0.72.

The analysis of rice consumption focuses on comparing the differences in the daily consumption rate post intervention between the treatment and control groups. Assuming a successful randomization, all observable and non-observable characteristics and events are matched between the two groups that difference in average rice consumption rate between groups is the impact of the intervention. Specifically, the model with covariates is estimated as equation 2 (ITT):

$$Y_i(IR) = \alpha_0 + \alpha_1 * Z_i + \alpha_2 * X_i + \varepsilon \qquad \text{eq.2}$$

Where IR means post rice intake rate, X are covariates for rice consumption including pre rice intake rate and other socio-demographic variable. Pre intake rate is added as candidate covariate so that each subject serves as its own control to account for within-subject variation.

The analysis of risk perception focuses on comparing the differences in the scores of each of the five scales post intervention between the treatment and control groups. Holding the same assumption of randomization, difference in average score between groups is the impact of the intervention. I estimated this model with a different set of candidate covariates as equation 3 (ITT):

$$Y_i(scale) = \alpha_0 + \alpha_1 * Z_i + \alpha_2 * X_i' + \varepsilon \qquad eq. 3$$

Where scale refers to each of the five scales that a total of five submodel of Y (scale) were tested. X' are covariates for scales that pre rice intake is no longer included. Instead, the score of corresponding scale before intervention is used for the same purpose as in equation 2 to control for within-subject variation. For example, the submodel of Y(risk perception) has the pre score of risk perception as candidate covariate.

3.6 Statistical Analysis

The principal component analysis was performed using SPSS (IBM Corp. 2017). Cronbach's alpha, reliability correlation, multiple regression and ordinary least square regression were performed using R (R core team, 2013). Model selection was performed using stepwise comparison in R.

4. Results

4.1 Characteristics of College Rice Consumers and Risk Estimation

Table 1 Characteristics of Subjects by Groups

Demographic variables	Total (n=136)	Treatment (n=67)	Control (n=69)	Difference p value[1]
gender (male =1, female =2)	Male n=52 (39%), female n=82 (61%)	1.606[2]	1.618	0.8916
age	23.5 (0.354)[3]	24.1 (0.531)	22.9 (0.464)	0.1022
height (cm)	170.9 (0.861)[3]	170.2 (1.294)	171.4 (1.145)	0.4844
weight (kg)	68.1 (1.361)[3]	66.7 (1.649)	69.5 (2.151)	0.3052
race (1=white, 2=black, 3=asian, 4=hispanic, 5=other)	White n=69 (51%), black n=9 (7%), asian n=47 (35%), hispanic n=8 (6%), other n=3 (2%)	2.104 (0.148)[3]	1.942 (0.129)	0.4083
US Born (0=no, 1=yes)	Born in US n=104 (76%), Not in US n=30 (24%)	0.742[2]	0.809	0.3612

marriage (0=single, 1=in relationship/ married)	Single n= 110 (81%), in relationship/ married n=25 (19%)	0.179[2]	0.191	0.858
Employment(0=unemployed, 1=employed)	Employed n=77 (n=57%), unemployed n=54 (43%)	0.548[2]	0.623	0.3898
tobacco (0=no, 1=yes)	Nonsmoker n=129 (95%), smoker n=7 (5%)	0.089[2]	0.014	0.0515
alcohol (0=no, 1= yes)	Consumer n=91 (67%), non-consumer n=41 (33%)	0.769[2]	0.612	0.051
Daily Rice intake (g/ D)	139.0 (9.6)[3]	151.4 (15.7)	126.7 (11.1)	0.2019
Daily Wheat intake (g/ D)	226.9 (17.9)[3]	251.7 (32.8)	203.1 (15.1)	0.1919
Daily Potato intake (g/ D)	98.7 (7.5)[3]	97.4 (11.0)	100.0 (10.4)	0.8778

[1] independent two sample t test between treatment and control at 95% confidence level. [2] variables of gender, US Born, marriage, employment, tobacco and alcohol are coded in binary status that group specific values can be interpreted as the percentage of responses with Yes (female for gender). [3] mean (standard error)

Characteristics of subjects are displayed in table 1 combined and by groups. As expected, our sample population of rice consumers can be profiled as young (age $\bar{x}$ = 23.5), mostly domestic, non-smoking college students ($\bar{x}$ = 76%). More female rice consumers ($\bar{x}$ =61%) were recruited than males. Individuals of Asian ethnicity take a large proportion of our sample (35%, relative to 5.6% of national population), consistent with the fact that the Asian American population has higher rice intake (Mantha et al. 2017; U.S. FDA, 2016). The average daily intake rate of in our sample is 139 g/D (about one and half serving/D). Assuming this dietary behavior to be maintained throughout lifetime, more than 200 cases of lung and bladder cancers per million population would be expected which is five times higher than the general population.

No significant difference is found between treatment and control groups in any of the observed variables as shown in the last column of table 1. Notably, the treatment group has a larger mean and a larger standard error of daily rice intake than the control group. This larger within-group variance in the treatment group does not invalidate our assumption of randomization. However, it does support our inclusion of pre intervention intake as candidate covariate in the ITT model of intake rate (X in equation 1).

4.2 Psychometrical Measurements of HBM Constructs

Table 2 Validation of Psychometrical Instrument[2]

Rotated Component Matrix (n=136)					
Component Loading [1]					Question
BAR	EFF	CTA	RISK	BEN	
0.845					*Compared with other staple food, rice are: - Easy to purchase*
0.796					*Compared with other staple food, rice are: - Affordable*
0.737					*Compared with other staple food, rice are: - Easy to prepare*
0.581					*Compared with other staple food, rice are: - Delicious*
	0.788				*I can completely decide the amount of staple food I want to eat*
	0.775				*I can completely decide the way in which my staple food is prepared.*
	0.775				*I can completely decide what kind of staple food I want to eat*
	0.417		0.405	0.312	*I am vulnerable to long-term low-level inorganic arsenic exposure because of my diet.*
		0.819			*I would try to reduce rice consumption if recommended by family members or friends*
		0.794			*I would try to reduce rice consumption if I read information on the mass media*
		0.763			*I would try to reduce rice consumption if recommended by a doctor*
			0.809		*Long-term exposure to low-level inorganic arsenic will put a heavy burden on my life*
			0.755		*Long-term exposure to low-level inorganic arsenic can cause various diseases including cancer*
			0.711		*I am worried a lot about my long-term exposure to low-level inorganic arsenic.*
				0.944	*Rice consumption is an important source of long-term exposure to inorganic arsenic.*
				0.939	*Reducing rice consumption can help to reduce the long-term exposure to inorganic arsenic.*
BAR	EFF	CTA	RISK	BEN	
Variance Explained (n=136)					
3.245	2.585	1.791	1.564	1.459	Eigenvalues
20.3	36.4	47.6	57.4	66.5	Cumulative percentage of total variance explained (%)
Internal Consistency (n=136)					
0.735	0.74	0.737	0.682	0.853	Cronbach’s alpha
Test-retest Reliability					
0.42***	0.51***	0.56***	0.64***	0.42***	Pearson’s r

[1] BAR= perceived barriers, EFF= self-efficacy, CTA= cues to action, RISK= perceived risk/ risk perception, BEN= perceived benefits [2] ‘ $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$.

The construct validity was confirmed by the results of exploratory factor analysis. Results of principal component analysis (PCA) and Varimax rotation are shown in the top half of table 2. With good construct validity, items should represent the construct as specified theoretically (Champion 1984). Factors with eigenvalue greater than 1 were extracted. Since number of extracted factors equal to number of constructs, we consider all five scales for HBM constructs are successfully identified. As explained in section 1.6, a criteria of 0.4 is used to judge item-factor loading. Loadings of all items pass the criteria except that one item “*I am vulnerable to long-term low-level inorganic arsenic exposure because of my diet.*” has its loading spread across perceived risks, self-efficacy and perceived benefits (> 0.4), which should be related exclusively to perceived risks. This item was dropped in the following analysis of reliability, predictivity and intervention evaluation. Eigenvalues are total variance that can be explained by the individual component. The first extracted factor always has largest eigenvalues, i.e. the most variance explained. Factors are extracted and order by eigenvalues. Cumulative percentages of variance explained are provided for illustration in table 2. A cumulative of 66.5% variance explained by the five extracted factors demonstrated that our scales are sufficiently good for psychometric measurements (Champion 1993).

Our instruments were demonstrated to be reliable. Internal consistency is tested using pre intervention scale data and found to be good for all five scales (>0.7) (Champion 1993) as shown in the lower half of table 2. Alpha value of perceived risks is marginally lower than others due to the drop of the item mentioned in the last paragraph. The examination of test-retest reliability is conducted by calculating the correlation of scales before and after intervention in the control group only. Lowest correlations (0.42) were found in scales of perceived barriers and perceived benefits, which are acceptable. All correlations are significant at 0.001 level.

Values of post-intervention scales are summarized at the bottom of table 2. Since a seven-level Likert design was used, the range of each scale equals (k, 7k), with k being number of items included in the scale. All scores are towards the positive (agree) side. Mean of perceived barriers are close to the maximum, which indicates that considerably barriers of financial, social and psychological are perceived by subjects to prevent them from taking actions.

Table 3 Predictive Validity of HBM Scales on Rice Consumption Behavior[3]

	Descriptive Statistics		Regression Coefficient	
Scale	Mean±SD	Range	Change of rice IR(g/D) [1]	Controlling for Wheat

				and Potato [2]
self-efficacy	16.2±3.7	3-21	3.45(3.36)	6.88 (4.15)
cues to action	13.3±3.9	3-21	-3.40(3.41)	-1.49 (3.97)
Perceived barriers	24.1±3.4	4-28	3.81(3.69)	-1.14 (4.89)
Perceived benefits	9.3±2.8	2-14	-4.88(5.71)	-5.35 (6.76)
Perceived risks	12.0±3.0	3-21	8.77(5.12)*	10.68 (5.88)'
Adjusted R squared			3.3%	6.4%

[1] Post rice daily intake rate – pre rice daily intake rate. [2] add changes of intake rate in wheat and potato as candidate covariates [3] ' p < .1, * p < .05, ** p < .01, *** p < .001.

Table 3 shows the summary statistics of post-intervention scales in the left panel. Mean score of self-efficacy is more than median (of the range), indicating that the subjects believe their level of control over behavioral change are good on average. Mean of cues to action is slightly greater than median, which reflects that cues from other sources (family, friends and doctor) can slightly encourage subjects to take actions. High mean scores of perceived barriers show that considerable barriers of financial, social and psychological are perceived by subjects. The more than median value of perceived benefits demonstrate that the risk mitigation benefit of reducing rice consumption was slightly acknowledged by subjects. Finally, mean score of perceived risks is neutral, indicating that health risks associated with iAs exposure via rice intake were not well realized on average. The scales' predictive abilities are judged by its of prediction on the change in rice intake by scales. Since no randomization of subjects were considered in this step, coefficients in the right panel of table 3 demonstrate only correlations. The first model use a linear combination of scales to predict change in rice intake rate, which is calculated as the difference before and after intervention. Positive value of change indicates reduction. Perceived risks is the only factor of significant correlation with behavioral change. Perceived risks are positively associated with reduction in rice intake (beta= 8.77, p<0.05) that individuals with higher levels of risk perception have larger degree of reduction in consumption. A second model with change in wheat and potato consumption included as candidate covariates was compared with the previous model. Perceived risk remains the single significant predictor of change in rice intake. However, predictors in the second model have a larger percentage of variances explained from 3.3% to 6%.

4.3 Results of Intervention on Behavior and Perception

Given the experimental setting of this study, the differences in average values of outcomes between the treatment and control group are caused by the intervention. Two outcomes variables, rice intake rate and five HBM scales after intervention, are modelled using following equation 2 and 3 respectively. Final models are presented with only selected covariates in table 4 and 5.

Table 4 Estimates of Final Model for Intervention Impact on HBM Scales[1]

Variable	Scale				
	Perceived Risks	Perceived Benefits	Perceived Barriers	Cues to Action	Self-Efficacy
Receiving our risk communication intervention	0.91 (0.45)*	2.31 (0.42)***	0.54 (0.53)	0.94 (0.61)	0.88 (0.54)
Corresponding pre-intervention scale	0.42 (0.06)***	0.33 (0.08)***	0.40 (0.08) ***	0.50 (0.08)***	0.57 (0.08)***
Gender	0.63 (0.46)'	0.91 (0.43) *	-0.42 (0.55)	0.76 (0.62)	-0.18 (0.55)

[1] ‘ p < .1, * p < .05, ** p < .01, *** p < .001.

Each scale is fitted by its own submodel, with its corresponding pre-intervention scale value included in the candidate covariates. Results of the five submodels were summarized in table 4. Interestingly, gender is included as covariate along with corresponding pre-intervention scale in each submodel. Receiving our risk communication intervention caused positive changes in perceived risks and benefits. After watching our presentation, subjects were better acknowledged on the health risks associated with iAs exposure via rice intake that they gained a better perception on the their susceptibility to iAs exposure because of their rice diet and the seriousness (adverse health effects) of iAs exposure. Subjects also realized that reducing rice consumption is one beneficial strategy that can mitigate the risks. Given that our intervention material was designed to exclusively target the perceived risks, we propose several possible explanations for the unanticipated change in perceived benefits. First, some contents in our risk communication material could directly convince rice consumers the benefits of reducing rice consumption, although the “side effect” of these contents was not originally planned. Second, it is possible that our items for perceived benefits actually explain some variances in perceived risks that factors of RISK and BEN are not exclusive to each other. Another possibility would be raise in risk perception regarding iAs exposure in rice consumers can indirectly cause an increase in the perceived benefits of preventatively reducing rice consumption, which is supported by similar findings from previous studies on the interrelationship between perceived benefits and perceived susceptibility of risky sexual behavior (Joseph et al., 2009; Champion & Skinner, 2008).

Table 5 Estimates of Final Model for Intervention Impact on Rice Consumption[1]

Variable	Daily Rice Intake Rate (g/day)
Receiving our risk communication intervention	0.16 (22.78)
Daily rice intake before intervention (g/day)	0.46 (0.10)***
Race (ref= White)	
Black	39.07 (46.63)
Asian	61.46 (30.67)**
Hispanic (Mexican and other)	12.26 (52.68)
Other (Native, Pacific Islander and etc.)	62.08 (73.02)
Born in the U.S.	7.78 (32.64)

[1] ‘ $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Receiving our intervention does not cause significant change of rice consumption in our subjects of college rice consumers. The validity, reliability and predictive validity of perceived risk as a predictor on change in rice consumption have been established in section 4.2. Rice consumers also had increased perception of risks as the consequence of our intervention. We believe that the change in the variance of rice consumption from the change of risk perception could be insufficient to modify rice consumption, as risk perception is only one of the determinants of consumption behavior. For example, the five HBM scales explain a small variance in the consumption behavior as shown in table 3. Meanwhile, perceived barriers of reducing rice consumption (financial, social and psychological) seem to critical in behavioral change as indicated by high mean score of perceived barriers. Consequently, changes in risk perception regarding iAs exposure via rice intake caused by our risk communication intervention was not powerful enough to initiate reduction in rice consumption. Moreover, one noteworthy result is the regression coefficient on the fixed effect of “being Asian”. After controlling for other variables, Asian Americans have greater daily rice consumption rates, which makes them the subpopulation of priority for risk assessment and mitigation.

5. Discussion

This study, to the best of our knowledge, is the first to advance the knowledge of the feasibility and effectiveness of risk communication intervention in mitigating the risk of iAs exposure via rice intake. The role of risk perception in the change of rice consumption behavior is highlighted in our findings of psychometrical measurements. Furthermore, results of randomized controlled trials indicate that risk communication can effectively raise the susceptibility and seriousness of iAs exposure. Although the impact of our intervention on short-term rice consumption behavior was not significant, our data provide plausible hypothesis for the gap between improvements in risk perception and initiation of behavioral changes. This study has shortcomings in demonstrating direct behavioral change due to limited sample size. The number of participants enrolled in our study was limited by the population of IUB campus, which can be addressed by expanding the scope of data collection. Sufficient sample size can enhance the significance of our study by enabling more complex study designs as well. As demonstrated by previous risk assessment studies and our data, Asian American population is indeed at much greater risks. Future psychological and intervention studies can be tailored to address the Asian American population as major target audience. Longitudinal studies with more samples would also contribute to the knowledge of long-term behavioral change, given the nature of chronic exposure to iAs via rice intake. Our intervention program has potential to be improved based on the results of HBM measurements. Risk perception, perceived barriers and other determinants can be better expressed and emphasized by combining risk communication theory, Health Belief Model and other health education theories.

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