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EXPLORING THE IMPACT OF KNOWLEDGE AND SOCIAL ENVIRONMENT ON INFLUENZA PREVENTION AND TRANSMISSION IN MIDWESTERN UNITED STATES HIGH SCHOOL STUDENTS

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ABSTRACT

We used data from a convenience sample of 410 Midwestern United States students from six secondary schools to develop parsimonious models for explaining and predicting precautions and illness related to influenza. Scores for knowledge and perceptions were obtained using two-parameter Item Response Theory (IRT) models. Relationships between outcome variables and predictors were verified using Pearson and Spearman correlations, and nested [student within school] fixed effects multinomial logistic regression models were specified from these using Akaike's Information Criterion (AIC). Neural network models were then formulated as classifiers using 10-fold cross validation to predict precautions and illness. Perceived barriers against taking precautions lowered compliance with the CDC recommended preventative practices of vaccination, hand washing quality, and respiratory etiquette. Perceived complications from influenza illness improved social distancing. Knowledge of the influenza illness was a significant predictor for hand washing frequency and respiratory etiquette. Ethnicity and gender had varying effects on precautions and illness severity, as did school-level effects: enrollment size, proficiency on the state's biology end-of-course examination, and use of free or reduced lunch. Neural networks were able to predict illness, hand hygiene, and respiratory etiquette with moderate success. Models presented may prove useful for future development of strategies aimed at mitigation of influenza in high school youths. As more data becomes available, health professionals and educators will have the opportunity to test and refine these models.

Keywords: Health behavior, influenza, health belief model, mitigation, item response theory, neural network, prediction, classifier training

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INTRODUCTION

Influenza is a highly transmissible virus which infects 10-20% of people worldwide and about 10% of school children each year (Principi *et al*, 2003). Influenza costs the United States over $80 billion annually (Molinari *et al*, 2007) due to increased absenteeism from school and work, medical visits, need for extra care for ill children (Principi *et al*, 2003), and over 30,000 deaths and 100,000 hospitalizations (Dushoff *et al*, 2006; Harper *et al*, 2005; Thompson *et al*, 2004).

In schools, absences and closures caused by influenza pandemics can lead to a multitude of problems, including missed time on task and exclusion of students from benefits such as free or reduced lunch and adult supervision while parents are at work, which can lead to hunger, delinquency, and missed income for parents who stay home to supervise children (Cauchemez *et al*, 2009). Hence, schools must be proactive in taking measures to mitigate influenza infections and their burden upon education. In lieu of socially disruptive precautions such as intense screening, quarantine and closure, schools are encouraged to address the problem at its root—to understand factors that motivate students to comply with accepted best practices for influenza mitigation (Inglesby *et al*, 2006; Wensing, Van der Weijden and Grol, 1998). Of the best practices, vaccination is by far the most important. Other practices which cause minimal social impact include respiratory etiquette (covering the mouth with the shirt sleeve instead of the hands), proper hand washing, keeping hands away from the eyes, nose and mouth, self quarantine (staying home when sick), and keeping a distance of 3-6 feet from infected individuals (Inglesby *et al*, 2006; CDC, 2009).

Since a major goal of interventions is to impart knowledge in such a way that it will lead to behavioral change (Wensing, Van der Weijden and Grol, 1998), an important question arises - does understanding of influenza relate to responsible behavior or are interventions aimed at imparting knowledge a waste of time and money? What aspects of influenza must be understood to facilitate a particular desired behavior, and what is the relative importance of knowledge of the disease compared to other factors such as gender, previous negative experiences with the disease, and perceived susceptibility? Answers to these questions are essential to the development of efficient, effective, well-targeted interventions, but as of now, they remain unanswered.

Research Questions

The objectives of this study were to: (1) explore the effect of a number of student-level and school-level predictors on experienced illness and compliance level with preventative practice, (2) find the combination of predictors which best model each outcome, and (3) test the efficacy of the models for prediction. In light of these objectives, the following questions were addressed:

1. How do the following factors: (1) knowledge of the influenza virus and the illness it causes, (2) perceptions of risk and complications from influenza illness, (3) perceived barriers against taking preventative measures against spread of infection by influenza virus, (4) past experience of illness, and (5) demographic factors, relate to compliance with the following mitigation practices: (1) vaccination, (2) proper hand sanitation, (3) self quarantine, (4) social distancing, (5) refraining from touching the eyes, nose, and mouth, and (6) respiratory etiquette?
2. Which variables best model the behavior outcomes of vaccination, proper hand sanitation, self quarantine, social distancing, refraining from touching the eyes, nose, and mouth, and respiratory etiquette?
3. How well do these variables predict reported behavior outcomes?

REVIEW OF LITERATURE

Noncompliance with health advice is an age old problem. We describe theHealth Belief Model and Protection Motivation Theory, two behavior theories which have been developed to explain health-related decisions. We then describe how knowledge and culture influence these decisions in light of current studies.

The Health Belief Model and Protection Motivation Theory

The Health Belief Model (Rosenstock, 1966, 1974; Janz and Becker, 1984) contains six independent factors influencing a person's likelihood of being proactive about their health and complying with medical advice (Becker and Maiman, 1975): (1) perceived susceptibility to a disease; (2) perceived seriousness of the disease; (3) perceived benefits of taking preventative action; (4) perceived barriers to preventative action; (5) strength of external forces promoting the behavior (e.g. family, peer, and media pressure); and (6) self efficacy of the individual. While it is difficult to quantify the inter-relations between these variables (Rosenstock, 1966), the Health Belief Model has been one of the most widely used models for understanding health decisions (Janz and Becker, 1984), providing a useful framework for exploring prevention practices and what motivates people to undertake them in this study.

Protection Motivation Theory (Rogers, 1975) describes how people respond to fear, simplifying the Health Belief Model by eliminating the variables of social pressure and perceived benefits, leaving three components: (1) perceived severity of the disease; (2) perceived probability of the disease's occurrence, and (3) the perceived effectiveness of the person's response. The fact that this model was designed under the assumption of fear limits it to analysis of responses to emergency situations such as pandemics where genuine fear exists. Studies have explored the effects that knowledge of influenza, perceptions about influenza, and sociocultural variables, have on individual mitigation efforts. This leads us to better understanding of the possibilities for modeling compliance.

The Flu Vaccination

The relationship between knowledge and perceptions of the influenza vaccine and decision to vaccinate has been of particular interest in medical research. Martinello, Jones and Topal (2003) explored the link between misconceptions and likelihood of getting the influenza vaccination through a cross-sectional study of doctors and nurses at a large urban teaching hospital. The knowledge instrument, "Survey Regarding General Knowledge of Influenza," asked health care workers five questions regarding knowledge of the risk of influenza to themselves and their patients, and the efficacy of the vaccine. They found a significant increase in vaccination rate in response to knowledge among nurses, but no significant difference among doctors. Reasons for declining the vaccination among nursing staff included concerns over catching the flu from the vaccine, pregnancy or breast feeding, aversion to needles, that the vaccine does not work, and that influenza does not pose a significant health risk. Reasons reported by doctors were either informed, including ready availability of neuraminidase inhibitor medications, or not information-based, including inconvenience and forgetfulness.

Relationships between risk perception and vaccination were assessed by Weinstein *et al* (2007) in a study of students, faculty, and staff at three universities. Variables studied included risk magnitude, beliefs about risk, and feelings about risk, as well as socio-demographic variables. Through logistic regression analysis, they found anticipated regret about not getting the flu shot, the female gender, and feeling at risk of the flu to be significant positive predictors, and the belief that the vaccine causes influenza illness to be a significant negative predictor. A positive relationship between perceived risk and compliance with vaccination was also found by Kiviniemi *et al* (2011) in a telephone survey of adults in the state of New York.

Relationships between ethnicity and decision to vaccinate have also been explored. Chen *et al* (2006) conducted a telephone survey of adults in Los Angeles and Honolulu assessing the effect of ethnicity on attitudes towards vaccination, perceived susceptibility to, and severity of influenza. Adult participants from 76 church parishes were asked questions regarding their race and socio-economic status, medical conditions, perceived susceptibility and severity of influenza, whether or not they got vaccinated in the past year, and if not, what barriers prevented them. Perceived risk of getting the influenza illness was a strong predictor for vaccination among Whites and African Americans, and a moderate predictor for Hispanics. Vaccination rates of Whites and Japanese Americans were significantly higher than African Americans, Hispanics, and Filipino Americans (Chen *et al*, 2006). The negative impact of minority status on vaccination was also reported by Lindley *et al* (2006) in a comparative study between African American and White Medicare beneficiaries in five US states. Economic barriers such as low income and lack of health insurance (Chen *et al*, 2006), and more persistent negative attitudes (Lindley *et al*, 2006) were shown to deter vaccination in minority populations.

Joshi *et al* (2009) designed a vaccination knowledge instrument called the "Knowledge, Attitudes, and Practice" (KAP) questionnaire in order to assess the impact of a computer-based vaccination intervention called "the Patient Education Motivation Tool" (PEMT) which targeted parents of children aged six months to five years. Six questions addressed knowledge of the vaccine; nine addressed perceptions related to the vaccine's usefulness, safety, pain, and side effects. Practice was assessed with a single question asking parents whether or not they will get their child vaccinated this year. Significantly increased knowledge, attitude, and practice were documented outcomes of the PEMT. Explorations of correlations between knowledge, attitude, and practice were not within the scope of this study. However, the positive impact of knowledge of vaccination and perceived complications from the flu on intent to vaccinate was documented in a study of nurses in Switzerland (Falomir-Pichastor, Toscani, and Despointes, 2009).

Hand Hygiene

The relationship between knowledge and hand washing is similar to that documented for vaccination. In a knowledge-based intervention to improve hand washing, where posters describing nosocomial infection, cross transmission, hand carriage and hygiene, and disinfection with creams were posted in a hospital (Pittet *et al*, 2000), compliance improved among nursing staff, but not among doctors. Reported barriers against hand washing included skin irritation, the belief that hand washing supplies are inaccessible, wearing gloves, "being too busy," and "not thinking about it" (Pittet *et al*, 2000; Kretzer and Larson, 1998). As with vaccination, doctors' reasons for noncompliance with hand washing were not based on information deficit, and so knowledge-based intervention strategies were less likely to work. Increased perceptions of risk to patients were positively correlated with hand washing in health care professionals working in higher stakes environments, such as intensive care and surgical units, where procedures carry a high risk of bacterial contamination (Pittet *et al*, 2000; Harbarth *et al*, 2001).

Cross-culturally, main ideas about disgust and the importance of hygiene are found to be relatively consistent (Curtis and Biran, 2001). However, religion has been established as a cause for cross-cultural differences in reasons for washing hands, and attitudes towards hand washing (Allegranzi *et al*, 2009). Specifically, Asian religions such as sects of Buddism, Sikhism, and Islam, strictly forbid proximity to alcohol, potentially reducing compliance with use of alcohol-based hand sanitizers. Additionally, some sects of Jainism and Buddhism forbid the killing of any entity perceived as having life force, including bacteria and viruses, which may present a significant barrier to hand washing regimens of any form (Allegranzi *et al*, 2009).

Other Precautions

Studies exploring the impact of factors such as knowledge, perceptions, and socio-demographics on precautions outside of hand washing and vaccination are relatively few. A recent telephone survey study of adults in New York State explored motivations for a number of precautions (Kiviniemi *et al*, 2011). Through logistic regression analysis, age was found as a positive predictor for social distancing and not touching the eyes, nose, and mouth; working outside the home was a positive predictor for hand washing. Perceived efficacy of the precaution was a positive predictor for all precautions, and perceived severity of influenza was found to be a positive predictor for hand sanitizer use, social distancing, and vaccination. Knowledge was not considered in this study.

The Need for Additional Study

Literature addressing the role of knowledge, perceptions, and socio-demographic factors in the prevention of influenza illness has seen much growth over the past decade, opening up a multitude of questions. Studies addressing motivations for hand washing and vaccination for adults and workers in the medical community open up questions on how these apply to students. Motivations behind other important precautions, including social distancing, staying home when sick, respiratory etiquette, and keeping the hands away from the face, also need further exploration. Formulation of parsimonious toolboxes for understanding and predicting preventative practice and contraction of illness in a single diverse sample of high school students may prove useful for educators and health professionals seeking to develop intervention strategies aimed at reducing the impact of influenza in high schools.

METHODS

Subjects

Schools participating in a summer student and teacher enrichment program called, “Maps in Medicine” were solicited for inclusion in this study. Instruments were given to a convenience sample of 410 students enrolled in grades 9-12 from six school districts. Three large, urban schools were sampled, with 29, 186, and 25 participants, respectively; one small, rural school was sampled for a total of 16 participants; one hundred students from a medium-sized school, and 54 students from a large, suburban school also participated. Science teachers administered the assessments during the spring semester of 2011. All procedures were reviewed and approved by our university’s Institutional Review Board (IRB).

Instrumentation

Three instruments were utilized for data collection. The Assessment of Understanding of Influenza (AUI), consisting of 13 dichotomously-scored items (Romine, Barrow and Folk, 2012; Romine, 2011), was used to measure knowledge of influenza transmission (6 items; α = 0.701; marginal reliability = 0.675) and management (7 items; α = 0.755; marginal reliability = 0.680). The 10-item Survey of Background, Experience, and Risk (SOBER) (Romine, 2011) asked students to choose the statement they most agree with on a 1 to 5 scale regarding perceived risk from influenza (2 items; α = 0.640; marginal reliability = 0.677), complications from influenza (3 items; α = 0.677; marginal reliability = 0.783), and barriers against prevention (5 items; α = 0.629; marginal reliability = 0.616). The SOBER also included questions about students' backgrounds including age, grade, gender, ethnicity, number of health professionals in the family, and experience with illness during the 2010-2011 school year (Romine, 2011).

The 8-item Influenza Mitigation Behavior Survey (IMBS) included a list of questions asking students to rate their compliance with eight influenza mitigation behaviors: vaccination, hand washing quality and frequency, personal distancing, not touching the eyes, nose, and mouth, respiratory etiquette, staying home when sick, and hand sanitizer use (Romine, 2011). Level of compliance was scored 1-5 depending on the statement a student chose which they felt best described their practice with the influenza vaccination, hand hygiene, social distancing, respiratory etiquette, and not touching the face.

Data Analysis

Variables in the models. Efficacy of a variety of potential predictors in modeling compliance level was explored. These included: (1) demographic variables (gender, ethnicity, age, and grade), (2) experiences (illness experienced in 2010 and presence of health professionals in the student's family), (3) knowledge of influenza (transmission and management), (4) perceptions of influenza (risk, complications, and barriers to preventative practice), and (5) school-level effects, including number of students enrolled in Grades 9-12 (a measure of school size), percent of students on free or reduced lunch (a measure of socio-economic status of the student body), and percent of students scoring "proficient" on the state's Biology end-of-course examination (a measure of the school's science fluency).

The outcome variables of compliance level were coded ordinally (1-5). Ordinally coded predictors included grade (9-12), age (15-19), sickness severity (none = 0, cold = 1, flu = 2), and number of health professionals in the student's family (0-4). Nominal dummy coding was used for gender and ethnicity (Black, White, Asian, Hispanic and Other), and logit measures were used for influenza knowledge and perceptions. Actual values for school-level effects were used in the models.

Item scoring and correlation tests. The 2-parameter logistic model (2PL) was used to calculate scores in logits (log-odds units ± standard error) for factors on the dichotomous AUI; the 2-parameter generalized graded response model (Samejima, 1969, 1972) was used to calculate logit measures and their standard errors on the polytomous SOBER. Logit measures are normalized to 0, with a standard deviation of 1. Both models were implemented using Marginal Maximum Likelihood Estimation (MMLE) in MULTILOG 7.03 and assumed measurement invariance across groups. 2PL models were chosen because we were seeking accurate parameters through data-driven model fitting (Lord and Novick, 1968).

Pearson's r and Spearman's ρ correlations were used to test the null hypothesis of no relationship between predictor and outcome variables. Pearson's r is a test of linear association, and will be high if the relationship between the outcome and predictor variable is linear. Spearman's ρ is a test of monotonicity; a high ρ value does not necessarily imply linearity, but general increase in the value of the outcome variable with the predictor variable. Since both types of relationships were of interest, variables with statistically significant r or ρ values were considered for inclusion in the logistic regression and neural network models.

Finding significant regression models. The purpose of regression modeling was two-fold: first, to develop an informative, parsimonious theory for understanding student illness and motivation for taking precautions against the flu; and second, to test the significance of the elements of the theory. Data were fit with a multinomial logistic regression model taking the form:

$$\ln(\pi_{ij}/\pi_{ik}) = x_i^T b_j, \; j \neq k,$$

where j is the category being tested, k is the baseline category, and b_j is the coefficient for the predictor variable x_i. π_{ij} is the probability of variable x_i being in category j, and π_{ik} is the probability of variable x_i being in the baseline category k. The multinomial model is more complex than the proportional odds model, but is advantageous in that it is not limited by the proportional odds assumption (Brant, 1990).

Student fixed effects were nested within school fixed effects. For models of precautions, student-level effects (experience of illness, grade, gender, number of health professionals in the family, ethnicity, knowledge of flu transmission and management, and perceived risk, complications, and barriers) were nested within school-level effects (total enrollment, percentage of students on free or reduced lunch, and the percentage of students scoring in the proficient range on the state's biology end of course examination). Models for precautions were formulated in reference to the statement of highest compliance (the "5" level) on IMBS items.

In modeling sickness severity, the eight precautions measured by the IMBS were added to the list of potential predictors in order to find their relative importance. The reference of "no reported illness" was used in this model.

Selection bias can be introduced to a regression model by including unnecessary variables or leaving out important ones. Hence, the primary challenge in model specification was deciding which variables to include in the model. In an attempt to avoid selection bias, we first included the variables which were significantly correlated with the outcome variable ($\alpha = 0.05$) through either the Pearson or Spearman correlation test. We then chose the combination of main effects and interactions which minimized Akaike's Information Criterion (AIC). Information criteria such as the AIC have been routinely shown to be superior to other methods, such as stepwise regression, the t-test, and R^2, for proper model specification (Steyerberg *et al*, 1999; George, 2000; Burnham and Anderson, 1998). SPSS 16.0 was used for all regression analyses.

Neural network analysis. Predictors leading to well-specified regression models were used in neural networks to provide predictive models. Artificial feed-forward neural networks can be used in a wide variety of classification problems since they have the capability to learn patterns in noisy data. Some of the applications of neural networks can be found in character recognition, image compression, stock market prediction, loan/mortgage granting as well as machine learning. Once trained, a neural network can provide reasonable solutions for similar inputs, making them able to generalize and tolerate slight deviations from the training data (Kriesel, 2007). While neural networks do not have the explanatory capacity of regression models (i.e. it is much more difficult to ascertain which parameters are more important and which ones don't contribute to the predictions), they have several advantages over regression models in prediction, including allowance for nonlinear decision boundaries, higher tolerance for noisy data, and less tendency toward overfitting. These characteristics make them an especially useful tool for prediction in the social sciences.

Neural networks with gradient descent method were coded in MATLAB's Neural Networks Toolbox (Demuth and Beale, 1998). The input layer consisted of a number of nodes equivalent to the number of variables that were input into the model. Two hidden layers, with 15 nodes in each, were used in all models. Backpropagation through a standard feed-forward neural network sends the difference between the calculated and expected output back through its layers, and the weights in each hidden layer update themselves to minimize the error (Haykin, 1999). In the gradient descent method, the weights were updated using the equation:

$$w(t+1) = w(t) - \eta \frac{\partial(Error)}{\partial w}$$

Here, the weight vector w(t) is expressed as a function of time. For the next iteration t+1, the gradient of the error with respect to the weights is subtracted. The idea is that if the gradient is increasing, we want the weights to reduce so it goes back to the direction of the minima and if the gradient is decreasing, then the direction is correct and we want the weights to keep going towards the optimal solution (Bishop, 2006). A learning rate η was set to 0.7 (Bishop, 2006) and the error was measured by the sum of squared error between the expected values and the values obtained from the neural network. This update was done for 10,000 iterations, which allowed the network to learn, but not memorize, the training set. The hyperbolic tangent activation function normalized to the range [-1, 1] was used for the two hidden layers. This function is preferred since it is differentiable at all values.

Decision boundaries for the output were chosen using the k-means clustering algorithm (Theodoridis and Koutroumbas, 2006) implemented in SPSS 16.0. This clustering technique is based on expectation maximization. This involved beginning with five randomly picked centers and then assigning data points to the nearest cluster center. Once all points were clustered, the mean of each cluster was computed and treated as the new cluster center, and again points were reassigned as before. This process continued until there was no change in the cluster centers.

In order to obtain a realistic prediction scenario which can be generalized to the sample, the 10-fold cross-validation technique was used. In this technique, data were divided into ten portions.

Nine portions were used to train the neural network, which was tested on the tenth portion. Next, another model was built with a different portion of the data and was tested on another portion. This is similar to the work found in Cooper *et al* (2012), where the authors predicted the future scores of college undergraduates in a chemistry class using a neural network and validated the results using a leave-N-out validation. In tenfold cross validation, N is equal to 10% of the data size. After 10 cycles, all of the data were tested outside of the models that produced them. This ensured that overfitting had not occurred (that the neural network had not memorized the noise in the data set), making the models generalizable outside of the test data. This allowed a more realistic classification error than simple resubstitution, which has a tendency to memorize the inputs and perform poorly when exposed to new data. We note, however, that generalization outside of the sample should be done with caution due to the convenience sample design.

Success of a prediction scheme can be measured straightforwardly by comparing the percentage of correct predictions to what one would expect by random chance alone. However, for an ordered outcome variable, there is also value in wrong predictions being close to the actual value. The Kendall-tau B test implemented in SPSS 16.0 provided a measure of concordance between observed and predicted values, considering closeness of predictions to the actual value in its measure. As a measure of practical significance, Cohen's D effect sizes were calculated from Kendall-tau B coefficients using the formulas of Kendall (1970) and Rosenthal (1994). Effect sizes under 0.2 indicate negligible concordance; 0.2-0.49 small concordance; 0.5-0.79 moderate concordance; and 0.8 and above indicate large concordance (Cohen, 1988). Confusion matrices were used to provide qualitative information on how distributions of predictions compare with those of the actual data.

RESULTS

Description of the Sample

Six schools (see table 1) were represented in the study Schools 1 and 5 were located in a medium-sized Midwestern city supporting a public research university with very high research activity (Carnegie Commission on Higher Education, 2010). School 1 had a total enrollment of 1820 students, with 20.5% on free or reduced lunch, and 53.7% scoring "proficient" on the state's biology end-of-course examination in 2010. School 5 had a total enrollment of 1941 students, with 36.3% on free or reduced lunch, and 41.3% scoring "proficient" on the biology end-of course examination in 2010. School 2 had 1648 students from a medium-sized Midwestern city supporting a public baccalaureate university with diverse colleges (Carnegie Commission on Higher Education, 2010). 39.7% of these students were on free or reduced lunch, and 47.0% scored "proficient" on the state's 2010 biology end-of-course examination. School 4 had an enrollment of 1906 students from a medium-sized Midwestern city supporting a primarily baccalaureate public university with multiple master's colleges (Carnegie Commission on Higher Education, 2010). 37.5% of the students at School 4 collected free or reduced lunch, and 52.3% scored at or above proficiency on the biology end-of-course examination. 1292 students in a medium-sized suburb within a Midwestern metropolis were enrolled in School 6, which was located near a private not-for-profit research university with very high research activity (Carnegie Commission on Higher Education, 2010). 14.9% of these students were on free or reduced lunch, and 47.6% scored at or above proficiency on the biology end-of-course examination. School 3, set in a small Midwestern town, had a relatively small enrollment of 223 students. 31.5% of these students were on the free or reduced lunch program, and 25.9% scored at or above proficiency on the biology end-of-course examination.

Descriptive statistics for the sample of high school students participating in this study are shown in Table 1. Four hundred ten students participated; 342 provided fully completed assessments. Of 405 students reporting age, most students were between the ages of 15 and 18. While all grades were represented, just over half were sophomores. Gender was represented nearly equally, with a slight majority of females over males, and a variety of ethnicities were represented, most of whom were White.

Over half of the students reported experience with cold-like symptoms; distribution of flu-like illness and absence of illness was nearly equal for the remainder. About half of the students reported an absence of health professionals in their family. About a quarter reported a single health professional, and the remaining quarter reported two or three health professionals.

Table 1. Measurements of sample size, mean, and standard deviation for demographic variables

Variable	Category	N	M	SD

School	School 1	29		
	School 2	100		
	School 3	16		
	School 4	186		
	School 5	25		
	School 6	54		
	Total	410	NA	NA
Age	15	94		
	16	169		
	17	76		
	18	53		
	19	13		
	Total	405	16.3	1.1
Grade	Freshman	62		
	Sophomore	201		
	Junior	75		
	Senior	58		
	Total	396	2.3	0.9
Gender	Male	169		
	Female	206		
	Total	375	NA	NA
Ethnicity	Black	50		
	White	266		
	Asian	27		
	Hispanic	22		
	Other	24		
	Total	389	NA	NA
Sickness Severity	None	83		
	Cold	213		
	Flu	78		
	Total	374	1.0	0.7
Health Professionals	0	199		
	1	101		
	2	53		
	3	20		
	4	19		
	Total	392	0.9	1.1

Description of Assessment Scores

Scores for the IMBS questionnaire, and the AUI and SOBER instruments, are described in Table 2. On the IMBS, 408 (99.5%) students reported on their favorability towards getting vaccinated (M = 3.3, SD = 1.3). Four hundred nine students (99.8%) reported on touching the eyes, nose, and mouth (M = 2.4, SD = 1.2), respiratory etiquette (M = 4.1, SD = 1.2), and staying home when sick (M = 3.4, SD = 1.1). Four hundred ten (100%) reported on hand washing quality (M = 3.9, SD = 1.0) and frequency (M = 3.2, SD = 1.2), personal distancing (M = 2.9, SD = 1.2), and hand sanitizer use (M = 2.8, SD = 1.6).

Table 2. Means and standard deviations of scores, and number of respondents, for variables measured by the IMBS, AUI, and SOBER assessments

Assessment	Variable	N	M	SD
Influenza Mitigation Behavior Survey				
	Vaccination	408	3.3	1.3
	Hand Washing Quality	410	3.9	1.0
	Hand Washing Frequency	410	3.2	1.2
	Personal Distancing	410	2.9	1.2
	Touching Eyes, Nose, and Mouth	409	2.4	1.2
	Respiratory Etiquette	409	4.1	1.2
	Staying Home When Sick	409	3.4	1.1
	Hand Sanitizer Use	410	2.8	1.6
Assessment of Understanding of Influenza				
	AUI f1 Flu Transmission	410	-0.03	0.79
	AUI f2 Flu Management	410	0.45	0.81
Survey of Background, Experience, and Risk				
	SOBER f1 Perceived Risk	410	-0.13	0.48
	SOBER f2 Perceived Complications	410	-0.11	0.48
	SOBER f3 Perceived Barriers	410	-0.73	0.57

On the AUI, the mean logit knowledge score for flu transmission was -0.03 ± 0.66, with a standard deviation of 0.79. For flu management, the mean score was 0.45 ± 0.64, with a standard deviation of 0.81. On the SOBER, the mean score for perceived risk was -0.13 ± 0.75, with a standard deviation of 0.48. Perceived complications and barriers had means of -0.11 ± 0.67 and -0.73 ± 0.61, with standard deviations of 0.48 and 0.57, respectively.

Correlations and Regression Models

All outcome variables had a statistically significant relationship with one or more predictors (see table 3). These relationships and well-specified multinomial regression models are discussed.

Table 3. Predictor variables which have statistically significant correlations (α = 0.05) to outcome variables.

Outcome	Positive Correlations (r or ρ, α = 0.05)	Negative Correlations (r or ρ, α = 0.05)
Sickness Severity	Vaccination, Staying Home, Female, Health Professionals, Hispanic, Perceived Risk, Perceived Complications, Perceived Barriers	Hand Wsh. Quality, White, Enrollment, %Proficiency Bio
Flu Vaccination	Sickness Severity, Knowledge of Flu Management, Perceived Risk	Perceived Barriers
Hand Wsh. Quality	Female, Enrollment, %Free or Reduced Lunch, %Proficiency Bio	Sickness Severity, Perceived Barriers
Hand Wsh. Frequency	Female, Knowledge of Flu Management, %Free or Reduced Lunch	Perceived Barriers, Enrollment, %Proficiency Bio
Personal Distancing	Perceived Complications	
Not Touching Face	Asian, Other	White, Knowledge of Flu Transmission
Resp. Etiquette	White, Knowledge of Flu Transmission, Knowledge of Flu Management	Grade level, Black, Perceived Complications, Perceived Barriers, %Free or Reduced Lunch
Staying Home	Perceived Complications	
Hand Sanit. Use	Female, Black, %Free or Reduced Lunch	Asian, Knowledge of Flu Transmission, Enrollment

Hand sanitation. Hand washing quality held a positive relationship to being female ($r = 0.123$, $\rho = 0.107$, $n = 375$), school enrollment ($r = 0.136$, $n = 410$), percent of students on free or reduced lunch ($\rho = 0.103$, $n = 410$) and percent proficiency on the biology end-of-course examination ($r = 0.097$, $n = 410$). It held a negative relationship to reported sickness severity in 2010 ($r = -0.125$, $\rho = -0.123$, $n = 374$) and perceived barriers ($r = -0.269$, $\rho = -0.201$, $n = 410$).

The predictors of sickness severity, gender, and perceived barriers against taking precautions minimized the AIC at 641.9 in the model for hand washing quality (see Table 4). The statement, "I wash my hands by making sure they are covered with soap, rubbing them together for 15 to 20 seconds and then rinsing," scored "5," was used as the reference for comparison. One or more predictors had a significant effect on the likelihood of students reporting a lesser hand washing practice, including compliance levels 4 “I wash my hands by making sure they are completely covered with soap and rubbing them together for a few seconds, and then rinsing,” 3 “I wash my hands by soaping them for a second or two and rinsing,” 2 “I wash my hands by rinsing them with water - I normally don’t use soap,” and 1 “I wash my hands by rubbing them on my clothes, or a dry towel or tissue.” Students experiencing higher levels of sickness were significantly more likely to report compliance levels 4 (OR = 1.553) or 2 (OR = 1.932). Perceived barriers showed a similar trend, with significantly lower odds of choosing 3 (OR = 2.021), 2 (OR = 2.551) and 1 (OR = 13.895). Being female significantly decreased the odds of selecting lower levels of compliance, including compliance levels 2 (OR = 0.437) and 1 (OR = 0.238).

Several similar relationships were seen with hand washing frequency. These include being female (r = 0.128, ρ = 0.140, n = 375), perceived barriers (r = -0.181, ρ = -0.161, n = 410), and percent of students on free or reduced lunch (ρ = 0.108, n = 410). School enrollment (ρ = -0.125, n = 410) and percent proficiency on the biology end-of-course examination (ρ = -0.190, n = 410) were negatively correlated with hand washing frequency, and knowledge of flu management (r = 0.194, ρ = 0.157, n = 410) held a positive correlation.

The main effects, gender, knowledge of flu management, and percent proficiency of the student’s school in the biology end-of-course examination minimized the AIC at 520.7. Adding the interaction between knowledge of flu management and score on the biology end-of-course examination further lowered the AIC to 512.9. The statement, “I wash my hands greater than 6 times per day,” scored “5,” was used as the baseline level for comparison in the model for hand washing frequency (Table 4). One or more predictors had a significant effect on the likelihood of students reporting the lesser three compliance levels, including 3 “I wash my hands three or four times per day,” 2 “I wash my hands one or two times per day,” and 1 “I seldom wash my hands.” Similarly to hand washing quality, females were less likely to report lower compliance with hand washing frequency, although none of the odds ratios were statistically significant. Higher knowledge of flu management had a significant negative effect on reporting the compliance levels 3 (OR = 0.020), 2 (OR = 0.001), and 1 (OR = 0.000). The school-level effect of percent proficiency in the biology end-of-course examination caused a slight but significant increase in the probability of choosing compliance levels 3 (OR = 1.028) and 2 (OR = 1.023). The interaction between knowledge of flu management and percent proficiency on the biology end-of-course examination was significant and positive for compliance levels 2 (OR = 1.134) and 1 (OR = 1.225).

Similar to the other hand washing traits, being female was positively correlated with hand sanitizer use (*r* = 0.151, ρ = 0.153, *n* = 375). Other positive relationships included the Black ethnicity (*r* = 0.127, ρ = 0.128, *n* = 410) and percent of students on the free or reduced lunch program (ρ = 0.119, *n* = 410). Being Asian (*r* = -0.115, ρ = -0.110, *n* = 410), knowledge of flu transmission (*r* = -0.152, ρ = -0.152, *n* = 410), and school enrollment (ρ = -0.106, *n* = 410) held negative relationships with hand sanitizer use. In describing hand sanitizer use, the AIC was minimized to 533.6 using the main effects of gender, knowledge of flu transmission, and enrollment of the student's school as predictors. Adding an interaction term between knowledge of flu transmission and school enrollment further lowered the AIC to 532.5. In this model (Table 4), categories were compared to that of highest (5) compliance, "Whenever I walk past a hand sanitizer, I use it." The model shows that females were significantly less likely to choose a compliance level of 1, "I seldom use hand sanitizers" (OR = 0.471). School enrollment had a small but significant positive effect on the likelihood of students reporting the lowest (1) compliance level (OR = 1.001).

Table 4. Multinomial models for hand sanitation

Outcome[a]	Predictor	B (SE)	Wald χ^2	p (1 df)	OR (95% CI)
Hand Washing Quality					
1	Sickness	0.099 (0.740)	0.018	0.894	1.104 (0.259-4.709)
	Female	-1.438 (0.687)	4.378	0.036	0.238 (0.062-0.913)
	PerceivedBarrier	2.632 (0.689)	14.581	0.000	13.895 (3.602-53.648)
2	Sickness	0.658 (0.301)	4.796	0.029	1.932 (1.070-3.483)
	Female	-0.827 (0.284)	8.507	0.004	0.437 (0.251-0.763)
	PerceivedBarrier	0.936 (0.347)	7.291	0.007	2.551 (1.292-5.034)
3	Sickness	0.140 (0.239)	0.342	0.559	1.150 (0.720-1.838)
	Female	-0.112 (0.204)	0.303	0.582	0.894 (0.599-1.334)

	PerceivedBarrier	0.703 (0.287)	5.990	0.014	2.021 (1.151-3.545)
4	Sickness	0.440 (0.196)	5.039	0.025	1.553 (1.057-2.280)
	Female	-0.150 (0.175)	0.736	0.391	0.861 (0.611-1.213)
	PerceivedBarrier	0.096 (0.241)	0.159	0.690	1.101 (0.686-1.765)
Hand Washing Frequency					
1	PercProfBio	0.000 (0.015)	0.001	0.978	1.000 (0.971-1.030)
	Female	-0.517 (0.465)	1.236	0.266	0.596 (0.240-1.483)
	KnowlMgmt	-11.267 (3.040)	13.735	0.000	0.000 (0.000-0.005)
	KnowlMgmt * PercProfBio	0.203 (0.061)	10.974	0.001	1.225 (1.087-1.381)
2	PercProfBio	0.023 (0.011)	4.460	0.035	1.023 (1.001-1.046)
	Female	-0.635 (0.334)	3.604	0.058	0.530 (0.275-1.020)
	KnowlMgmt	-6.579 (2.499)	6.930	0.008	0.001 (0.000-0.186)
	KnowlMgmt * PercProfBio	0.126 (0.050)	6.276	0.012	1.134 (1.028-1.251)
3	PercProfBio	0.027 (0.010)	8.144	0.004	1.028 (1.007-1.048)
	Female	-0.256 (0.284)	0.813	0.367	0.774 (0.444-1.351)
	KnowlMgmt	-3.900 (1.956)	3.975	0.046	0.020 (0.000-0.936)
	KnowlMgmt * PercProfBio	0.074 (0.040)	3.490	0.062	1.077 (0.996-1.165)
4	PercProfBio	-0.014 (0.012)	1.307	0.253	0.986 (0.963-1.010)
	Female	0.344 (0.347)	0.983	0.321	1.41 (0.715-2.785)
	KnowlMgmt	-1.482 (1.957)	0.574	0.449	0.227 (0.005-10.525)
	KnowlMgmt * PercProfBio	0.030 (0.040)	0.576	0.448	1.031 (0.953-1.114)
Hand Sanitizer Use					
1	Enrolled	0.001 (0.000)	13.478	0.000	1.001 (1.001-1.001)
	Female	-0.753	8.867	0.003	0.471 (0.287-0.773)

		(0.253)			
	KnowlTrans	-0.425 (0.868)	0.240	0.624	0.653 (0.119-3.583)
	KnowlTrans * Enrolled	0.001 (0.001)	1.303	0.254	1.001 (0.999-1.003)
2	Enrolled	0.000 (0.000)	0.677	0.411	1.000 (1.000-1.000)
	Female	-0.488 (0.294)	2.754	0.097	0.614 (0.345-1.092)
	KnowlTrans	1.513 (1.222)	1.533	0.216	4.543 (0.414-49.805)
	KnowlTrans * Enrolled	-0.001 (0.001)	1.023	0.312	0.999 (0.997-1.001)
3	Enrolled	0.000 (0.000)	0.001	0.973	1.000 (1.000-1.000)
	Female	-0.372 (0.300)	1.529	0.216	0.690 (0.383-1.241)
	KnowlTrans	-0.026 (0.922)	0.001	0.977	0.974 (0.160-5.937)
	KnowlTrans * Enrolled	0.000 (0.001)	0.786	0.375	1.000 (0.998-1.002)
4	Enrolled	0.000 (0.000)	0.665	0.415	1.000 (1.000-1.000)
	Female	-0.562 (0.305)	3.399	0.065	0.570 (0.314-1.036)
	KnowlTrans	2.467 (1.386)	3.169	0.075	11.793 (0.779-178.316)
	KnowlTrans * Enrolled	-0.001 (0.001)	2.696	0.101	0.999 (0.997-1.001)

[a]Reference category is 5

Vaccination. Compliance with vaccination was positively correlated with reported sickness severity experienced in 2010 (r = 0.133, ρ = 0.136, n = 372), knowledge of flu management (r = 0.130, ρ = 0.109, n = 408), and perceptions of risk from the flu (r = 0.109, ρ = 0.110, n = 408), and negatively correlated with barriers to preventative practice (r = -0.153, ρ = -0.153, n = 408). Of these, sickness severity and perceived barriers were shown to minimize the AIC at 667.1. In this model (Table 5), higher reported sickness severity significantly decreased the likelihood of a student reporting compliance level 1, "I will never be vaccinated for the flu no matter what" as opposed to 5 "I make sure to get vaccinated against the flu every year" (OR = 0.635).

Higher reported perceived barriers appeared to have the opposite effect (OR = 2.476).

Social distancing. Both personal distancing (*r* = 0.098, *ρ* = 0.118, *n* = 410) and staying home when sick (*r* = 0.113, *ρ* = 0.137, *n* = 409) were positively correlated with perceived complications. Perceived complications minimized the AIC at 501.7 and 430.6 for personal distancing and staying home when sick (Table 5), respectively. The highest (5) level of compliance was used as the reference in the model for personal distancing: "When I see a sick person at school, I make sure to keep a safe distance from that person, to avoid touching the things he/she touches, and to wash my hands between each class." Students with higher scores on perceived complications were significantly less likely to report compliance levels 2, "Since that person chose to come to school, I talk with them like any other student" and 3, "I try to keep a safe distance from him/her because I don't want to get sick" (OR = 0.405 and 0.402, respectively).

The highest (5) level of compliance, "I almost always stay home when sick," was also used as the reference category in the model for staying home when sick. Students reporting higher perceived complications were significantly less likely to choose compliance level 3, "I go to school if I have minor symptoms such as coughing and sneezing because these don't interfere too much with my studies," (OR = 0.204).

Respiratory etiquette and not touching the face. Other methods of minimizing direct contact with the flu virus include not touching the eyes, nose, and mouth (Table 5), and practicing respiratory etiquette (Table 5). Not touching the face held a positive relationship with the ethnicities, Asian (*ρ* = 0.100, *n* = 388) and Other (*r* = 0.147, *ρ* = 0.119, *n* = 388), and a negative relationship with the White ethnicity (*r* = -0.107, *n* = 388) and knowledge of flu transmission (*r* = -0.109, *n* = 409). The White ethnicity minimized the AIC at 70.5 in the model for not touching the face. The highest (5) level of compliance, "I rarely do any of these [rubbing my nose and eyes, biting my fingernails, resting my head in my hand or on the desk, and chewing on my pencil]," was used as the reference category. Students of White ethnicity were significantly more likely to report lower compliance levels, including 3, "I do one of these most days, but not all the time," (OR = 2.261) 2, "I do one or more of these multiple times per day," (OR = 4.609) and 1, "I do one or more of these almost all the time" (OR = 2.739).

Respiratory etiquette held positive correlations with the White ethnicity (r = 0.175, ρ = 0.159, n = 388), and knowledge of flu transmission (r = 0.220, ρ = 0.220, n = 409) and management (r = 0.256, ρ = 0.229, n = 409). Negative relationships included the Black ethnicity (r = -0.132, ρ = -0.138, n = 388), grade level (r = -0.100, ρ = -0.117, n = 395), perceived complications (r = -0.112, n = 409) and barriers (r = -0.232, ρ = -0.182, n = 409), and percent of students using the free or reduced lunch program (r = -0.128, n = 409).

For respiratory etiquette (Table 5), percentage of students on free or reduced lunch at the student's school, knowledge of flu management, perceived barriers, and the White ethnicity minimized the AIC at 744.6. Adding the interaction between perceived barriers and percentage of students on free or reduced lunch further lowered the AIC to 739.5. The highest (5) level of compliance, "When I cough or sneeze, I cover my mouth with my shirt sleeve or a tissue which I throw away afterwards," was used as the reference in this model. The effect of one or more predictors was significant at each lower level of compliance, including 4 "I usually cover my mouth with a tissue or handkerchief that I have in my pocket," 3 "I usually cover my mouth with my hand," 2 "I seldom cover my mouth, but try to turn away from people around me", and 1 "I seldom cover my mouth." Percentage of students on free or reduced lunch at a student's school, knowledge of flu management, and the interaction between perceived barriers and percentage of students on free or reduced lunch, significantly decreased the likelihood of a student reporting a lower level of compliance. The effect of percentage of students on free or reduced lunch on selecting lower compliance levels was slight but nonetheless significant for all levels, including 4 (OR = 0.948), 3 (OR = 0.979), 2 (OR = 0.977), and 1 (OR = 0.950). Effects of increased score on knowledge of flu management were greater, significantly lowering the likelihood of selecting compliance level 4 (OR = 0.422), 2 (OR = 0.568), and 1 (OR = 0.324). Ethnicity also had a significant effect. White ethnicity lowered the likelihood of reporting compliance level 2 (OR = 0.348). Likelihood of reporting lower compliance levels significantly increased with perceived barriers. Significant effects were observed within compliance levels 4 (OR = 82.416), 3 (OR = 6.682), and 2 (OR = 7.292). The interaction between perceived barriers and percentage of students on free or reduced lunch caused a small but significant reduction of the likelihood of a student choosing compliance level 3 (OR = 0.952).

Table 5. Multinomial models for vaccination, social distancing, and minimizing contact

Outcome[a]	Predictor	B (SE)	Wald χ^2	p (1 df)	OR (95% CI)
Vaccination					
1	Sickness	-0.427 (0.203)	4.441	0.035	0.653 (0.438-0.971)
	PerceivedBarrier	0.906 (0.256)	12.494	0.000	2.476 (1.498-4.087)
2	Sickness	-0.297 (0.181)	2.704	0.100	0.743 (0.521-1.059)
	PerceivedBarrier	0.079 (0.212)	0.139	0.710	1.082 (0.714-1.640)
3	Sickness	-0.058 (0.167)	0.119	0.731	0.944 (0.680-1.309)
	PerceivedBarrier	0.358 (0.212)	2.859	0.091	1.430 (0.944-2.167)
4	Sickness	0.118 (0.156)	0.570	0.450	1.125 (0.829-1.528)
	PerceivedBarrier	0.329 (0.202)	2.663	0.103	1.390 (0.935-2.065)
Personal Distancing					
1	PerceivedCompl	-0.121 (0.340)	0.127	0.722	0.886 (0.455-1.725)
2	PerceivedCompl	-0.903 (0.330)	7.493	0.006	0.405 (0.212-0.774)
3	PerceivedCompl	-0.911 (0.330)	7.649	0.006	0.402 (0.211-0.768)
4	PerceivedCompl	0.299 (0.335)	0.795	0.373	1.348 (0.699-2.600)
Staying Home					
1	PerceivedCompl	-0.296 (0.341)	0.754	0.385	0.744 (0.381-1.451)
2	PerceivedCompl	-0.359 (0.342)	1.099	0.295	0.699 (0.357-1.365)
3	PerceivedCompl	-1.590 (0.328)	23.444	0.000	0.204 (0.107-0.388)
4	PerceivedCompl	-0.554 (0.344)	2.595	0.107	0.575 (0.293-1.128)
Not Touching Face					
1	White	1.008 (0.244)	17.107	0.000	2.739 (1.699-4.420)
2	White	1.528 (0.230)	44.122	0.000	4.609 (2.936-7.234)
3	White	0.816	10.612	0.001	2.261 (1.385-3.691)

		(0.250)			
4	White	-0.091 (0.302)	0.091	0.763	0.913 (0.505-1.650)
Respiratory Etiquette					
1	PercFRL	-0.051 (0.014)	12.666	0.000	0.950 (0.925-0.977)
	KnowlMgmt	-1.128 (0.546)	4.263	0.039	0.324 (0.111-0.944)
	White	-1.025 (0.660)	2.415	0.120	0.359 (0.098-1.308)
	PerceivedBarrier	3.656 (2.477)	2.178	0.140	38.711 (0.302-4968.732)
	PerceivedBarrier * PercFRL	-0.060 (0.067)	0.808	0.369	0.942 (0.826-1.074)
2	PercFRL	-0.023 (0.009)	6.352	0.012	0.977 (0.960-0.995)
	KnowlMgmt	-0.566 (0.274)	4.265	0.039	0.568 (0.332-0.971)
	White	-1.056 (0.383)	7.620	0.006	0.348 (0.164-0.737)
	PerceivedBarrier	1.987 (0.967)	4.224	0.040	7.292 (1.096-48.537)
	PerceivedBarrier * PercFRL	-0.048 (0.028)	3.022	0.082	0.953 (0.902-1.007)
3	PercFRL	-0.022 (0.008)	6.909	0.009	0.979 (0.963-0.994)
	KnowlMgmt	-0.293 (0.191)	2.344	0.126	0.746 (0.513-1.085)
	White	0.123 (0.290)	0.179	0.672	1.131 (0.641-1.997)
	PerceivedBarrier	1.899 (0.622)	9.320	0.002	6.682 (1.974-22.604)
	PerceivedBarrier * PercFRL	-0.049 (0.018)	7.321	0.007	0.952 (0.919-0.986)
4	PercFRL	-0.053 (0.013)	15.716	0.000	0.948 (0.925-0.973)
	KnowlMgmt	-0.862 (0.407)	4.478	0.034	0.422 (0.190-0.938)
	White	-0.122 (0.551)	0.049	0.824	0.885 (0.301-2.606)
	PerceivedBarrier	4.412 (2.054)	4.615	0.032	82.416 (1.471-4618.568)
	PerceivedBarrier * PercFRL	-0.096 (0.056)	2.939	0.086	0.909 (0.814-1.014)

[a]Reference category is 5

Sickness severity. Reported illness severity in 2010 was positively correlated with getting the flu vaccination (r = 0.133, ρ = 0.136, n = 372) and staying home when sick (ρ = 0.108, n = 373). Positive correlations also existed with being female (r = 0.127, ρ = 0.128, n = 352), number of health professionals in the family (r = 0.117, ρ = 0.134, n = 373), the Hispanic ethnicity (r = 0.116, ρ = 0.116, n = 371), and perceptions of risk (r = 0.279, ρ = 0.254, n = 374), complications (r = 0.209, ρ = 0.192, n = 374), and barriers against preventative practice (r = 0.154, ρ = 0.112, n = 374). Illness was negatively correlated with hand washing quality (r = -0.125, ρ = -0.123, n = 374), the White ethnicity (r = -0.154, ρ = -0.154, n = 371), and the school-level effects of enrollment size (ρ = -0.107, n = 374) and percentage of students scoring proficient on the biology end-of-course examination (ρ = -0.122, n = 374). In the regression model (Table 6), the precautions of vaccination and hand washing quality, the demographic variables of gender and ethnicity, and perceived risk and complications, served as predictors for sickness severity, minimizing the AIC at 599.7. The reference category of "no symptoms this year" was used. Students reporting more favorable attitudes towards compliance with the flu vaccination were more likely to report illness, including experiences of cold-like (OR = 1.200) and flu-like (OR = 1.309) symptoms. The opposite effect was found for hand washing quality - greater compliance with hand washing quality significantly decreased the likelihood of reporting flu-like symptoms (OR = 0.701). Females were more likely to report cold-like (OR = 1.642) and flu-like (OR = 2.302) symptoms. And students of White ethnicity had lower incidences of flu-like symptoms (OR = 0.338). Greater reporting of perceived risks and complications significantly increased the likelihood of reporting flu-like symptoms (OR = 13.568 and 2.795, respectively).

Neural Network Predictions

General measures of efficacy for the 10-fold cross validated prediction models, including percentage of categories identified correctly, Kendall-tau B concordance indices, and effect sizes for concordance, are provided in Table 7. Confusion matrices for the eight precautions and sickness severity are provided in Tables 8 and 9, respectively.

Table 6. Multinomial model for reported sickness severity

Outcome[a]	Predictor	B (SE)	Wald χ^2	p (1 df)	OR (95% CI)
Cold-like symptoms	Vaccination	0.182 (0.092)	3.885	0.049	1.200 (1.002-1.437)
	Washing Quality	0.020 (0.103)	0.037	0.847	1.020 (0.834-1.248)
	Female	0.496 (0.251)	3.893	0.048	1.642 (1.004-2.686)
	White	-0.405 (0.313)	1.675	0.196	0.667 (0.361-1.232)
	PerceivedRisk	0.326 (0.310)	1.107	0.293	1.385 (0.755-2.544)
	PerceivedCompl	0.485 (0.294)	2.721	0.099	1.625 (0.913-2.890)
Flu-like symptoms	Vaccination	0.269 (0.128)	4.402	0.036	1.309 (1.018-1.682)
	Washing Quality	-0.356 (0.145)	6.056	0.014	0.701 (0.527-0.931)
	Female	0.834 (0.345)	5.853	0.016	2.302 (1.171-4.528)
	White	-1.083 (0.411)	6.965	0.008	0.338 (0.151-0.758)
	PerceivedRisk	2.608 (0.474)	30.298	0.000	13.568 (5.360-34.365)
	PerceivedCompl	1.028 (0.398)	6.669	0.010	2.795 (1.281-6.099)

[a]Reference category is no symptoms of illness

Table 7. Measures of efficacy for predictive models

Outcome	% Correct	Kendall Tau-B	Cohen's D	Effect Size
Vaccination	22	0.148	0.473	Small
Hnd Wash Qual	35	0.235	0.773	Moderate
Hnd Wash Freq	33	0.294	0.995	Large
Hnd Sanit Use	21	0.165	0.530	Moderate
Personal Dist	41	0.166	0.533	Moderate
Staying Home	24	0.160	0.513	Moderate
Not Touch Face	20	0.089	0.281	Small
Resp Etiquette	19	0.279	0.937	Large
Sickness	42	0.197	0.639	Moderate

Table 8. Confusion matrices for predictions of precautions

		Predicted Value								Predicted Value					
		1	2	3	4	5	Total			1	2	3	4	5	Total
Vaccine Data	1	2	12	16	4	0	34	Person Dist Data	1	2	5	24	1	0	32
	2	1	23	45	8	0	77		2	3	24	98	8	0	133
	3	3	27	42	7	0	79		3	1	16	137	4	1	159
	4	2	17	55	11	1	86		4	0	0	7	4	1	12
	5	0	22	50	21	3	96		5	0	5	62	6	1	74
Total		8	101	208	51	4	372	Total		6	50	328	23	3	410
Hand Wash Quality Data	1	2	1	2	0	0	5	Staying Home Data	1	5	8	12	1	1	27
	2	1	1	23	8	2	35		2	2	20	16	3	1	42
	3	1	3	27	27	5	63		3	7	71	52	21	3	154
	4	0	2	43	74	11	130		4	3	39	49	14	8	113
	5	1	2	33	63	20	119		5	2	19	36	9	7	73
Total		5	9	128	172	38	352	Total		19	157	165	48	20	409
Hand Wash Freq Data	1	2	6	13	4	0	25	Not Touch Face Data	1	63	0	19	0	3	85
	2	0	4	40	21	2	67		2	106	0	31	0	16	153
	3	0	6	76	49	20	151		3	52	0	13	0	9	74
	4	0	0	25	25	12	62		4	21	0	11	0	4	36
	5	0	1	19	34	16	70		5	23	0	14	0	3	40
Total		2	17	173	133	50	375	Total		265	0	88	0	35	388
Hand Sanit Data	1	45	46	33	0	1	125	Resp Etiq Data	1	9	2	1	0	0	12
	2	24	16	19	0	0	59		2	9	8	18	1	0	36
	3	15	20	14	0	0	49		3	12	17	53	4	0	86
	4	12	19	22	0	0	53		4	2	7	6	0	0	15
	5	17	29	38	3	2	89		5	8	39	176	13	3	239
Total		113	130	126	3	3	375	Total		40	73	254	18	3	388

Correct Prediction
Most Common Incorrect Value

Hand hygiene. The predictive model for hand washing quality gave the correct prediction 35% of the time. Its moderate concordance demonstrates that most of the incorrect predictions were close to the true value, which can be verified in Table 8. Its tendency was to predict one level high for categories 2 and 3, and one level low for categories 4 and 5. A very similar prediction pattern was observed for hand washing frequency, which predicted correctly 33% of the time and showed high concordance. In comparison, the model for hand sanitizer use was weak, showing small concordance and predicting correctly only slightly more often than random chance. This model had the tendency to predict one level high for the lowest level, one level low for levels, 2, 3, and 4, and two levels low for level 5.

Vaccination. The inputs of sickness and perceived barriers resulted in a relatively weak predictive model for vaccination with low concordance and correct responses only slightly higher than random chance. The model had the tendency to predict high for the lower categories (1 and 2), and low for the higher categories (3 and 4).

Social distancing. The perceived complications measure was shown to predict personal distancing and staying home when sick with moderate concordance. The model for personal distancing gave the correct prediction 41% of the time while the model for staying home when sick was correct 24% of the time. Both models had the tendency to predict high for the lower categories, and low for the higher categories.

Minimizing contact. The White ethnicity yielded poor predictions for not touching the eyes, nose, and mouth. The model's success was no better than random chance, and the concordance of the predicted values with the data was low. While predicting 1's with relative accuracy, the model had the tendency to predict this value for all other categories, severely limiting its efficacy.

Predictions for respiratory etiquette, while only 19% correct, demonstrated high concordance with the data, showing that predictions which missed the mark were nonetheless relatively close to the actual value. Table 8 shows that a majority of predictions were within one level of the actual value for levels 1, 2 and 3. However, this model tended to predict two levels low for categories 4 and 5.

Sickness severity. Student illness in 2010 (Table 9) could be predicted with moderate success, giving a 42% correct prediction rate with moderate concordance. Incorrect predictions for cold and flu symptoms tended towards the lower respective categories.

Table 9. Confusion matrix for prediction of sickness severity

		Predicted Value			
		None	Cold	Flu	Total
Sickness Data	None	40	33	6	79
	Cold	95	80	27	202
	Flu	18	23	26	67
Total		153	136	59	348

Correct Prediction

Most Common Incorrect Value

DISCUSSION

The primary objective of this study was to gain an understanding of factors which serve as predictors for behavior related to prevention of influenza illness. What is the role of knowledge of influenza, perceptions about the severity and prevention of the disease, and sociodemographic variables in prevention? And what is the relative importance of knowledge compared to the other factors? Links between the most significant predictors and the compliance outcomes are diagrammed in Figure 1. Implications of these relationships are discussed below.

The Role of Perceived Risk, Complications, and Barriers

Three elements of Health Belief Model were of interest in this study: Perceived risk of catching the influenza illness, perceived complications from the illness, and perceived barriers against taking preventative measures. These were found to play a large part in compliance with certain preventative practices. Students reporting high sickness severity in 2010 were more likely to get vaccinated, which is a finding corroborated by Chen *et al* (2006). And perceived complications from influenza illness were positively correlated to staying home when sick and practice of personal distancing, a link cited by Kiviniemi *et al* (2011). It follows that a significant challenge for interventions aiming to raise vaccination rates and social distancing is to heighten perception of risk and complications from influenza before students directly experience the illness. There is currently no literature linking specific intervention strategies to resulting perceptions of risk and complications from the illness.

Perceived barriers significantly lowered compliance with vaccination, hand washing quality, and respiratory etiquette, a finding which is corroborated by Kretzer and Larson (1998), Pittet (2000), and Dubbert *et al* (1990). Pittet (2000) suggests that efforts to minimize these barriers may be one of the most effective intervention strategies, including providing easy access to skin care lotion and alcohol-based hand rub. Addressing self-reported and observed reasons for non-compliance at the individual, group, and institutional levels is necessary to increase compliance (Pittet, 2000). White *et al* (2003) explains that a measure as simple as installing hand sanitizers in college dormitories, restrooms, and dining halls significantly improved hand hygiene and reduced rates of illness and absenteeism.

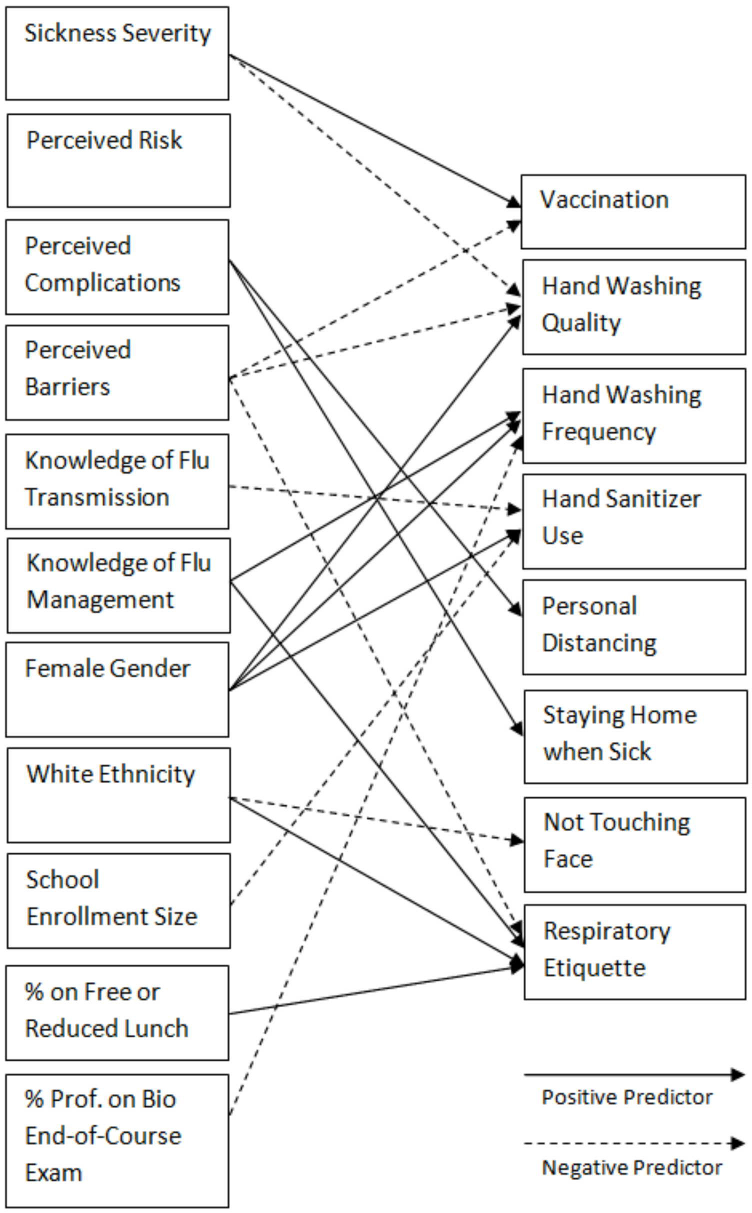

Figure 1. A map of the most significant predictors to compliance with precautions based on the AIC

As with hand washing, vaccination rates can be improved when reported and observed concerns over getting vaccinated are addressed directly, and efforts are taken to make the vaccine more convenient, including reducing cost and having an on-site vaccination nurse present (Harbarth *et al*, 1998).

Vaccination is the most effective measure that can be taken to significantly reduce cost and absenteeism due to influenza (CDC, 2009; White, Lavoie and Nettleman, 1999). Given the common barriers of expense and inconvenience, the low cost of the vaccination, and the high cost of student illness and absences to schools (Nichol *et al*, 1994), the effort of schools to offer the vaccination free of charge may prove lucrative in preventing illness and saving money.

Sociocultural Impacts

Results indicate that a student's cultural and school environments may have a significant impact on reported mitigation practice. The effect of gender was significant for hand hygiene. The finding that females are more likely than males to practice effective hand washing is corroborated by Pittet (2000) and the American Society for Microbiology (2000). Students' ethnic background also appeared to play a role in certain behaviors. Black students reported lower respiratory etiquette, but increased use of alcohol-based hand sanitizers. Reports of respiratory etiquette by white students, on the other hand, were significantly higher. Ethnographic studies have found that although ideas and objects that people find unhygienic vary slightly from culture to culture, ideas are more alike than different, and possibly originate from instincts for disease prevention that humans have developed through their evolution (Curtis and Biran, 2001). Perhaps this explains why many of the precautions associated with hygiene, such as hand washing, showed little variance between cultural categories in this study. However, the fact that proximity to alcohol and killing bacteria and viruses are discouraged by many religions of Asia, including Buddhism, Hinduism, Islam, and Sikhism, could be a possible reason for the negative correlation between Asian ethnicity and hand sanitizer use (Allegranzi *et al*, 2009).

While racial and ethnic barriers to the flu vaccination are discussed by Chen *et al* (2006), who report that people of Black and Hispanic origin have significantly lower vaccination rates than other ethnic groups due to low household income and lack of health insurance, no such relationships were observed in this sample of high school students. The absence of this finding could possibly be attributed to the homogenization of culture in the schools sampled, or to the fact that the study design did not control for individual financial factors such as household income.

Effects of school environment were important predictors for three precautions. Respiratory etiquette increased as socioeconomic status declined as measured by percentage of students on free or reduced lunch. This could be explained by the fact that schools with underprivileged students tend to offer more free services for students including instructional materials on how to prevent disease spread. Hand washing frequency decreased with the academic success of the school as measured by the percentage of students scoring "proficient" on the biology end-of-course examination. Although Martinello, Jones and Topal (2003) documented that information based reasons for non-compliance (not knowing how to take preventative measures) were easier to change than non-information based reasons (like inconvenience) in health care workers, understanding how this applies to high school students, and the comparatively low compliance with hand washing in higher achieving schools, will require further research.

The negative effect of school enrollment size on hand sanitizer use was significant between the highest and lowest levels of compliance. Although the effect was small, reasons why students in bigger schools would be less likely to comply with hand sanitizer use is worth investigating. Due to the larger numbers of students, hand sanitizers may be more difficult to access, making inconvenience outweigh the perceived benefits. Installing hand sanitizers where students frequent, and keeping them maintained, is an important step to improve hand hygiene (White *et al*, 2003).

No school effects on social distancing were observed in this study, indicating that this is an issue common to many schools, and one that has uniformly not been addressed. On average, students' willingness to stay home from school when sick is higher than willingness to keep a safe distance from those who are visibly sick. This finding, coupled with the difficulty of identifying a visibly sick person and the ease at which flu spreads, indicates that encouraging students to stay home when they are sick is the best way to encourage social distancing. Findings indicate that interventions focused on increasing perceptions of the severity of influenza, and negative consequences for their friends, may increase students' willingness to practice social distancing. The issue of social distancing is more complex than the other preventative practices, however, due to the competing incentive structures for going to school versus staying home. Possible school policy incentives for encouraging students staying home when sick include not penalizing students for absence or rewarding perfect attendance. Unfortunately, other factors are out of schools' control. These include parents' need for free or reduced meals (not corroborated in our findings), free adult supervision, and not having to take off work, and students' desire to spend time with friends (Blendon *et al*, 2008). Constraining the effects of these incentives on noncompliance is an important problem for future research, and addressing these issues in an ethical manner presents a significant challenge for school systems wishing to improve social distancing.

The Role of Knowledge, and Implications for Interventions

Both Pittet (2000) and Harbarth *et al* (1998) found that education to improve knowledge is an important intervention strategy to improve hand washing and vaccination, respectively. This finding is corroborated with findings from this study, which show that knowledge of flu management is positively correlated to compliance with vaccination, hand washing frequency, and respiratory etiquette. And for the latter two, knowledge of flu management was among the most important predictors. Although a significant negative relationship between knowledge of flu transmission and hand sanitizer use was discovered and shown to be an important component in the model, it is statistically insignificant at the 0.05 level. Nonetheless, it is interesting to speculate on reasons why students who know more about flu transmission may be less likely to use hand sanitizers. It is possible that more knowledgeable students understand other possible downfalls of hand sanitizer use, including antibiotic resistance, which inhibits desire to comply. We leave systematic exploration of this relationship to future studies.

Although studies on how knowledge of influenza relates to compliance with respiratory etiquette are absent, successful intervention strategies may be similar to documented efforts to improve hand washing and vaccination. An example of the positive impact of knowledge is explaining that using the shirt sleeve to cover the mouth and nose while sneezing is much safer than using the hands (CDC, 2009). Since a shirt sleeve is more accessible than a tissue in most situations, and is as easy to use as the hands, knowledge of this mitigation procedure may be valuable to students.

Factual knowledge of influenza management was found to significantly improve compliance with certain precautions. However, the limitations of these effects imply that interventions focusing on factual knowledge alone are unlikely to be effective in changing many preventative behaviors related to hygiene and social distancing. Perceived risks and complications can likely be heightened through strategies which focus on student experience as opposed to knowledge alone. Meers (2009) suggests the authentic approach of encouraging students to reflect on different ways that their lives are impacted by the flu, including prior illnesses and pandemics that students and their families may have experienced. For students to understand the risks and complications due to influenza, concepts should be addressed through explicit questions like, "What can businesses do to stay competitive during times of excessive absenteeism?" (Meers, 2009).

Predictive Models - Usefulness and Limitations

Development of neural network models puts forth the claim that predictions can be established using a small number of variables, which may be useful to schools in anticipating the impacts of specific intervention techniques, or to health professionals and policymakers wishing to predict the preventative measures taken by a school system based on more accessible factors. A major strength of the predictive models in this study is that testing was done outside of model construction through 10-fold cross validation, establishing generalizability of conclusions for the sample. We note, however, that generalization of conclusions to the population should be done with caution due to the convenience sample design. Hand washing, social distancing, respiratory etiquette, and student illness could be predicted with moderate success and thus may be useful to researchers needing a close estimate of students' compliance levels based on the models' inputs.

An important point to highlight would be the fact that neural networks are able to identify general trends in noisy data such as that collected using self-reported surveys. For example, if a particular student claims to have a higher respiratory etiquette value than indicated by the neural network, it is possible that the network gave a more accurate response with regard to this student's actual behavior after weighting by the more truthful responses of similar students. Hence, neural networks can provide some degree of robustness against intentional over- or under-reporting of compliance. This robustness to noisy data can be seen in the studies, Lee (2004) and Foster (1992), which emphasize the generalizable nature of neural networks that makes them so useful in predicting outcomes for inconsistent data.

While these models may have some utility in predicting students' behavior, they are also limited. Although a sample of 410 is sufficient to establish statistical conclusions for a modest number of predictors, larger sample size, and thus more data in the order of thousands to train the neural networks, would significantly add to the robustness of the predictive models. Perhaps the most significant limitation of the models in this study that can be addressed through future research is their stationary, isolated nature; they do not take into account interaction between students over time. Through history, human decision making has been shown to be highly influenced through peer interaction, and threshold models are commonly used in sociology to explain collective behaviors of many types, including riots, strikes, and group decisions to adopt new health practices such as birth control (Granovetter, 1978). These collective behavior models make the assumption that engaging in a behavior increases for an individual when others nearby are doing the same, and that one's threshold - the amount of social pressure required to convince him/her to adopt the behavior - changes with certain factors. Results from this study give valuable insights into factors which may increase or decrease these thresholds, opening up the possibility for development of more complex recursive models aimed at predicting whether or not a particular student group will take up a particular behavior, and if not, which types of intervention strategies are needed to encourage group compliance.

CONCLUSION

In this study, we quantified how knowledge, perceptions, past experience, and sociodemographic variables relate to preventative behavior through correlation analysis and logistic regression, and examined their utility in prediction using neural networks. But these are a few of many methods which can be used to address this multivariate problem. Techniques such as path analysis and structural equation modeling could be used in future studies to explore how these variables inter-relate. And fuzzy logic (Zadeh, 1996) may be a valuable alternative method for predicting illness and compliance based on school- and student-level factors.

Toward the goal of understanding compliance on a conceptual level, a necessary next step involves exploration of specific reasons behind these relationships, which could possibly be addressed through case study designs. A number of questions are raised. What specific factors affect proneness of certain cultures to engage in certain preventative practices, but not others? What aspects of a student's school environment and community outside of school encourage or inhibit practice of certain preventative behaviors? Efforts to address these questions would further inform the design and implementation of influenza-related instruction and intervention efforts for high school students. Given that the most successful curriculum/intervention efforts tend to be well-tailored to the needs of the target student body (Wallace and Louden, 1992; Shepard, 2000), findings from this study may prove valuable in informing future efforts.

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