Bayesian Analysis of Quality of Life and PPE (Personal Protective Equipment) Use During the Coronavirus (COVID-19) Pandemic

Abstract

Concerned with the documented psychological effects of the COVID-19 pandemic, this study examines factors associated with quality of life and PPE use during the pandemic. After controlling for demographics, we created a Bayesian multiple regression model to examine the associated factors of quality of life; we also utilized Bayesian LASSO techniques to create a model predicting PPE use. As hypothesized, annual income, being employed, being in long-term relationships, and mindfulness were all positively associated with quality of life scores during the pandemic; whereas self isolation was negatively related to psychological well-being. We found that the variables with the highest predictive power for PPE use were age, education, marital status, religion, intolerance of uncertainty, and avoidance of public settings. These results suggest that it is critical to keep in mind that financial difficulties and social isolation have an impact on mental health when planning pandemic responses. For individuals, our results stress the importance of maintaining social relationships as well as the potential benefit of adopting mindfulness practices. Additionally, understanding the key predictors of PPE usage can better drive education about PPE as well as the allocation of PPE-related resources.

Background and Significance

The rise of the COVID-19 international public health emergency has caused unexpected disruptions on both personal and societal levels. As of December 14, 2020, there have been over 72 million total reported cases of COVID-19 worldwide, resulting in 1.6 million deaths[1]. As the result of the pandemic, unemployment rates skyrocketed from 3.8% in February 2020 to 14.5% in April[2].

Psychological distress increased significantly from March to April as a result of COVID-19[3]. Considering the psychological burden caused by COVID-19, it is critical to understand the factors associated with individual wellbeing. A study conducted during the pandemic shows that the most frequently reported COVID-19 stressor among American adults was financial concerns[4]. This study plans to examine how financial disruptions due to COVID are related to psychological well-being. Additionally, to prevent the spread of COVID, self isolation and social interaction limitations have been strongly recommended nationwide. Across systematic reviews, results consistently report that social isolation and loneliness were associated with poorer mental health outcomes[5]. To better understand the impact of isolation during quarantine, this study investigates how self-isolation and marital status are associated with quality of life. To alleviate distress, mindfulness-based stress reduction has been shown to be associated with improved quality of life[6]. As mindfulness was reported to enhance well-being and help cope with the stressful pandemic, this study will also examine mindfulness[7].

To protect people from infection and prevent the spread of COVID-19, both the Center for Diseases Control and Prevention[8] and WHO[9] have issued guidelines on using face masks. Empirical research has provided evidence on the effectiveness of community-wide mask wearing on the control of COVID-19[10]. Therefore, ensuring the compliance of mask wearing advice is important to control community transmission. This study plans to understand what factors best predict individual mask wearing.

The current study aims to understand the factors that facilitate preventive health behaviors and protect psychological health at this difficult times. Based on previous studies, we hypothesize that 1) higher income and being employed will be positively associated with quality of life; 2) self isolation and lack of a long-term relationship might be associated with poor quality of life; 3) individuals with higher mindfulness scores will have better quality of life. This study also aims to predict PPE usage identifying variables with the strongest power to predict PPE use to better pave the way for personal health education during the COVID-19 pandemic.

Methods

The dataset we used is from the Harvard Dataverse, an open data repository. The original research was approved by the Bowling Green State University IRB[11]. Four hundred and fifty participants were Amazon Mechanical Turk Workers recruited through CloudResearch. In April 2020, participants completed self-reported questionnaires online. The following description covers the relevant variables in our models.

Participants reported demographics, including age, gender, education level, chronic illness, religion, and annual income. Annual income was log-transformed due to the skewed distribution. Employment Status After COVID was coded into three categories: unemployed, part-time employment, and full-time employment. Marital Status was coded into two categories: one group for current long-term relationships, and one for single individuals. Quality of Life was measured by the psychological well being subscale of the WHO Quality-Of-Life Scale[12]. Total scores range from 10 to 50, with higher scores indicating better psychological well-being. The Preventive Actions Taken Scale (PATS) was used to measure PPE use and avoidance of public settings. Participants also reported whether or not they were practicing social isolation (binary yes or no). The Intolerance of Uncertainty Scale[13] measures anxiety and worry about uncertain events; higher scores indicate more intolerance of uncertainty. The Five Facet Mindfulness Questionnaire is a scale that measures mindfulness in daily life[14]. Total scores range from

0-120 with higher scores indicating higher levels of mindfulness. *Please refer to the Appendix for full variable descriptions.*

Analytic Methods

Data Preparation: RStudio (version 1.2) was used to analyze the data. We assumed the data was missing completely at random based on the Little's MCAR Test ($p > 0.05$). Missing data was computed by multiple imputations. Categorical variables were transformed into numerical "dummy" variables to be used in our models of predicting PPE use.

Association Model: Bayesian multiple regression was used to determine the associations between variables and quality of life using Stan via the package `rstanarm`[15]. Bayesian analysis allows us to capture uncertainty in the model. The Bayesian regression model reflects both sampling variability in the outcome variable and posterior variability in the regression parameters by giving each parameter a corresponding distribution. Rstanarm selected the weakly informative prior by default. Markov Chain Monte Carlo (MCMC) methods were used to simulate the posterior. Four Markov chains with 10000 iterations each were simulated. Age, gender, education, and chronic illness were controlled for in the regression model. Predictors of quality of life included marital status, employment status, annual income, self-isolation, and mindfulness. We assess our models by examining MCMC trace plots, MCMC density overlay plots, and R-hat values to confirm that our chains have stabilized. Posterior predictive checks were graphed to compare to the actual and predicted distributions of quality of life. Cross-validation was conducted to compute the median absolute error and compared the portion of observed scores that fell within the corresponding predictive intervals.

Predictive Model: The dataset was split into a training and a testing set prior to setting up the model, and both were transformed into matrix form. An extreme multiple regression model formula was created with all variables in the dataset as predictors except for PPE usage, which was used as the outcome variable. We used the `blasso` function from the `monomvn` package to perform Bayesian LASSO. Parameters included in the function were the following: iterations set to 10000 with 5000 burn-in, extreme priors of 500 set for all initial beta values, extreme variance of 500 set as initial variance, and extreme lambda value set initially as 10. Cross-validation was performed to identify the optimal lambda square value for the model. We employed our test set and the optimal lambda square value to predict new outcome values in the test set for PPE usage.

Results

Of participants in this study, 37% were female, and the mean age was 36.7 (range 18 – 76). Over half of the participants are Caucasian (55.3%), while 22.9% are Black/African American and 4.4% are Asian. About half (55.6%) of the participants have a Bachelor's degree, and 26.5% have a Master's degree or higher. Pearson correlation tests were conducted to test correlations between quality of life and numerical explanatory variables (Table 1). Income ($r = 0.18$, $p < .01$) and mindfulness($r = 0.30$, $p < .01$) are positively correlated with quality of life.

Association Model: We fitted the Bayesian multiple regression model with the variables of interest and controlled for demographic differences, with quality of life as the response variable. The global trend of the regression is:

Quality of Life = 6.980 - 0.008(Age) + 0.739(Gender) + 0.544(Education) -2.704(Illness) + 1.051(Relationship Status) + 0.804(Income) + 2.136(Part-time Employment) + 1.918(Full-Time Employment) - 1.056(Isolation) + 0.194(FFMQ)

The coefficients above are the mean coefficients of the variables. Based on the MCMC trace plot and density plot, the simulated chains were consistent and stable for all parameters (Figs. 2 & 3). The values of R-hat all approached 1, which supported the consistency across all chains (Table 2). The distribution of posterior predictive values well matched with the distribution of observed quality of life scores, suggesting the model had satisfying predictive accuracy (Fig.

4). The mean coefficients and 90% credible intervals of variables were reported. A 90% credible interval indicates the coefficient has 90% probability of falling within the interval.

For financial stability, both income and being employed are positively associated with quality of life. Individuals who had higher annual income experience better quality of life (β = 0.80, 90%CI[0.28, 1.34]). Compared to those who were unemployed, individuals who were employed part-time (β = 2.14, 90%CI[0.71, 3.45]) or full-time (β = 1.92, 90%CI[0.43, 3.38]) reported better psychological wellbeing. Consistent with our hypotheses about social relationships, individuals in long-term relationships showed higher quality of life scores than those who were not in relationships (β = 1.05, 90%CI[0.02, 2.08]); whereas self-isolation was negatively associated with psychological well-being (β= -1.06, 90%CI[-1.96, -0.16]). Lastly, as hypothesized, individuals who had higher levels of mindfulness reported better psychological wellbeing (β = 0.19, 90%CI[0.15, 0.23]) Ten-fold cross-validation was conducted to ensure the model's precision and reliability (Table 3). Results show that the scaled mean absolute error is 0.91, indicating the posterior prediction was accurate. Fifty-three percent of observed quality of life fell within the 50% posterior prediction interval, and 96% of observed values fell within the 95% posterior prediction interval, which also supported the prediction accuracy.

Prediction of PPE Usage: Comparing regular LASSO to Bayesian LASSO, regular LASSO with the same model formula shrank a total of 32 out of 37 predictive variable coefficients to 0 at the optimal lambda square parameter value (Fig. 5). Bayesian LASSO shrank a total of 31 out of 37 predictive variable coefficients at the same lambda square value (Table 4). The six variables selected by Bayesian LASSO were Age, Education, Marital Status, Intolerance of Uncertainty, and Preventive Action Taken to avoid Travel/People. Cross-validation on the training data was implemented to determine the optimal lambda square value that minimizes the MSE in the model (Fig. 6). The optimal lambda square value (lambda square = 0.415) was used to predict new outcome observations for the testing set.

Discussion and Conclusions

In our Bayesian regression model, indicators of financial stability are correlated with increased quality of life. Our hypotheses about social relationships were supported, as being in a relationship and less self-isolation were positively correlated with quality of life. Increased mindfulness was also correlated with higher quality of life as hypothesized. In our predictive LASSO model, the variables most predictive of PPE usage were demographic variables (education, religion, marital status), as well as preventive actions taken to protect oneself from viral exposure. Many of these variables define how individuals conduct themselves in a social environment, and how they may subsequently perceive the pandemic and personal implications.

Improving quality of life entails both governmental and personal efforts. The detrimental effects of COVID-19 on employment rate and financial stability negatively impacted ordinary people's well being. Governments should be aware of the financial difficulties many people face and carefully design plans to increase employment rates. While self isolation is urgent and necessary to prevent the spread of the virus, we could not overlook the poor mental health outcome associated with a lack of social interactions. Community health providers could consider alternative social activities and use social resources that do not require in person contact but still provide social support. Lastly, our study confirmed the positive effects of mindfulness on quality of life. Since mindfulness is widely available in online formats, individuals could practice mindfulness exercises to increase their awareness of the current situations.

There are some limitations to the study. Participants were recruited from an online platform and might not fully represent the population of American adults. Thus, the generalizability of the study is compromised. In addition, the instruments used in this study were self-report questionnaires, which might not accurately reflect participants' responses. In terms of study design, this study only collected cross-sectional data and thus the results could not infer any causal relationship. In the future, a longitudinal study would be helpful to understand what factors lead to better quality of life and PPE use.

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16. Additional Citations and Documentation can be downloaded from our project repository: https://github.com/hmsnell/COVID19-Bayesian-Analysis

Appendix

Full Variable Descriptions:

Demographics. Participants reported their age, gender, education level, religion, and accomodation type.

Occupation and SOC Category. Participants recorded their current relevant occupation. In order to incorporate this information into our model, we releveled recorded occupations based on the U.S. Bureau of Labor Statistics' Standard Occupational Classification (SOC) System.

Employment Status After COVID. Participants reported their employment status, which we re-coded into three categories: 1. unemployed (unable to work, retired, not looking for work, looking for work); 2. part-time employment (1-24 and 25-39 hours a week); and 3. full time employment (40+ hours per week).

Marital Status. Participants reported marital status as 1. Single, 2. Cohabitating (not married), 3. Long term relationship (not married or cohabitating), 4. Married, 5. Divorced, 6. Widowed, or 7. Other. Marital status was re-coded into a binary variable indicating relationship status: one group for individuals in long term relationships, cohabiting, or married, and one for individuals who are single, divorced, or widowed.

Annual Income. Participants reported their annual income. A logarithmic transformation was performed on these values due to the difference in magnitude between these responses and the scale of other variables.

Quality of Life. Quality of life was measured by the 10-item psychological well being subscale of the World Health Organization Quality-Of-Life Scale (WHOQOL Group, 1998). Participants responded to descriptions of their quality of life on a Likert scale. Items include "how satisfied are you with your health" with ratings from 1 "Very Dissatisfied" to 5 "Very Satisfied." Total scores can range from 10 to 50, with higher scores indicating better psychological well-being.

PPE Use. Three items from the Preventive Actions Taken Scale (PATS; citation) were used to measure PPE use. The PATS scale was initially developed to measure adoption of COVID-19 preventive behaviors in a Chinese community in late January 2020. Participants were asked to rate how the statements described their behaviors (e.g., "I wear a mask everywhere").The total scores ranged from 3 to 12, with higher scores indicating more extensive PPE use.

Avoid Public Settings And Contact. Five items from the PATS were used to measure individuals' preventive behaviors to avoid travel and crowds. Participants rated how each statement described their behaviors (e.g., "I avoided public events and crowded places"). Higher scores indicate more engagement in avoiding public settings.

Self-Isolation. Participants reported whether or not they were practicing social isolation/quarantining in binary response of yes or no.

Illnesses. Participants reported whether or not they had a medical condition or chronic illness in binary response of yes or no.

Intolerance of Uncertainty. The 12-item Intolerance of Uncertainty Scale (IUS-12; Carleton, Norton, & Asmundson, 2007) measures anxiety and worry to ambiguous and uncertain events (e.g., "Unforeseen events upset me greatly"). Participants reported their reaction to uncertainty on a 5-point scale ranging from 1 "not at all characteristic of me" to 5 "entirely characteristic of me." Higher scores indicate more intolerance of uncertainty.

Mindfulness. The Five Facet Mindfulness Questionnaire is a scale that measures mindfulness in daily life (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). This study uses the 24-item version generating five subscales (awareness, observe, describe, non-judgment, and nonreactivity) which were summed to produce a total FFMQ score. Participants rated items using a 5-point scale ranging from 1 "never or very rarely true" to 5 "very often or always true". Total scores range from 0 to 120 with higher scores indicating higher levels of mindfulness.

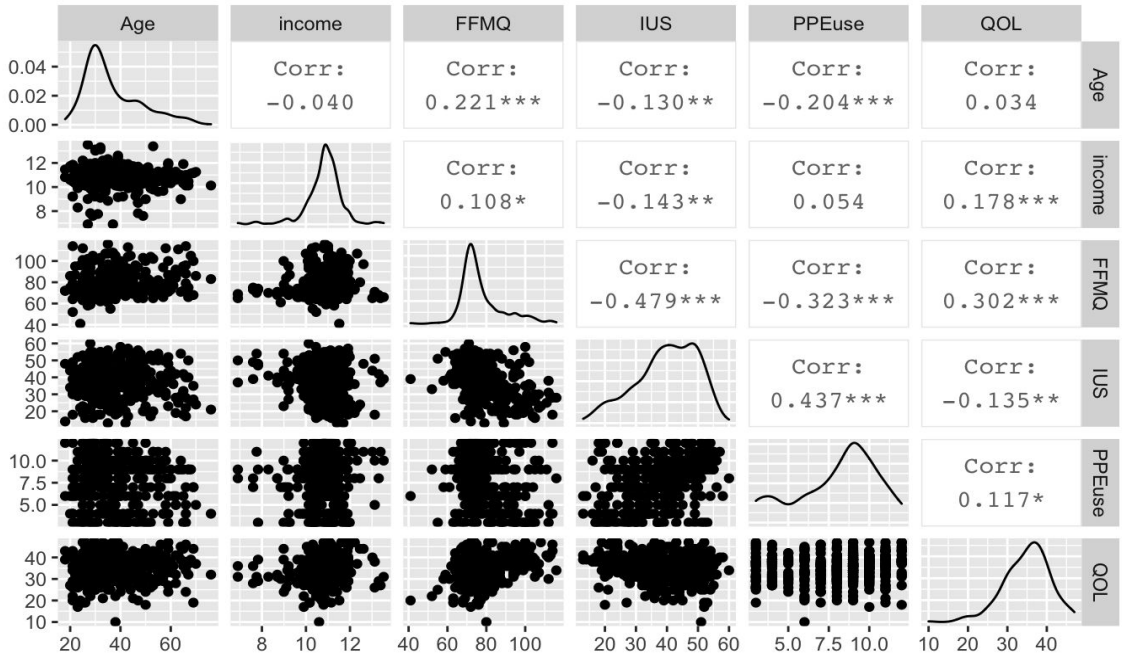

Figure 1. Correlation plot
Income: log of annual income; **FFMQ**: Five-Factor Mindfulness Questionnaire score (measurement of mindfulness); **IUS**: Intolerance of Uncertainty total score; **PPEuse:** Personal Protective Equipment use; **QOL**: Quality of Life total

Variable	*M*	*SD*	1	2	3	4	5
1. Age	36.66	11.27					
2. income	10.82	0.80	-.04 [-.13, .05]				
3. FFMQ	77.35	10.93	.22** [.13, .31]	.11* [.02, .20]			
4. IUS	39.81	9.88	-.13** [-.22, -.04]	-.14** [-.23, -.05]	-.48** [-.55, -.40]		
5. PPEuse	8.09	2.45	-.20** [-.29, -.11]	.05 [-.04, .15]	-.32** [-.40, -.24]	.44** [.36, .51]	
6. QOL	35.00	5.81	.03 [-.06, .13]	.18** [.09, .27]	.30** [.22, .38]	-.13** [-.22, -.04]	.12* [.03, .21]

Table 1. Means, Standard deviations, and correlations with confidence intervals
Note. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.
Income: log of annual income; **FFMQ**: Five-Factor Mindfulness Questionnaire score (measurement of mindfulness); **IUS**: Intolerance of Uncertainty total score; **PPEuse:** Personal Protective Equipment use; **QOL**: Quality of Life total

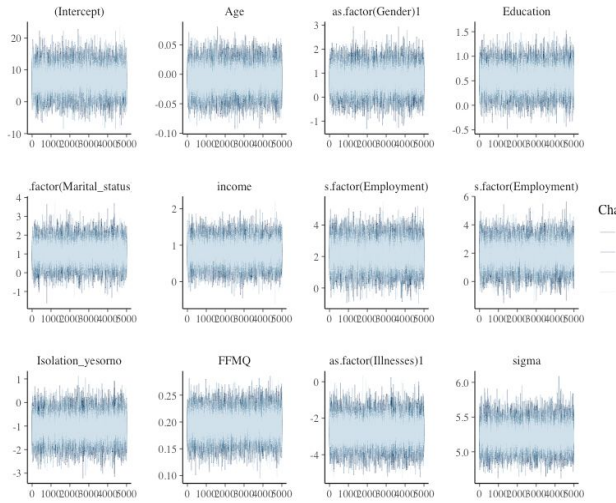

Figure 2. Trace Plots of MCMC chains for Bayesian regression in association model

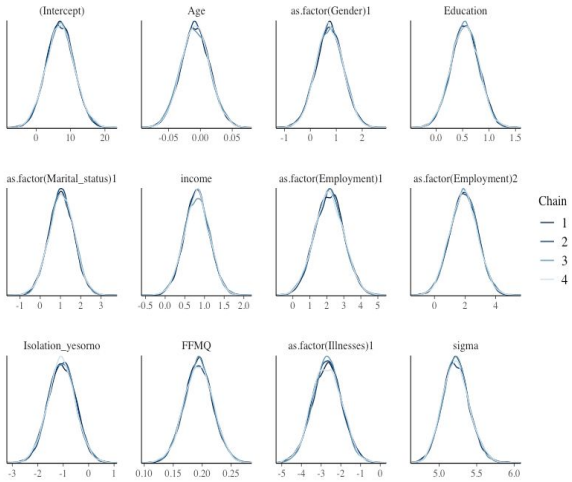

Figure 3. Density plots for Bayesian regression MCMC chains

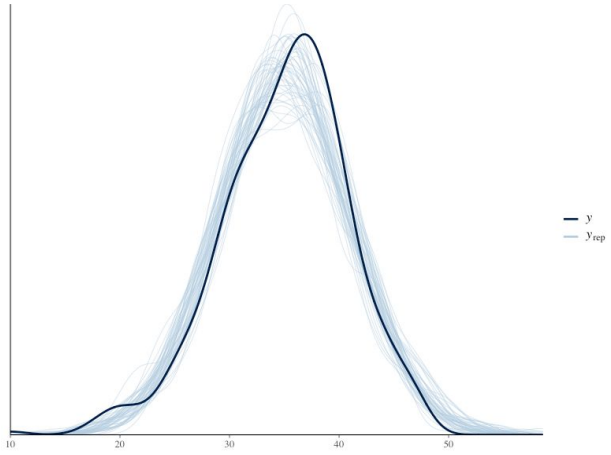

Figure 4. Distribution of observed y values and 50 predicted y values

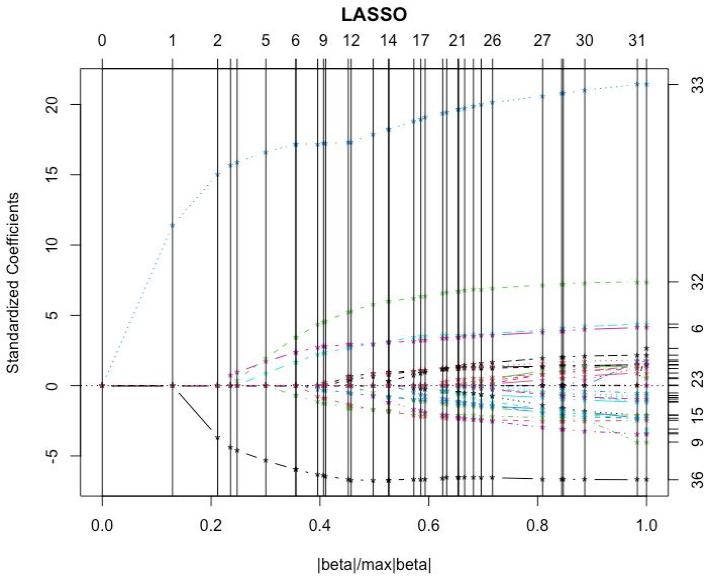

Figure 5. Regular LASSO Model for predicting PPE usage.

Variables	meanβ	mcse	sd	Rhat	5%	95%
(Intercept)	6.96	0.02	4.04	0.9998455	0.32	13.74
Age	-0.01	0.00	0.02	0.9999322	-0.05	0.03
Gender: Male	0.74	0.00	0.52	0.9998303	-0.12	1.61
Education	0.54	0.00	0.26	0.9999407	0.11	0.97
Illnesses: Yes	-2.70	0.00	0.74	0.9999113	-3.92	-1.49
Marital Status: Relationship	1.05	0.00	0.62	1.0000193	0.02	2.08
Annual Income	0.81	0.00	0.32	0.9999403	0.28	1.34
Employment: Part-Time	2.13	0.01	0.86	0.9999043	0.71	3.54
Employment: Full-Time	1.92	0.01	0.9	0.9999595	0.43	3.38
Self Isolation: Yes	-1.06	0.00	0.55	0.9999676	-1.96	-0.16
FFMQ	0.19	0.00	0.02	1.0001050	0.15	0.23
sigma	5.23	0.00	0.18	0.9998415	4.94	5.53

Table 2. Bayesian Regression Output

mae	mae_scaled	within_50	within_95
3.25	0.91	0.53	0.96

Table 3. Cross-Validation of Bayesian Multiple Regression Model

Variables	beta	median β	median τ^2
Age	beta1	-0.001	0.325
Religion	beta4	-0.171	0.14
Marital status	beta8	0.396	0.249
Education	beta9	0.171	0.248
Intolerance of Uncertainty	beta35	0.132	0.154
Avoid Public Setting	beta36	0.049	0.059

Table 4. Variables selected for optimal prediction of PPE usage in Bayesian LASSO model.

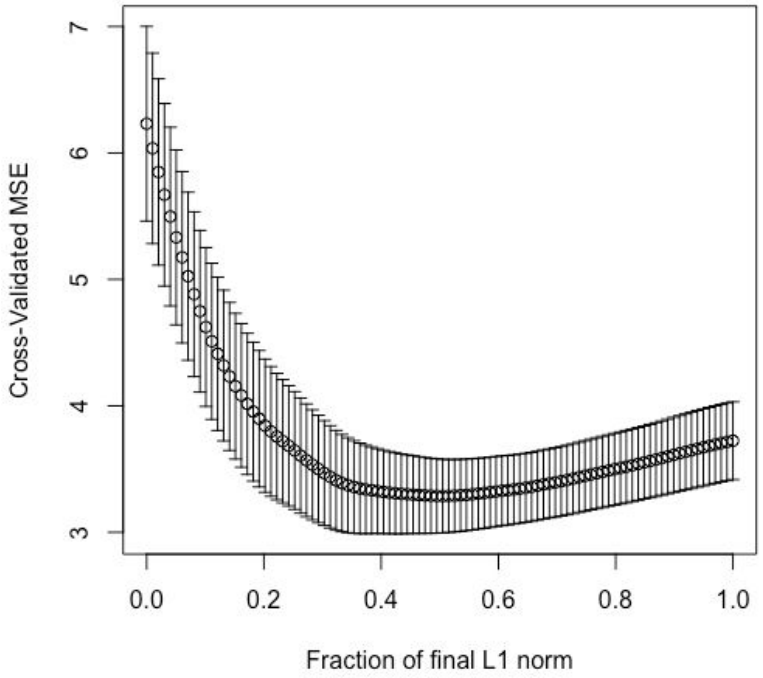

Figure 6. Cross-Validation on the Bayesian LASSO Model for predicting PPE usage. The optimal lambda square parameter where MSE was minimized was at 0.415.