STA490 2019-20 Winter Project Final Report

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Summary

This report investigates the effects of exercise on the mental health status. In the experimental design, mental health status is measured by a mental health indicator which assesses the subject's concentration, energy level, feeling and sleep quality. For each of the indicators, the lower the indicator values, the better the mental health status. Whereas the level of exercise is defined by whether or not the subjects have met the recommended levels of exercise set in the WHO guidelines. For those who have met the requirements, they would be placed into the treatment group, and for those who did not, they would be placed into the control group.

It is found that the average hours of sleep, number of stressors and survey month are covariates that influence the mental health status, then the main predictor variable the levels of exercise. It is found that the treatment and control groups indicating the levels of exercise have very little to none effect on the mental health status. This answers the research question, showing that the recommended levels of exercises provided by the WHO, have little to no positive effects on the mental health status of the subjects.

Introduction

Many studies have suggested that physical activity has positive effects on health conditions of a person with health benefits, including but not limited to: lower risk of cardiovascular disease, hypertension, diabetes, and better mental health (Stevens, Gretchen & Riley, Leanne & Bull, Fiona, 2018). In recognition of this strong link between physical activity and general health of the population, the World Health Organization (WHO) has implemented guidelines, recommending the levels of physical activities that adults aged 18-64 should partake each week, to improve cardiorespiratory and muscular fitness, bone health, reduce the risk of NCDs and depression (WHO, 2010). The recommendations include: 1) Adults aged 18–64 should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week or 2) do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week or 3) an equivalent combination of the physical activity mentioned above.

The research question of this study is to determine whether or not the recommended levels of exercises provided by the WHO, have positive effects on the mental health status of a subject. The observations are collected from 140 PSL372 students who have agreed to provide information related to their exercise frequency and mental health status, through monthly surveys conducted over the span of 3 months (September-November 2019). In the experimental design, the subject's mental health status is measured by the mental health indicator created using question 15-19 of the survey [Appendix A], which assesses the subject's concentration, energy level, feeling and sleep quality. On a likert scale of 1-7, the lower the indicator the subject is at, the better the mental health status. On the other hand, the treatment group is defined by those who have met the recommended levels of exercise set in the WHO guidelines.

The reminder of the report is organized as follows. In the Method section, the results from the initial exploratory data analysis are first discussed, undercovering the observed trends and relationship between mental health status, levels of exercise and various covariates. Then, the model selection process from the data analysis is discussed, explaining the components of the chosen generalized linear mixed model, which include four covariates and one random effect. In the Result section, first the results from the simple model and final model are compared. Then, the effects of individual predictor variables and covariates are assessed, revealing whether or not they have statistical significance on the mental health status of the subjects. Lastly in the Conclusion & Discussion section, the results are summarized and interpreted to answer the research question. Additionally, the limitations, concerns for the statistical method, and suggestions for future experimental designs are discussed.

Methods

Feature Selection

In the initial exploratory data analysis, graphical tools such as boxplots, histograms and heatmaps are used to examine the relationship between mental health status and levels of exercise of the subjects. Visualizations are created to compare the mental health status of the subjects under different variables, including the main predictor variable levels of exercise, and potentially relevant covariates such as the age, the Body Mass Index (BMI), number of stressors, average hours of sleep,

the activeness of the subject and the month the survey was conducted. From this process, it is found that besides the levels of exercise, BMI, number of stressors, average hours of sleep and survey month seem to have significant effects on mental health status.

Model Selection

In the data analysis, a generalized linear mixed model is used. Although the four covariates used are not directly related to the primary research question, given their significant effects on the response variable, their inclusion may improve the model fit. In the experimental design, each subject provided three observations, hence there is no independence in the data and pseudoreplication may exist. It is found that the differences among subjects attribute 52.4%[Appendix B] to the variability in the mental health status. In this case, a linear mixed model may be the most appropriate model to use.

This model is fitted with the number of stressors, average hours of sleep, BMI of the subjects and survey month, and the subject's ID is included as a random effect. The random effect is assumed to follow a normal distribution independent of the error term. The model also assumes that the intercepts differ randomly across the 140 subjects, but the mental health status changes with the levels of exercise. For comparison, I also used a simple model that includes the levels of distractions as the only predictor variable.

Results

As mentioned before, for comparison we have fitted a model that includes the levels of exercise as the only predictor variable.

	Estimate	Std. Error	Pr(>|t|)	2.5 %	97.5 %
(Intercept)	3.150	0.080	0.00	2.994	3.307
Treatment	-0.061	0.138	0.66	-0.333	0.211

Table 1. Coefficient Estimates for Simple Model

From Table 1, it seems like without any other covariates, the treatment group does have somewhat better mental health status compared to the control group, as it has a lower estimate by -0.061(p-value = 0.66). However the estimate of the treatment group does not seem to have a statistically significant difference compared to that of the control group, as the 95% CI of the estimate contains zero and it has a p-value of 0.66 > 0.05. Hence, I am not able to draw any conclusions from this model.

	numDF	denDF	F-value	p-value
(Intercept)	1	261	1575.301	0.000
Treatment	1	261	0.476	0.491
as.factor(BMI)	4	261	5.977	0.000
as.factor(AvgHoursOfSleep)	7	261	8.916	0.000
as.factor(NumStressors)	5	261	11.915	0.000
as.factor(SurveyMonth)	2	261	7.507	0.001

Table 2. ANOVA Summary Table for Final Model

Table 2 is an ANOVA table that breaks down the components of variation. It includes BMI of the subjects, average hours of sleep, number of stressors and month of survey as the potential significant covariates of mental health indicators. From the table, it seems like the p-values for the chosen covariates are low (<0.05), indicating that they have significant effects on the mental health status. Whereas for the levels of exercise, the estimate of the treatment group does not seem to have a significant difference compared to that of the control group given its p-value of 0.49 > 0.05. This outcome is somewhat aligned with the result I derived from the simple model. However, ANOVA test does not reflect the directions and degrees of the effects, thus I need to run a post-hoc analysis to determine which of the individual level comparisons are significant and whether or not there is a trend within each of the variables.

	Value	Std.Error	p-value	lower	upper
(Intercept)	5.168	0.339	0.000	4.501	5.835
Treatment	-0.046	0.116	0.692	-0.276	0.183
as.factor(BMI)>29.9	0.613	0.387	0.115	-0.150	1.375
as.factor(BMI)0	0.478	0.578	0.409	-0.660	1.616
as.factor(BMI)18.5-24.9	-0.128	0.216	0.553	-0.554	0.297
as.factor(BMI)25-29.9	0.197	0.284	0.489	-0.362	0.755
as.factor(AvgHoursOfSleep)>9	-0.597	0.464	0.199	-1.510	0.316
as.factor(AvgHoursOfSleep)0	-1.739	0.576	0.003	-2.874	-0.604
as.factor(AvgHoursOfSleep)5	-0.741	0.287	0.010	-1.306	-0.176
as.factor(AvgHoursOfSleep)6	-0.963	0.278	0.001	-1.510	-0.416
as.factor(AvgHoursOfSleep)7	-1.317	0.280	0.000	-1.867	-0.766
as.factor(AvgHoursOfSleep)8	-1.351	0.298	0.000	-1.938	-0.764
as.factor(AvgHoursOfSleep)9	-1.401	0.353	0.000	-2.095	-0.707
as.factor(NumStressors)0	-1.001	0.211	0.000	-1.417	-0.585
as.factor(NumStressors)1	-1.044	0.167	0.000	-1.373	-0.714
as.factor(NumStressors)2	-0.642	0.156	0.000	-0.949	-0.335
as.factor(NumStressors)3	-0.722	0.156	0.000	-1.028	-0.415
as.factor(NumStressors)4	-0.587	0.194	0.003	-0.970	-0.204
as.factor(SurveyMonth)October	-0.253	0.097	0.009	-0.443	-0.063
as.factor(SurveyMonth)September	-0.379	0.101	0.000	-0.578	-0.179

Table 3. Coefficient Estimates for Final Model

Table 3 further elaborates the relationship between mental health status and the three covariates. From '(Intercept)', it can be inferred that the baseline estimate of mental health indicator is 5.168, for a subject in the control group with BMI < 18.5, slept for less than 5 hours on average, had more than 4 major stressors during the week of the survey, and completed the survey in November.

Level of Exercise/Treatment

The level of exercise seems to have no significant effect on the mental health status given its estimates and p-values. In the treatment group, the estimate only decreases by 0.046 (p-value=0.69), indicating that there is little to no difference in mental health status between the treatment and control group.

Body Mass Index (BMI) of Subjects

	Value	Std.Error	p-value	lower	upper
as.factor(BMI)18.5-24.9	-0.128	0.216	0.553	-0.554	0.297
as.factor(BMI)25-29.9	0.197	0.284	0.489	-0.362	0.755
as.factor(BMI)>29.9	0.613	0.387	0.115	-0.150	1.375

Table 3.1: Coefficient Estimates for Variable 'BMI'

Compared to the levels of exercises, the BMI of the subjects seems to have more influence on the mental health status of the subject. From the estimates there exists a trend, showing that in comparison with the baseline BMI (<18.5), subjects with BMI ranging 18.5-24.9 have lower estimates by 0.128 (p-value = 0.55), indicating they have better mental health status. Whereas subjects with BMI ranging 25-29.9 and above 29.9, have higher estimates by 0.197 (p-value = 0.49)and 0.613 (p-value = 0.12) respectively, indicating they have worse mental health status. This result is somewhat intuitive, people with BMI ranging 18.5-24.9 are typically considered to be within the healthy weight range, whereas people with BMI below 18.5 or above 24.9 are either underweight or overweight. Therefore, I can say that people with healthy weights have better mental health status than the others. However, given the p-values and 95% CI of these estimates containing zeroes, although there is a trend present, there is no sufficient evidence for me to draw that conclusion.

Average Hours of Sleep (In the Past Week)

	Value	Std.Error	p-value	lower	upper
as.factor(AvgHoursOfSleep)5	-0.741	0.287	0.010	-1.306	-0.176
as.factor(AvgHoursOfSleep)6	-0.963	0.278	0.001	-1.510	-0.416
as.factor(AvgHoursOfSleep)7	-1.317	0.280	0.000	-1.867	-0.766
as.factor(AvgHoursOfSleep)8	-1.351	0.298	0.000	-1.938	-0.764
as.factor(AvgHoursOfSleep)9	-1.401	0.353	0.000	-2.095	-0.707
as.factor(AvgHoursOfSleep)>9	-0.597	0.464	0.199	-1.510	0.316

Table 3.2: Coefficient Estimates for Variable 'Average Hours of Sleep'

From the estimates in Table 3.2, I can identify a clear relationship between this covariate and the mental health status: the higher the average hours of sleep, the lower the mental health indicator, which infers that the mental health status becomes better. Given the p-values and 95% CI's of the coefficient estimates, which are generally less than 0.05 and do not contain zero respectively, there is strong statistical evidence showing that there is a significant difference between the individual levels of hours of sleep, and the relationship is true. However, there is an exception at the estimate for average hours of sleep above 9 hours, coefficient estimate of this level decreases by 0.597 compared to the baseline level, with a 95% CI falling in the range of -1.51 and 0.32 which contains zero, and a p-value of 0.20. This indicates that perhaps too much sleep has little positive effect on improving mental health status.

Number of Major Stressors (In the Past Week)

	Value	Std.Error	p-value	lower	upper
as.factor(NumStressors)1	-1.044	0.167	0.000	-1.373	-0.714
as.factor(NumStressors)2	-0.642	0.156	0.000	-0.949	-0.335
as.factor(NumStressors)3	-0.722	0.156	0.000	-1.028	-0.415
as.factor(NumStressors)4	-0.587	0.194	0.003	-0.970	-0.204

Table 3.3: Coefficient Estimates for Variable 'Number of Stressors

From the estimates in Table 3.3, there also exists a clear relationship between the number of stressors and the mental health status of the subjects. It seems like the higher the number of major stressors the subjects are facing in that week, the higher the mental health indicator, inferring that the mental health status becomes worse. Given the p-values and 95% CI's of the coefficient estimates, which are generally less than 0.05 and do not contain zero respectively, there is strong statistical evidence showing that there is a significant difference between the individual number of stressors, and the relationship is true. This is also somewhat an intuitive result, as many studies have shown that stress is a major factor influencing the mental health status of a person.

Month the Survey was Taken

	Value	Std.Error	p-value	lower	upper
as.factor(SurveyMonth)October	-0.253	0.097	0.009	-0.443	-0.063
as.factor(SurveyMonth)September	-0.379	0.101	0.000	-0.578	-0.179

Table 3.4: Coefficient Estimates for Variable 'Survey Month'

The month the survey was taken also seems to have a significant effect on the mental health status. Compared to the baseline month November, the estimates for the month of September and October both decrease by 0.379 (p-value = 0.00) and 0.253 (p-value = 0.01) respectively, inferring that the mental health status of the subjects decreases throughout the school year. Given the p-values and 95% CI's which do not contain zero, I can also conclude that the month the survey was taken is a covariate with high statistical significance.

Conclusion & Discussion

In the model, it is found that the average hours of sleep, number of stressors and survey month are covariates that influence the mental health status, then the main predictor variable the levels of exercise. It is found that the treatment and control groups indicating the levels of exercise have very little to none effect on the mental health status. This answers the research question, showing that the recommended levels of exercises provided by the WHO, have little to no positive effects on the mental health status of the subjects. This model also provides some interesting insights on what contributes to a good mental health status. When analyzing the effect of BMI on mental health status, it is found that subjects within the normal range of BMI (18.5 - 24.9) tend to have a better mental health status, compared to the underweight or overweight individuals. When looking at the effect of sleep on mental health status, it is also found that subjects with a normal average hours of sleep (5-8 hours) tend to have a better mental health status than those who underslept or overslept.

There are three main limitations to the experiment. The first is the model sensitivity to the decision made in data cleaning. By removing or replacing values into the model, a different amount of bias can be introduced to the model. Secondly, the observations are collected from subjects with similar academic backgrounds and demographics, hence the sample selected for this study may not be as representative of the general population. Lastly, there is an imbalance in the sample sizes, with 143 observations in the treatment group and 277 observations in the control group. For future experimental design, a stratified randomized control trial would be more ideal, given it is able to ensure that there are no systematic differences existing between the treatment and control group. In this process, balance randomization can be used to ensure a similar distribution between the two groups in important variables thought to influence the results.

References

Stevens, Gretchen & Riley, Leanne & Bull, Fiona. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. The Lancet Global Health. 6. 10.1016/S2214-109X(18)30357-7.

Global Recommendations on Physical Activity for Health. Geneva: World Health Organization; 2010. Available from: https://www.ncbi.nlm.nih.gov/books/NBK305057/

Appendix

Appendix A: Survey Questions Related to Mental Health Status

During the <u>past week</u>, did you find that you had,

	All the time	Every day	Nearly every day	More than half the days	Several days	One day	Not at all
15. Trouble concentrating on things, like studying	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ	Ⓖ
16. Little energy/tiredness	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ	Ⓖ
17. Unhappy or stressed feelings	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ	Ⓖ
18. Poor appetite or overeating	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ	Ⓖ
19. Trouble falling/staying asleep, slept too much	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ	Ⓖ

Appendix B: Random Effect Outputs from Final Model

	Variance	StdDev
(Intercept)	0.6685579	0.8176539
Residual	0.6063341	0.7786746