Consulting Report on The Effectiveness of Intervention on Mental Distress

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1 Introduction

Nowadays, mental distress has become a common social issue and is affecting the quality of life of many people. According to the American Psychiatric Association, up to nineteen (19) percent of adults in the United States experience some degree of mental illness [Ass21]. Particularly, amid the COVID-19 pandemic, the mental well-being of the general population has received an unprecedented amount of attention [TJ20]. It is therefore important to study the effectiveness of mental health interventions on reducing the level of mental distress.

This study investigates changes in participants' mental distress over time in an intervention group and a control group. Specifically, we try to answer whether the participants' mental distresses decrease over time and whether the mental health intervention is effective in reducing the level of mental distress.

This report begins by introducing the data recorded for this study and drawing preliminary conclusions through some explorative data analysis. The reliability of these preliminary conclusions are then checked through some model-based statistical analysis. Finally, we provide a discussion on the implication of the findings in this study. The R code used for this report can be found at `https://github.com/NaitongChen/STAT550IndividualProject`.

2 Exploratory Data Analysis

We begin by giving an overview of the data recorded in the study. A description of each variable is shown in Table 1. Note that a higher GSI score indicates a higher level of mental distress. There are five recordings of the GSI score (response) for each participant, measured respectively at the beginning of the study (0), and three (3), six (6), eighteen (18), and sixty (60) months later, as indicated by the month variable. While none of the other variables change over time, the repeated GSI measurements make this study longitudinal.

Of all 271 participants in the study, 57.6% were randomly placed in the intervention group and the remaining 42.4% were in the control group. Excluding those whose gender are unknown, 34.1% of the participants are male and 65.9% are female (Table 9). While the split between the two treatment groups is roughly balanced, there may be a slight underrepresentation of male participants in the data. However, since there are as many as 271 participants in total, there are still many participants that are male. Therefore there should not be a major impact of the unbalanced gender proportions.

SN	subject number
treatment	treatment received by each subject (1 for intervention and 2 for control)
month	measurement time (in month)
gender	gender of each subject (1 for male and 2 for female)
education	education received by each subject (in years)
GSI	Global Severity Index: an index indicating level of mental distress

Table 1: Description of all variables recorded in the study

The means and standard deviations of all continuous variables are shown in Table 2. We see that the GSI scores decreases over time while the corresponding standard deviations roughly stay consistent. Another observation is that the GSI scores are much smaller in magnitude compared to the education and month variables. This difference in scale may make the estimated effects of these explanatory variables on GSI unusually small. To aviod getting results of low interpretability, the GSI scores are scaled by a factor of ten (10) for the remainder of this report.

A common issue in longitudinal studies is missing data. As expected, with the GSI scores recorded over the span of five years, some of the response values are missing. This is common as some of the participants may have dropped out of the study for various reasons. In addition, some participants' gender and amount of

education received are also missing. The count of missing values and the corresponding proportion of missing values are shown in Table 3. It is clear that more participants dropped out of the study as time went on. With the missing rates as high as 38.7%, it is important that we address the sensitivity of our subsequent analysis to these missing data in Section 3.

	education	GSI (0)	GSI (3)	GSI (6)	GSI (18)	GSI (60)
mean	13.705	1.125	1.036	0.854	0.834	0.780
sd	2.360	0.722	0.702	0.638	0.559	0.625

Table 2: Summary statistics for continuous variables

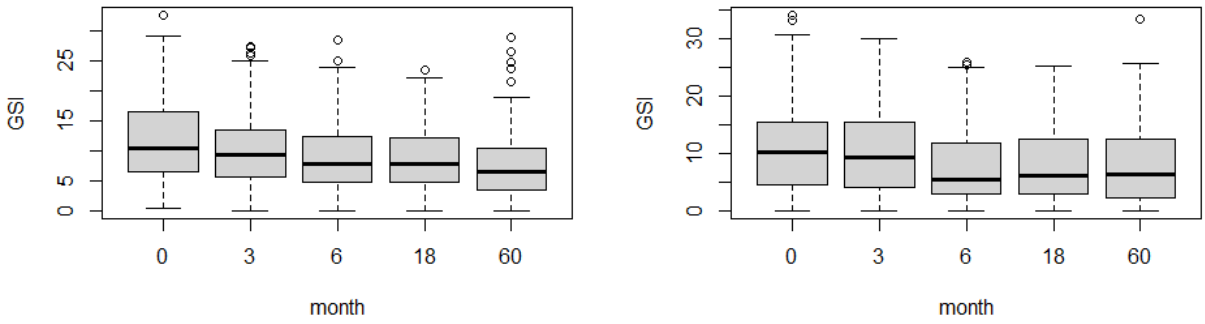
	gender	education	GSI (0)	GSI (3)	GSI (6)	GSI (18)	GSI (60)
count	4	7	10	38	52	105	98
proportion	0.015	0.026	0.037	0.140	0.192	0.387	0.362

Table 3: Missing rates of all variables in the study

2.1 Visualization of GSI

We now use side-by-side boxplots to get a rough idea of how the two main questions laid out in Section 1 can be answered. We first visualize the changes in the GSI scores over time for both the intervention group and the control group. Note that the p-values of the ANOVA and Kruskal-Wallis tests are also included in the caption for each of the two groups. In this case, ANOVA, as a generalization of the commonly known t-test, tests whether the mean GSI scores are the same across each of the five time points. Since ANOVA assumes the data to be normally distributed, which may not hold, the Kruskal-Wallis test is also conducted as a non-parametric alternative. The Kruskal-Wallis test does not make the normality assumption and is relatively robust against outliers, which can be seen to be present in Figure 1. The Kruskal-Wallis test here serves as a reference to check the reliability of the results from the ANOVA tests.

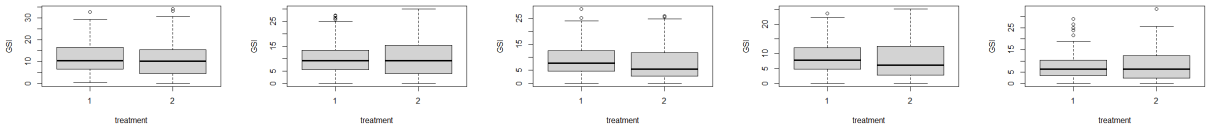
From Figure 1, we see that a downward trend of GSI over time is present in both groups. At the same time, the p-values from the ANOVA and Kruskal-Wallis tests (all < 0.021) indicate that there is moderate to strong evidence against that the mean GSI scores are the same across all five time points. It is then suggested that the participants' mental distresses in both groups decrease significantly over time.



(a) intervention group (ANOVA: 0, Kruskal-Wallis: 0) (b) control group (ANOVA: 0.021, Kruskal-Wallis: 0.006)

Figure 1: Side-by-side boxplots of the GSI scores across measurement times for each treatment group

To visualize whether the GSI scores are different between the intervention group and the control group at each of the five time points, we again use side-by-side boxplots. This is shown in Figure 2. Similarly, the p-values of two-sample t-tests and Wilcoxon tests are included in the caption to quantify the evidence we have against that the mean GSI scores are equal. Again, since the t-test assumes the data to be normally distributed and may be sensitive to outliers, the Wilcoxon test serves as a robust alternative. By the boxplots in Figure 2, the GSI scores of the two groups do not seem to differ much in any of the five times points. The p-values from the t-tests and Wilcoxon tests also indicate that, for the most part, there is no evidence against that the mean GSI scores between the two groups are the same.



(a) baseline (t-test: 0.457, Wilcoxon: 0.271) (b) 3 months (t-test: 0.995, Wilcoxon: 0.489) (c) 6 months (t-test: 0.332, Wilcoxon: 0.084) (d) 18 months (t-test: 0.405, Wilcoxon: 0.167) (e) 60 months (t-test: 0.826, Wilcoxon: 0.831)

Figure 2: Side-by-side boxplots of the GSI scores between two treatment groups across measurement times

2.2 Association between Explanatory Variables

Before summarizing our preliminary conclusions, it is worth inspecting the association between the two explanatory variables: gender and education. Since the gender variable is categorical, instead of computing the Pearson correlation coefficient, we use a side-by-side boxplot to study the association between the two variables Figure 3. Again, the p-values of t-test and Wilcoxon test are included in the caption. The plot suggests that the male participants as a group has received more education in terms of the number of years. The p-values (0.014 and 0.045) also indicates that there is moderate to strong evidence that the mean amount of education received in years among the male participants is different than that of the female participants. It is then possible that one of the two explanatory variables is enough to explain much of the variability present in the GSI scores of the corresponding participants. It is then worth inspecting whether including both of these explanatory variables leads to better fit models in Section 3.

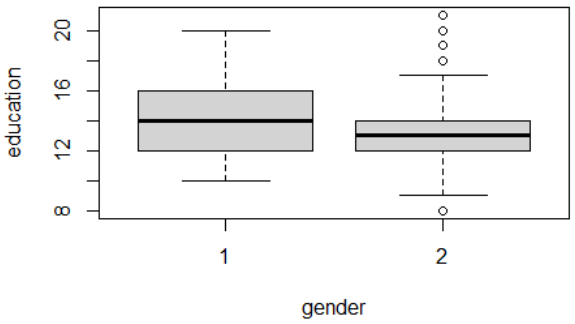


Figure 3: Side-by-side boxplot of education between the two genders (t-test: 0.014, Wilcoxon: 0.045)

2.3 Preliminary Conclusions

From the above graphical displays of the response variable, it is suggested that the participants' mental distresses in both the intervention group and the control group decrease over time. However, there does not seem to be a clear indication that the mental health intervention leads to a lower level of mental distress when compared to the control group. It is worth noting that the above preliminary conclusions are drawn without considering the gender and amount of education received of each participant. It is possible that these two explanatory variables exaggerate the effect of time or mask the effect of the mental health intervention on mental distress. Therefore, further analysis using various statistical models needs to be conducted to check the reliability of the conclusions drawn from the above exploratory data analysis.

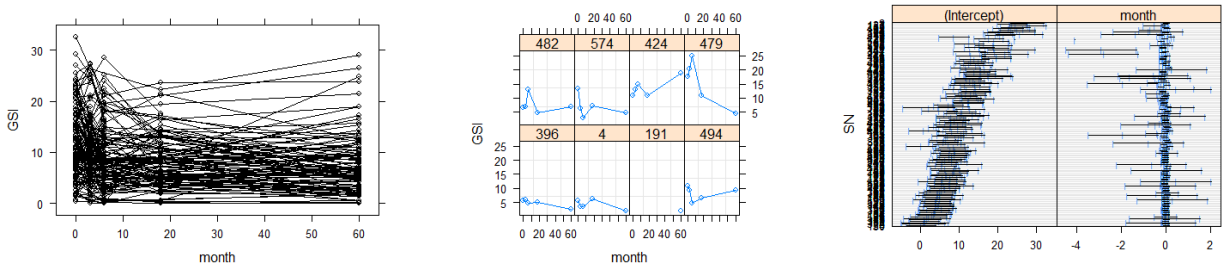
3 Model-Based Statistical Analysis

AIC [Wu09]

3.1 Model Selection

	month	month + gender	month + education	month + gender + education
AIC	3979.734	3947.393	3976.155	3946.259
BIC	3992.965	3965.027	3993.789	3968.293

Table 4: Comparison of models with different covariates under the intervention group



(a) trellis plot of all subjects in the intervention group

(b) trellis plot of randomly selected subjects

(c) confidence intervals of parameters from individual linear models

Figure 4: Diagnostic plots for selection of random effects for the intervention group

	no mixed effect	intercept	intercept and slope
AIC	3946.259	3646.267	3643.133
BIC	3968.293	3672.708	3678.388

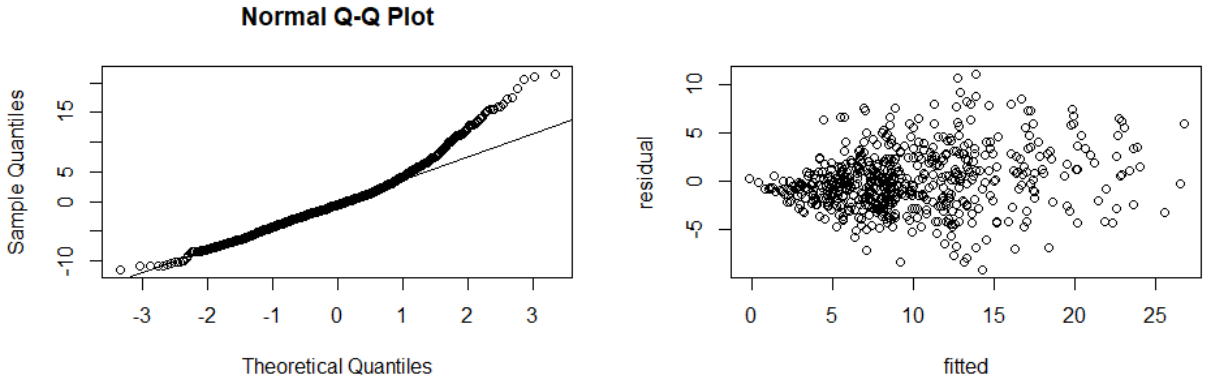
Table 5: Comparison of models with different mixed effects under the intervention group

	no mixed effect	intercept	intercept and slope
no mixed effect	N/A	0	0
intercept	0	N/A	0.028
intercept and slope	0	0.028	N/A

Table 6: P values of Likelihood Ratio tests between models with different mixed effects under the intervention group

3.2 Change in Mental Distress over Time in Each Group

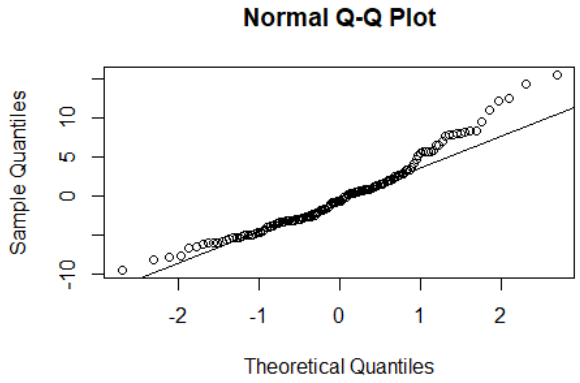
3.2.1 Assumption Check



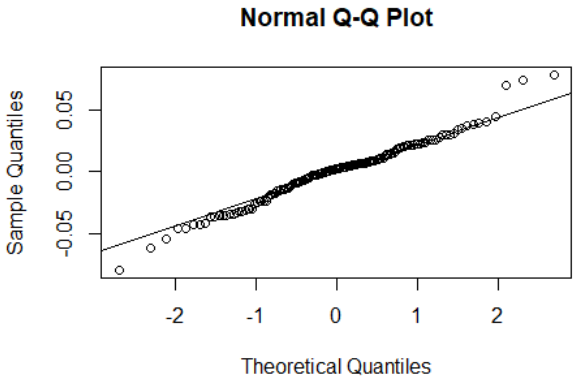
(a) residual QQ plot

(b) fitted value vs. residual (t-test: 1, Wilcoxon: 0.204)

Figure 5: Visualizing the residuals of the LME model under the intervention group



(a) QQ plot for the random effects on the intercept (t-test: 1, Wilcoxon: 0.335)



(b) QQ plot for the random effects on the slope (t-test: 1, Wilcoxon: 0.781)

Figure 6: Visualizing the random effects under the intervention group

3.2.2 Linear Mixed Model

3.2.3 Generalized Estimating Equation

	Value	Std.Error	DF	t-value	p-value
(Intercept)	11.933	2.758	465	4.326	0.000
month	-0.047	0.008	465	-5.671	0.000
gender2	2.764	0.925	141	2.990	0.003
education	-0.249	0.190	141	-1.314	0.191

Table 7: Output of Linear Mixed Model under the intervention group

	Estimate	Naive S.E.	Naive z	Robust S.E.	Robust z
(Intercept)	11.162	2.484	4.494	2.538	4.397
month	-0.047	0.010	-4.477	0.008	-5.852
gender2	2.827	0.834	3.391	0.869	3.253
education	-0.194	0.170	-1.146	0.173	-1.125

Table 8: Output of GEE model under the intervention group

3.3 Effectiveness of Intervention

3.3.1 Linear Mixed Model

3.3.2 Assumption Check

3.3.3 Generalized Estimating Equation

3.4 Handling Missing Data

3.4.1 Change in Mental Distress over Time in Each Group

3.4.2 Effectiveness of Intervention

4 Conclusions and Discussion

References

[Ass21] A. P. Association. *What Is Mental Illness?* https://www.psychiatry.org/patients-families/what-is-mental-illness. Online; accessed 18-April-2021. 2021.

[TJ20] J. M. Twenge and T. E. Joiner. "Mental distress among US adults during the COVID-19 pandemic". In: *Journal of Clinical Psychology* 76.12 (2020), pp. 2170–2182.

[Wu09] L. Wu. *Mixed effects models for complex data*. CRC press, 2009.

A Supplementary Plots

	treatment		gender
intervention	0.576	male	0.341
control	0.424	female	0.659

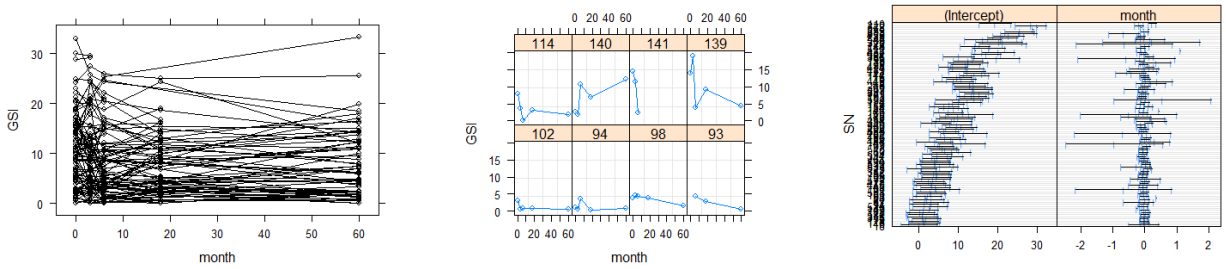
Table 9: Summary statistics (proportion) for categorical variables

	month	month + gender	month + education	month + gender + education
AIC	2756.056	2731.897	2717.689	2705.601
BIC	2768.067	2747.902	2733.695	2725.595

Table 10: Comparison of models with different covariates under the control group

	month	month + gender	month + education
intervention	0.016	0	0
control	0	0	0

Table 11: P values of Likelihood Ratio tests between models with different covariates for each treatment group



(a) trellis plot of all subjects in the control group

(b) trellis plot of randomly selected subjects

(c) confidence intervals of parameters from individual linear models

Figure 7: Diagnostic plots for selection of random effects for the control group

	no mixed effect	mixed effect on intercept	mixed effect on both intercept and month
AIC	2705.601	2415.440	2415.845
BIC	2725.595	2439.433	2447.837

Table 12: Comparison of models with different mixed effects under the control group

	no mixed effect	mixed effect on intercept	mixed effect on both intercept and month
no mixed effect	N/A	0	0
mixed effect on intercept	0	N/A	0.166
mixed effect on both intercept and month	0	0.166	N/A

Table 13: P values of Likelihood Ratio tests between models with different mixed effects under the control group

	month	month + gender	month + education	month + gender + education
AIC	6733.685	6676.801	6695.365	6650.988
BIC	6753.371	6701.404	6719.968	6680.506

Table 14: Comparison of models with different covariates

month	month + gender	month + education
0	0	0

Table 15: P values of Likelihood Ratio tests between models with different covariates

	no mixed effect	mixed effect on intercept	mixed effect on both intercept and month
AIC	6650.988	6060.302	6053.840
BIC	6680.506	6094.740	6098.118

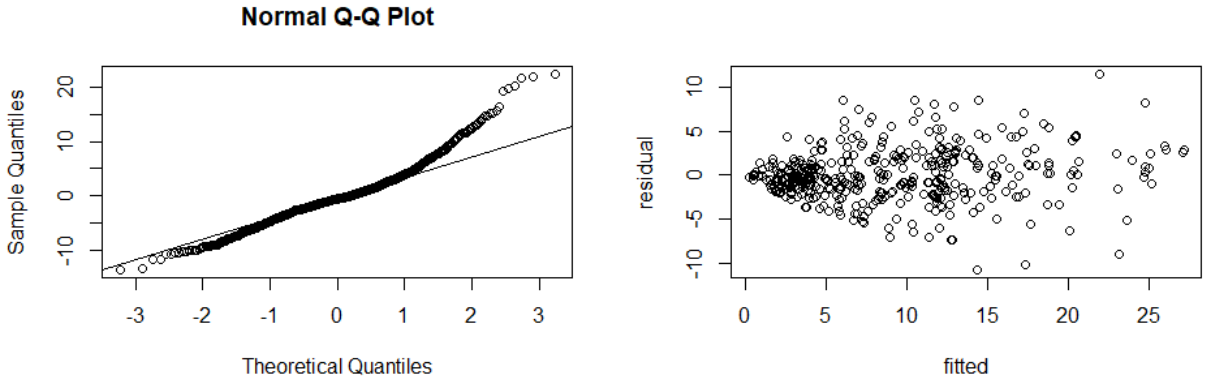
Table 16: Comparison of models with different mixed effects

	no mixed effect	mixed effect on intercept	mixed effect on both intercept and month
no mixed effect	N/A	0	0
mixed effect on intercept	0	N/A	0.005
mixed effect on both intercept and month	0	0.005	N/A

Table 17: P values of Likelihood Ratio tests between models with different mixed effects

	Value	Std.Error	DF	t-value	p-value
(Intercept)	19.235	4.151	308	4.634	0.000
month	-0.020	0.008	308	-2.394	0.017
gender2	2.606	1.383	95	1.884	0.063
education	-0.822	0.273	95	-3.015	0.003

Table 18: Output of Linear Mixed Model under the control group



(a) residual QQ plot

(b) fitted value vs. residual (t-test: 1, Wilcoxon: 0.501)

Figure 8: Visualizing the residuals of the LME model under the control group

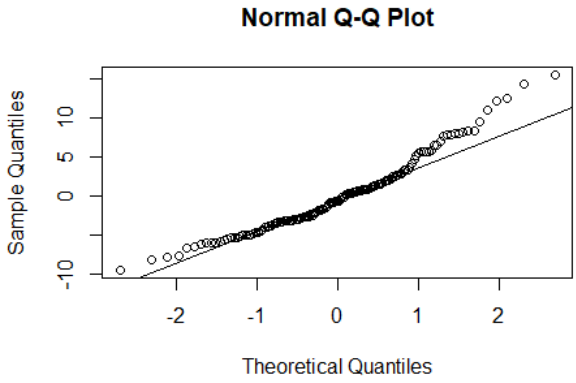


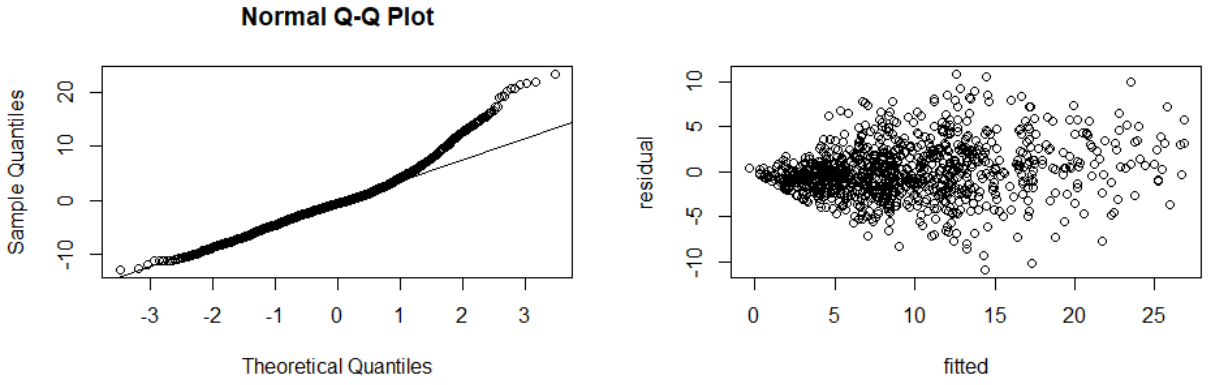
Figure 9: QQ plot for the random effects on the intercept (t-test: 1, Wilcoxon: 0.405)

	Estimate	Naive S.E.	Naive z	Robust S.E.	Robust z
(Intercept)	19.267	3.433	5.613	3.229	5.967
month	-0.027	0.013	-2.019	0.010	-2.606
gender2	2.220	1.148	1.935	1.216	1.825
education	-0.809	0.225	-3.596	0.203	-3.994

Table 19: Output of GEE model under the control group

	Value	Std.Error	DF	t-value	p-value
(Intercept)	15.418	2.341	774	6.586	0.000
treatment2	-0.193	0.731	238	-0.264	0.792
month	-0.037	0.006	774	-5.893	0.000
gender2	2.737	0.776	238	3.527	0.001
education	-0.516	0.157	238	-3.295	0.001

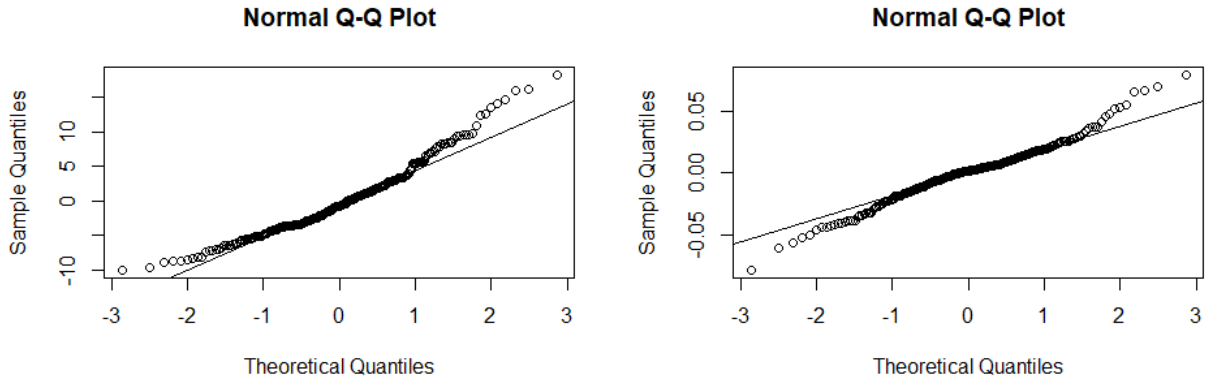
Table 20: Output of Linear Mixed Model



(a) residual QQ plot

(b) fitted value vs. residual (t-test: 1, Wilcoxon: 0.143)

Figure 10: Visualizing the residuals of the LME model



(a) QQ plot for the random effects on the intercept (t-test: 1, Wilcoxon: 0.207)

(b) QQ plot for the random effects on the slope (t-test: 1, Wilcoxon: 0.786)

Figure 11: Visualizing the random effects

	Estimate	Naive S.E.	Naive z	Robust S.E.	Robust z
(Intercept)	14.685	2.046	7.176	2.053	7.154
treatment2	-0.430	0.641	-0.671	0.735	-0.586
month	-0.039	0.008	-4.666	0.006	-6.040
gender2	2.693	0.680	3.961	0.716	3.763
education	-0.455	0.136	-3.337	0.139	-3.278

Table 21: Output of GEE model

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	11.526	2.809	4.104	231.840	0.000	0.151	0.139
month	-0.045	0.011	-3.999	23.557	0.001	0.701	0.456
gender2	2.734	0.968	2.824	239.207	0.005	0.149	0.137
education	-0.222	0.199	-1.115	107.937	0.268	0.238	0.207

Table 22: Output of pooled Linear Mixed Model under the intervention group

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	19.695	4.011	4.910	1786.900	0.000	0.050	0.048
month	-0.032	0.012	-2.571	10.407	0.027	1.631	0.677
gender2	2.277	1.315	1.732	5112.727	0.083	0.029	0.028
education	-0.828	0.268	-3.096	802.808	0.002	0.076	0.073

Table 23: Output of pooled Linear Mixed Model under the control group

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	11.102	2.789	3.981	158.677	0.000	0.189	0.169
month	-0.048	0.012	-4.090	12.698	0.001	1.279	0.617
gender2	2.733	0.942	2.902	355.509	0.004	0.119	0.111
education	-0.188	0.198	-0.947	78.666	0.347	0.291	0.244

Table 24: Output of pooled GEE model (naive) under the intervention group

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	20.598	4.119	5.000	208.709	0.000	0.161	0.147
month	-0.027	0.014	-1.999	14.750	0.064	1.087	0.575
gender2	1.821	1.328	1.371	440.506	0.171	0.105	0.099
education	-0.870	0.280	-3.103	105.337	0.002	0.242	0.210

Table 25: Output of pooled GEE model (naive) under the control group

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	11.102	2.692	4.124	137.732	0.000	0.205	0.182
month	-0.048	0.012	-3.939	14.758	0.001	1.086	0.575
gender2	2.733	0.908	3.009	307.277	0.003	0.129	0.120
education	-0.188	0.191	-0.985	67.256	0.328	0.323	0.265

Table 26: Output of pooled GEE model (robust) under the intervention group

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	20.598	3.695	5.575	135.062	0.000	0.208	0.184
month	-0.027	0.014	-1.949	16.329	0.069	0.980	0.547
gender2	1.821	1.302	1.399	406.382	0.163	0.110	0.104
education	-0.870	0.242	-3.590	58.813	0.001	0.353	0.285

Table 27: Output of pooled GEE model (robust) under the control group

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	14.858	2.439	6.091	135.244	0.000	0.208	0.184
treatment2	-0.171	0.733	-0.234	802.931	0.815	0.076	0.073
month	-0.039	0.009	-4.167	15.060	0.001	1.063	0.569
gender2	2.604	0.829	3.139	108.962	0.002	0.237	0.206
education	-0.467	0.172	-2.715	58.348	0.009	0.355	0.286

Table 28: Output of pooled Linear Mixed Model

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	14.644	2.449	5.980	98.809	0.000	0.252	0.217
treatment2	-0.223	0.724	-0.307	832.892	0.759	0.074	0.072
month	-0.039	0.011	-3.678	8.707	0.005	2.104	0.733
gender2	2.591	0.810	3.197	140.824	0.002	0.203	0.180
education	-0.446	0.173	-2.582	48.524	0.013	0.403	0.315

Table 29: Output of pooled GEE model (naive)

	Estimate	Std.Error	t.value	df	P value	RIV	FMI
(Intercept)	14.644	2.356	6.215	84.692	0.000	0.278	0.235
treatment2	-0.223	0.742	-0.300	917.614	0.764	0.071	0.068
month	-0.039	0.011	-3.594	9.554	0.005	1.833	0.703
gender2	2.591	0.786	3.298	124.401	0.001	0.218	0.192
education	-0.446	0.168	-2.655	43.400	0.011	0.436	0.334

Table 30: Output of pooled GEE model (robust)