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## The Relationship between Suicide Rates and Mental Health Provider Ratio

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## The Relationship between Suicide Rates and Mental Health Provider Ratio

### Abstract

This project is an analysis of the relationship between suicide rates and mental health provider ratio within the United States. Data from 2018 are collected for each state regarding its suicide rate, mental health provider ratio, and percent of population unable to receive treatment for mental health problems. An initial analysis is made using suicide rates and mental health provider ratio, with no correlation being found. A second analysis is conducted, using multiple linear regression with the percent of individuals within each state who were unable to access treatment for their mental health problems being the confounding variable. Controlling for the percent of individuals within each state who were unable to access treatment for their mental health problems provided a significant correlation between suicide rate and mental health provider ratio ( $R^2 = .961$ ). This allows for further analysis, using integration to determine the average suicide rate using the equation of the trendlines for the graphs of both the unadjusted and adjusted data. The average suicide rate for the unadjusted graph is 16.32 per 100,000. For the adjusted graph, this number is 16.07 per 100,000. Findings imply that access to mental health providers and treatment availability decreases the amount of suicides within the United States.

### Keywords

suicide rate, mental health provider ratio, multiple linear regression, matrix operations, average value of a function

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## PROBLEM STATEMENT

The mental health crisis within the United States involving suicide may be correlated with a lack of mental healthcare workers, so this concept should be analyzed.

## MOTIVATION

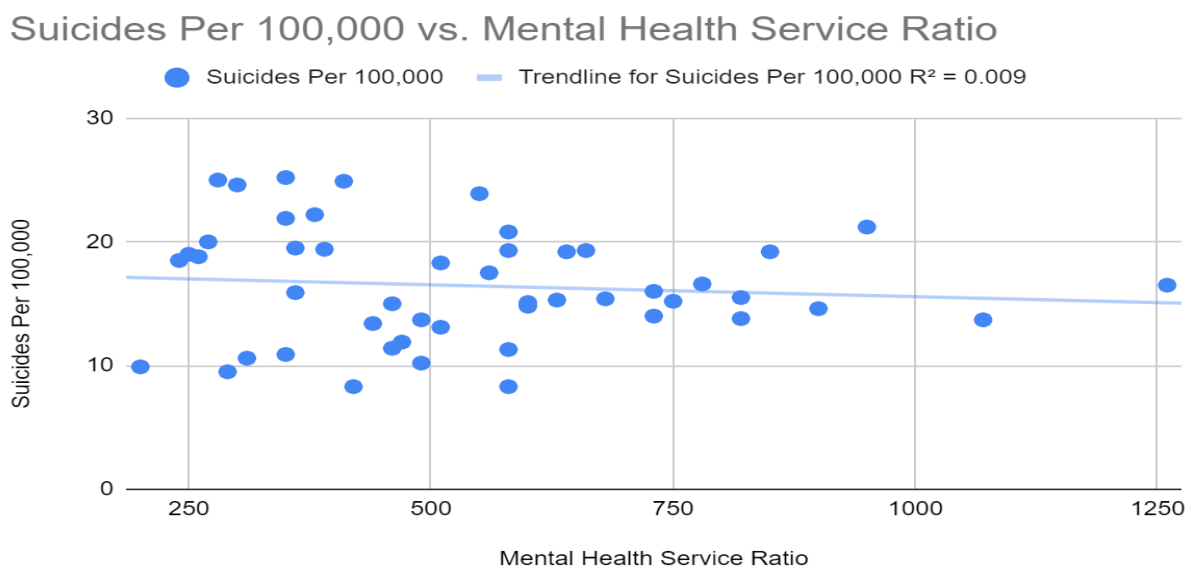
The mental health crisis in the United States is one of great importance, as rates of mental illness is relatively high. The effect of having mental health problems can be catastrophic for individuals, leading to many drastic consequences. Of these consequences is suicide, a major cause of death within the United States that has been increasing since 1999 (Stone et al., 2018). The United States struggles with this concept, which has led to a call for an increase in the amount of mental healthcare providers available (Walker et al., 2015). Access to mental healthcare providers would in theory, be crucial in reducing the amount of suicides. Thus, this paper aims to address how access to mental healthcare providers can affect suicide rates, by providing a mathematical analysis of how the ratio of mental healthcare workers within different regions affects suicide rates using data from. From this, implications regarding the reason for high suicide rates can be inferred.

## MATHEMATICAL DESCRIPTION AND SOLUTION APPROACH

To begin, data are collected from Mental Health America regarding the mental health provider ratio within each state in 2018 (Mental Health in America - Access to Care Data 2018, n.d.). Data are also collected from the CDC regarding the rates of suicide for each state (Stats of the State - Suicide Mortality, 2020). The mental health provider ratio displays how many people

there are per one mental health provider. The suicide rate displays how many suicides there are per 100,000 individuals. For both values, the lower the number the better. This is displayed in *Table 1* of the *Appendices*. The values are arranged into *Figure 1* shown below:

*Figure 1*



From *Figure 1*, no major trend is found within the data. Since there is a lack of statistical trend, multiple linear regression has to be used to account for a potential confounding variable. The confounding variable that is controlled for is the percent of individuals within each state population who do not have the ability to receive mental health treatment. See *Appendices*, *Table 2*.

To control for access to mental health treatment, data are converted into matrices for a multiple linear regression calculation. The suicide rate is variable  $Y$ ,  $X_1$  is the mental health provider ratio, and  $X_2$  is the percent of individuals who are unable to access treatment for their mental health problems. The multiple linear regression equation is:  $y = b_0 + b_1X_1 + b_2X_2$ . The intercept is  $b_0$ , while  $b_1$  and  $b_2$  are the regression coefficients for both the mental health provider

ratio and the percent of individuals who are unable to access treatment, respectively. To continue the multiple linear regression calculation, matrix X is generated:

*Matrix X (50 × 3)*

1	200	45.9
1	240	41.4
1	250	51.2
1	260	43.7
1	270	56.3
1	280	57.2
1	290	49.3
1	300	63.9
1	310	52.5
1	350	61.2
1	350	52.0
1	350	57.3
1	360	55.6
1	360	52.3
1	380	56.2
1	390	49.0
1	410	48.1
1	420	56.4
1	440	57.5
1	460	53.7
1	460	50.6
1	470	63.5
1	490	50.2

1	490	59.5
1	510	44.3
1	510	54.8
1	550	52.2
1	560	50.6
1	580	66.0
1	580	53.3
1	580	53.7
1	580	58.2
1	600	52.4
1	600	58.1
1	600	53.2
1	630	52.9
1	640	55.6
1	660	54.3
1	680	58.3
1	730	53.0
1	730	55.4
1	750	61.7
1	780	57.7
1	820	45.6
1	820	57.8
1	850	58.5
1	900	57.3
1	950	53.8
1	1070	60.4
1	1260	54.0



Matrix  $(X'X)^{-1}$  ( $3 \times 3$ )

2.263166185	0.00003432265	-0.04161335489
0.00003432265	0.00000041872267	-0.000004807005
-0.04161335489	-0.000004807005	0.000813562549

Then for the other half of the equation for matrix b, matrix  $X'$  is multiplied by

matrix Y ( $50 \times 1$ ):

Matrix  $X'Y$  ( $3 \times 1$ )

822.5
440889
44697.22

Now matrix  $(X'X)^{-1}$  and matrix  $(X'Y)$  are multiplied together in order to get matrix b:

Matrix b ( $3 \times 1$ )

16.58539054
-0.002019162285
0.01764416058

The first value of matrix b represents the intercept  $b_0$ . The second value represents the regression coefficient for  $X_1$ , or the Mental Health Provider ratio. Then the third value represents the regression coefficient for  $X_2$ , or the percent of individuals without the ability to receive treatment. This allows for the generation of the equation for the adjusted y-values:

$$y = 16.58539054 + (-0.002019162285)X_1 + (0.01764416058)X_2.$$



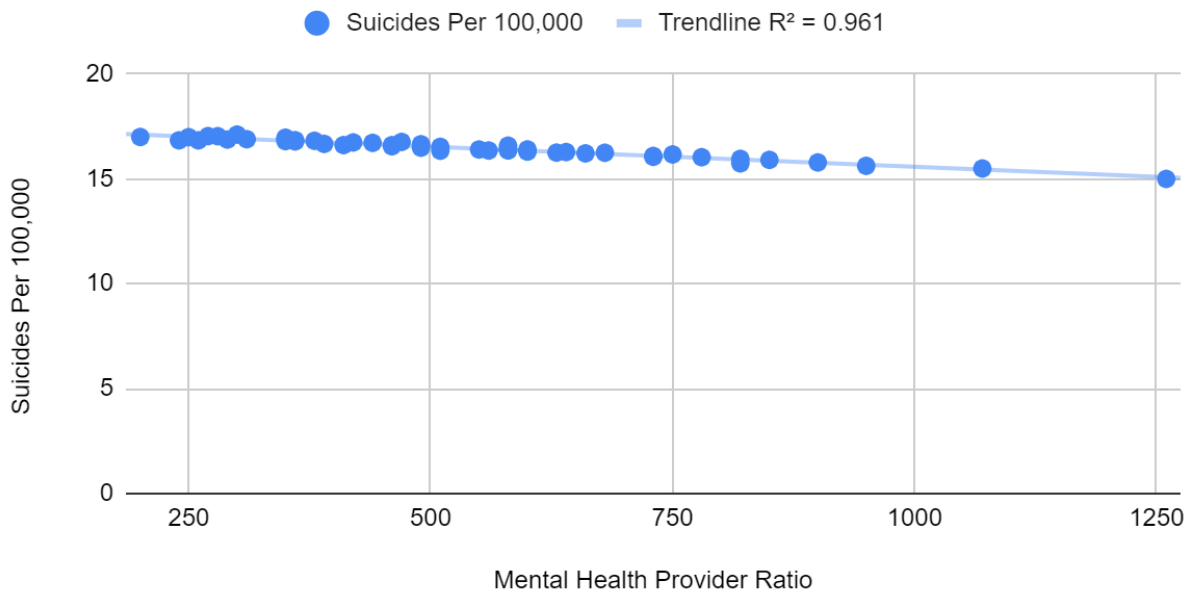
The equation allows for the creation of a table with the adjusted y-values for suicide rate, as well as mental health provider ratio. The table is displayed as *Table 3* in the *Appendices*.

This is graphed in *Figure 2* below:

*Figure 2*

## Suicides Per 100,000 vs. Mental Health Provider Ratio

Adjusted for Individuals Without Access to Mental Health Services



The trendline displays a significant trend, meaning that the data correlate when the confounding variable of individuals without access to mental health services, is removed. The data show a difference in suicide rate as mental health provider ratio changes, suggesting that access to healthcare is a significant factor when determining rates of suicide.

To further analyze the data, the equations of the trendlines are investigated. To do so, integrals of the trendlines are found to determine the average number of suicides within the range of the mental health provider ratio: 200-1260. The polynomial trendlines to the second degree are used for this calculation, as the linear trendlines are the same for both.

Trendline for Suicides Per 100,00 vs. Mental Health Provider Ratio (Without Adjustment):

$$f(x) = 19.6 - 0.00975x + 0.00000612x^2$$

$$F(x) = \int_0^x f(t)dt = 19.6x - 0.004875x^2 + 0.00000204x^3 \quad f_{ave} =$$

$$\frac{1}{(1260-200)} \int_{200}^{1260} f(x)dx$$

$$f_{ave} = [1/(1260-200)][F(1260) - F(200)] \approx (21037.2 - 3741.32)/1060 \approx 16.317$$

suicides per 100,000

Trendline for Suicides Per 100,000 vs. Mental Health Provider Ratio (With Adjustment):

$$f_A(x) = 17.4 - 0.00162x - 0.000000229x^2$$

$$F_A(x) = \int_0^x f_A(t)dt = 17.4x - 0.00081x^2 - 0.000000076333x^3$$

$$f_{A(ave)} = \frac{1}{(1260-200)} \int_{200}^{1260} f_A(x) dx$$

$$f_{A(ave)} = [1/(1260-200)][F_A(1260) - F_A(200)] \approx (20485.3 - 3446.99)/1060 \approx 16.074$$

suicides per 100,000

## DISCUSSION

The initial linear regression without any adjustments to the obtained data resulted in insignificant findings between suicide rates and mental health provider ratio. Multiple linear regression was required in order to find a correlation between suicide rates and mental health provider ratio, by accounting for a confounding factor. The confounding factor that was used was the percent of individuals within each state who were unable to access treatment for their mental health problems. After accounting for this the percent of individuals within each state who were unable to access treatment for their mental health problems, a correlation between suicide rates and mental health provider ratio was found, with an  $R^2$  value of .961. From the adjusted data,

there appeared to be no major difference within suicide rates when mental health provider ratio increased, however the graph did display a slight downwards trend as mental health provider ratio increased. This makes sense, as adjusting for individuals who did not have the ability to receive treatment allows the data to be viewed as if everyone is able to receive treatment, thus the effect of mental health provider ratio should be minimal on the adjusted graph. After calculating the average F value of the graphs using the equation of the polynomial trendline to the second degree, it was discovered that the average suicide rate was 16.32 per 100,000 before adjustment, while it was 16.07 after adjustment. Findings suggest access to mental health providers may decrease the suicide rate by 1.5%, if everyone has access to mental health providers.

There are many limitations to this investigation. The most glaring limitation is that there are many other confounding variables not addressed. This is especially present when investigating the adjusted graph, in which the suicide rate decreased as the mental health provider ratio increased, meaning that the more people per mental health provider, then the lower the suicide rate. Other limitations include the analysis of the polynomial trendline to the second degree, which provides values that do not quite fit the data. Overall however, it appears as though the rate of suicide decreases when everyone has access to mental health care, with the average suicides theoretically decreasing.

## CONCLUSION AND RECOMMENDATIONS

This project analyzes the relationship of suicide rates per 100,000 within each state, with the ratio of mental health providers (amount of people per mental health provider). Data are collected from 2018 from databases regarding these two factors for each state (Stats of the State -

Suicide Mortality, 2020); (Mental Health in America - Access to Care Data 2018, n.d.). From these data a graph is generated, but no strong correlation is displayed. Then data regarding the percent of the population within each state unable to receive treatment for mental health problems are collected from a database, and a multiple linear regression is used, controlling for the percent of the population unable to receive mental health treatment (Mental Health in America - Access to Care Data 2018, n.d.). The adjusted graph displays a correlation between suicide rate and mental health provider ratio, with an  $R^2$  value of .961. Analysis using integration displays the average suicide rate for the unadjusted and adjusted graph. The average suicide rate for the unadjusted graph is 16.32 per 100,000, while the average suicide rate for the adjusted graph is 16.07 per 100,000. This implies that access to mental health providers would generate a decrease in suicide within the population.

For further analysis, it is recommended to account for other confounding variables. This includes variables such as the rate of individuals who are unable to receive treatment due to insurance or financial issues, rather than a general unable to receive treatment category. Type of mental healthcare provider could also have been specified, in order to provide a more dynamic analysis.

## NOMENCLATURE

Symbol	Description
$Y$	The matrix of values related to suicide rates per 100,000
$X_1$	The matrix of values related to Mental Health Provider Ratio (amount of individuals per mental health provider)
$X_2$	The matrix of values related to the percent of individuals who were unable to receive treatment for mental health problems
$X$	The matrix of values that includes the values for the intercept, Mental Health Provider Ratio, and the percent of individuals who were unable to receive treatment for mental health problems, respectively
$X'$	The transposed matrix $X$
$X'X$	The transposed matrix $X'$ multiplied by matrix $X$

$(X'X)^{-1}$	The inverse of the transposed matrix $X'$ multiplied by matrix $X$
$X'Y$	The transposed matrix $X'$ multiplied by matrix $Y$
$b$	The matrix related to the coefficient values for multiple linear regression
$b_0$	The intercept of the multiple linear regression equation.
$b_1$	The regression coefficient for the values of the Mental Health Provider ratio
$X_1$	The values of the Mental Health Provider ratio
$b_2$	The regression coefficient for the percent of individuals unable to receive treatment
$X_2$	The values of the percent of individuals unable to receive treatment

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## APPENDICES

Table 1

State	Mental Health Provider Ratio	Suicides Per 100,000
Massachusetts	200	9.9
Maine	240	18.5
Oregon	250	19
Vermont	260	18.8
Oklahoma	270	20
New Mexico	280	25
Rhode Island	290	9.5
Alaska	300	24.6
Connecticut	310	10.6
California	350	10.9
Wyoming	350	25.2
Colorado	350	21.9
Washington	360	15.9
Missouri	360	19.5
Utah	380	22.2
New Hampshire	390	19.4
Montana	410	24.9
New York	420	8.3



Nebraska	440	13.4
Michigan	460	15
Delaware	460	11.4
Hawaii	470	11.9
North Carolina	490	13.7
Maryland	490	10.2
Minnesota	510	13.1
Arkansas	510	18.3
Idaho	550	23.9
Kentucky	560	17.5
Nevada	580	20.8
Illinois	580	11.3
Kansas	580	19.3
New Jersey	580	8.3
Wisconsin	600	14.8
Louisiana	600	15.1
Pennsylvania	600	14.9
Ohio	630	15.3
North Dakota	640	19.2
South Dakota	660	19.3
South Carolina	680	15.4
Virginia	730	14
Indiana	730	16

Florida	750	15.2
Tennessee	780	16.6
Iowa	820	15.5
Mississippi	820	13.8
Arizona	850	19.2
Georgia	900	14.6
West Virginia	950	21.2
Texas	1070	13.7
Alabama	1260	16.5

Sources:

(Mental Health in America - Access to Care Data 2018, n.d.)

(Stats of the State - Suicide Mortality, 2020)

*Table 2*

State	Suicides Per 100,000	Mental Health Provider Ratio	% With No Treatment
Massachusetts	9.9	200	45.9
Maine	18.5	240	41.4
Oregon	19	250	51.2
Vermont	18.8	260	43.7
Oklahoma	20	270	56.3
New Mexico	25	280	57.2
Rhode Island	9.5	290	49.3
Alaska	24.6	300	63.9

Connecticut	10.6	310	52.5
California	10.9	350	61.2
Wyoming	25.2	350	52.0
Colorado	21.9	350	57.3
Washington	15.9	360	55.6
Missouri	19.5	360	52.3
Utah	22.2	380	56.2
New Hampshire	19.4	390	49.0
Montana	24.9	410	48.1
New York	8.3	420	56.4
Nebraska	13.4	440	57.5
Michigan	15	460	53.7
Delaware	11.4	460	50.6
Hawaii	11.9	470	63.5
North Carolina	13.7	490	50.2
Maryland	10.2	490	59.5
Minnesota	13.1	510	44.3
Arkansas	18.3	510	54.8
Idaho	23.9	550	52.2
Kentucky	17.5	560	50.6
Nevada	20.8	580	66.0
Illinois	11.3	580	53.3

Kansas	19.3	580	53.7
New Jersey	8.3	580	58.2
Wisconsin	14.8	600	52.4
Louisiana	15.1	600	58.1
Pennsylvania	14.9	600	53.2
Ohio	15.3	630	52.9
North Dakota	19.2	640	55.6
South Dakota	19.3	660	54.3
South Carolina	15.4	680	58.3
Virginia	14	730	53.0
Indiana	16	730	55.4
Florida	15.2	750	61.7
Tennessee	16.6	780	57.7
Iowa	15.5	820	45.6
Mississippi	13.8	820	57.8
Arizona	19.2	850	58.5
Georgia	14.6	900	57.3
West Virginia	21.2	950	53.8
Texas	13.7	1070	60.4
Alabama	16.5	1260	54.0

Sources:

(Mental Health in America - Access to Care Data 2018, n.d.)

(Stats of the State - Suicide Mortality, 2020)

*Table 3*

Adjusted Suicide Rate Per 100,000	Mental Health Provider Ratio
16.99142505	200
16.83125984	240
16.98398099	250
16.83145816	260
17.03358296	270
17.02927109	280
16.86969059	290
17.10710372	300
16.88576866	310
16.95850637	350
16.79618009	350
16.88969414	350
16.83950745	360
16.78128172	360
16.8097107	380
16.66248112	390
16.60621813	410
16.73247304	420
16.71149837	440

16.60406731	460
16.54937041	460
16.75678846	470
16.48173788	490
16.64582857	490
16.33725409	510
16.52251777	510
16.39587647	550
16.34745419	560
16.57879101	580
16.35471017	580
16.36176784	580
16.44116656	580
16.29844718	600
16.3990189	600
16.31256251	600
16.2466944	630
16.27414201	640
16.21082135	660
16.24101475	680
16.04654258	730
16.08888857	730
16.15966353	750

16.02851202	780
15.73425119	820
15.94950995	820
15.90128599	850
15.77915488	900
15.61644221	950
15.49059419	1070
14.99403073	1260

## Sources:

(Mental Health in America - Access to Care Data 2018, n.d.)

(Stats of the State - Suicide Mortality, 2020)