An Investigation of Social Factors Influencing Emergency Healthcare Expenditure

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Contents

Abstract

This paper provides insight into an open investigation of personal healthcare spending in the United States, with focus on the emergency department (ED). We used data from the Disease Expenditure Project (DEX) at IHME, giving estimates for ED spending split into three major groups: public insurance, private insurance, and out of pocket. The data compiled is used to investigate the existence of a relationship between demographic (sex and age), disease, and expenditure. In the following report, we hypothesize demographic, disease, and type of expenditure from our three included groups are not independent of one another. For example, we expect that results will suggest that public healthcare spending will be higher in older populations when compared to younger populations, whereas private spending will be higher in those younger populations. From the analysis devised in this report, we gather that the data is consistent with the following conclusions: [INSERT CONCLUSIONS HERE]

Background & Significance

Emergency services ensure that individuals can receive timely care for unexpected ailments and injuries, making them a vital component of the healthcare industry. In recent years, however, emergency service spending has seen a significant increase (Scott and Liu 2021), which begs the question of equal accessibility. Expenditure is one of many ways by which to investigate interactions between demographic and healthcare access. [ELABORATE] As a preliminary piece of evaluation of the question of healthcare equity and accessibility by disease and demographic, we have prepared an analysis report of spending habits divided into the payer categories of public insurance, private insurance, and out of pocket. We hope to dive deeper into the relationship between spending habits and demographic through the lens of factors influencing payment models for the emergency department.

Methods

Data Collection

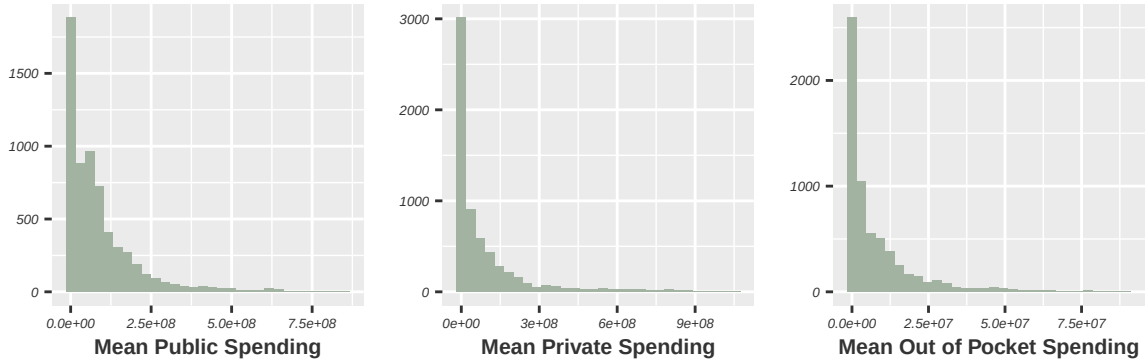
Our data is provided by the Institute of Health Metrics and Evaluation as part of the Disease Expenditure Project (DEX). These Emergency Department (ED) health spending data include estimates for U.S. spending on health care divided into three types of payers: public insurance (including Medicare, Medicaid, and other government programs), private insurance, and out-of-pocket payments. This dataset contains ED spending estimates by aggregate health category, age group, sex, and payer for 2006 through 2016, released in October 2021. Data were gathered from "government budgets, insurance claims, facility records, household surveys, and official US records" (IHME 2021). The data collection and agglomeration is funded by the National Institute on Aging (NIA) and the National Institutes of Health (NIH), and estimates were generated from an underlying data set—the National Emergency Department Sample (NEDS).

The data given includes summaries of identified gender and ages as ' "Both" ' and ' "All Ages" ' observations, respectively. In order to gauge accurate analysis of this data, we chose to exclude the aforementioned observations to avoid double counting.

It is important to acknowledge that this data set did not specify whether gender observations are based on individual reporting or otherwise observed identification and are limited to male and female. Therefore, the data may not encompass a complete representation of the population.

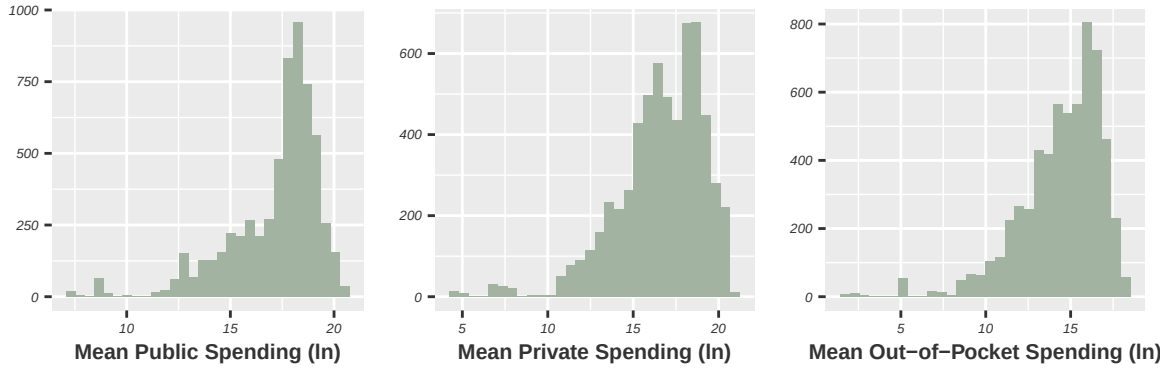
Exploratory Data Analysis

ANOVA Assumption Violation *Normal Distribution of Payer Groups*



The normal distribution for public spending, private spending, and out-of-pocket pending all show a severe right skew in the data. Therefore, all three variables do not meet the normal distribution assumption needed for many tests, such as ANOVA; however, this can easily be resolved by applying a log transformation to the data to give a fairly normal distribution of the data.

Normal Distribution of Payer Groups, Ln Applied



These graphs of the log distribution of the various spending means appear to be fairly normal in distribution, which means they meet the requirements to be used in various analyses. In order to convert to log scale, those with mean_all, mean_pub, mean_pri, and mean_oop equal to zero must be excluded.

Gender Our first step in investigating demographic factor influences on ED expenditure was through the lens of gender. We first performed an overall t-test looking at significant differences between log mean ED expenditure for males and females. As a follow-up to this result, we constructed further step-down tests to evaluate for data consistent with statistical significance for a difference in mean expenditure between the two genders outlined in the data frame.

Our overall two-sample t-test did not have a statistically significant p-value for alpha < 0.05 (Table 6, Test 1). Thereafter, the t-tests of gender differences for each type of payer expenditure (Table 6, Tests 2-4) indicate that the given data are not evidence for rejection of the null hypothesis evaluating gender influence on ED expenditure for our three outlined payers. Therefore, our data are not consistent with a relationship between gender and ED spending.

Aggregate Cause Along with demographic factors that may influence expenditure, the data set given allows for evaluation of the relationship between aggregate cause of spending in the emergency department and the resulting expenditure.

A one-way ANOVA (ndf = 14, ddf = 6035) was performed to compare the effect of aggregate cause of spending (log scale) on mean ED expenditure (Table 6, Test 5), revealing that there was a statistically significant difference in mean ED expenditure between at least two groups (F = 639.5). Based on our significance testing, we reject the overall null hypothesis of no effect. Thereafter, we performed step-down tests using a Holm correction for multiple comparisons, which indicated that 92/105 cause category pairs differ in mean expenditure. There is significant variation in almost all of the category pairs, consistent with the conclusion that there is a relationship between aggregate cause of spending and the expenditure result.

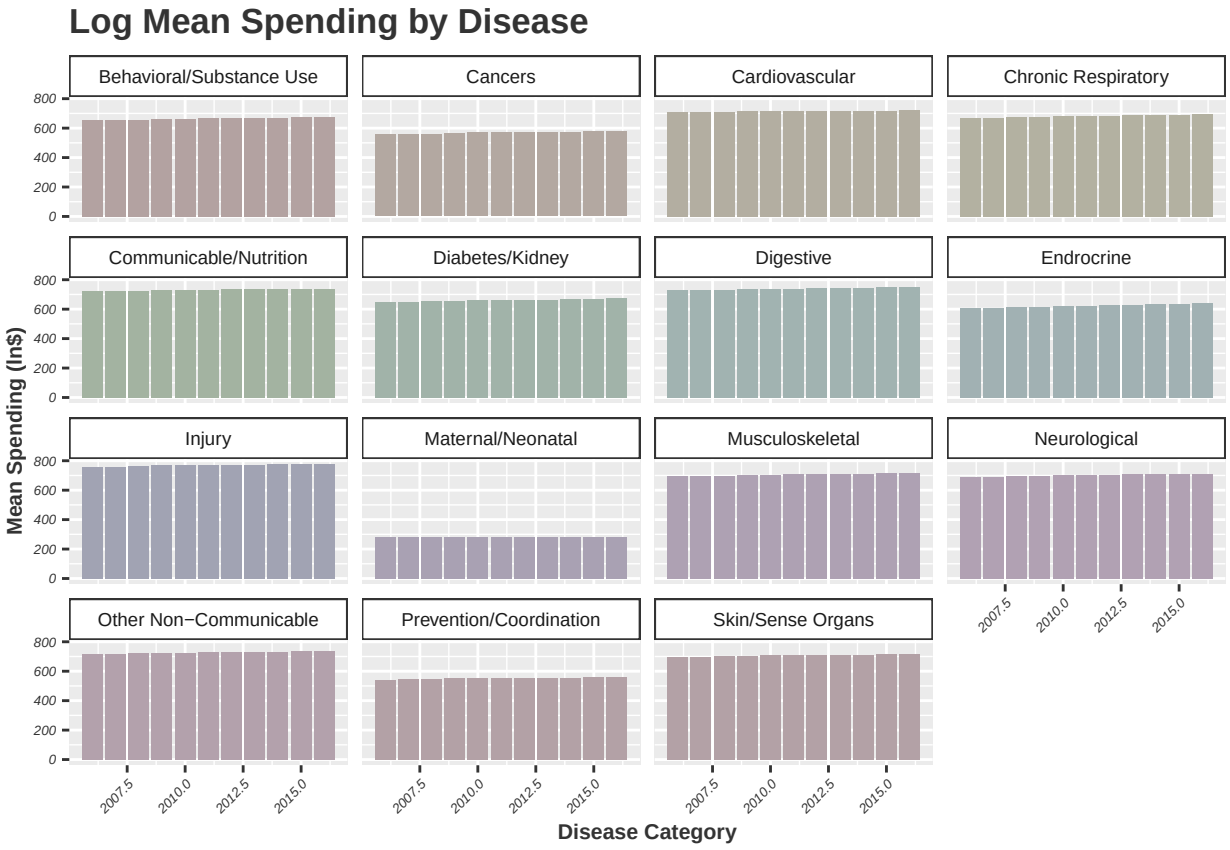
Table 1: Coefficient-Level Estimates for a Model Fitted to Estimate Variation in Mean Expenditure by Aggregate Cause Categories

Predictor	B	SE	t	p
Intercept (Behavioral/Substance Use)	17.48	0.071	246.66	<0.001
Cancers	-2.52	0.100	-25.16	<0.001
Cardiovascular	1.28	0.100	12.79	<0.001
Chronic Respiratory	1.43	0.102	14.10	<0.001
Communicable/Nutrition	1.76	0.100	17.61	<0.001
Diabetes/Kidney	-0.10	0.100	-0.97	0.334
Digestive	1.98	0.100	19.76	<0.001
Endrocrine	-1.12	0.100	-11.18	<0.001
Injury	2.71	0.100	27.02	<0.001
Maternal/Neonatal	-3.47	0.121	-28.75	<0.001
Musculoskeletal	1.07	0.100	10.63	<0.001
Neurological	0.99	0.100	9.92	<0.001
Other Non-Communicable	1.62	0.100	16.15	<0.001
Prevention/Coordination	-3.00	0.100	-29.95	<0.001
Skin/Sense Organs	1.12	0.100	11.19	<0.001

Note. Variables were log-transformed using the natural logarithm.

Table 2: Fit Values for Disease Type Analysis

Measure	Result
R^2	0.5973
Adjusted R^2	0.5964




```
## [1] 0.5959975
```

Age We wonder whether there is a correlation between government healthcare expenditures in the emergency department and age. The age variable is categorical, split into 19 groups that generally include 5 years each, apart from the first (<1 year) and last (85 plus) groups.

To address this question, we began by using an overall test with ANOVA.

Below is an overall test of the null hypothesis that all of the means for age groups across the years are equal, as opposed to the alternative that at least one mean is different.

In this F-test (ndf = 18, ddf = 6031), a significant difference among age groups was identified. Our p-value tells us that this data (or data more extreme) would be very unlikely if the null hypothesis were true because it shows statistical significance at an alpha well below 0.05. Therefore, we reject the null hypothesis that the mean expenditures for all age groups are equal.

To see which specific means may be different from one another, we used planned step-down tests with a Holm correction to minimize Type I errors.

The pairwise t-tests used for our ANOVA step-down tests suggest that there are 99 different age pairs out of the 171 possible combinations. This tells us that more age pairs are different than are similar and that therefore the majority of age group pairs differ in terms of mean expenditures.

```
agefit <- linear_reg() %>%
  set_engine("lm") %>%
  fit(lmean_all ~ age_group_name, data = spending_malefemale)
  tidy(agefit)
```

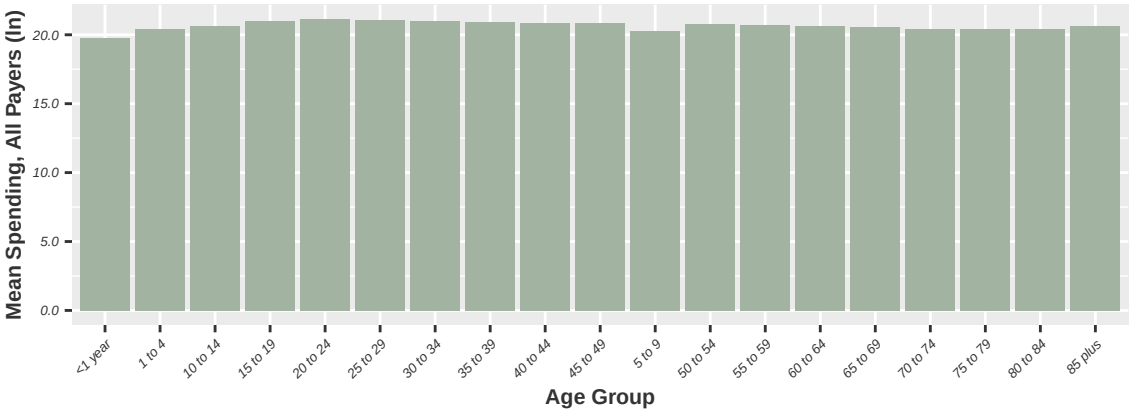
```
## # A tibble: 19 x 5
```

Table 3: Temp

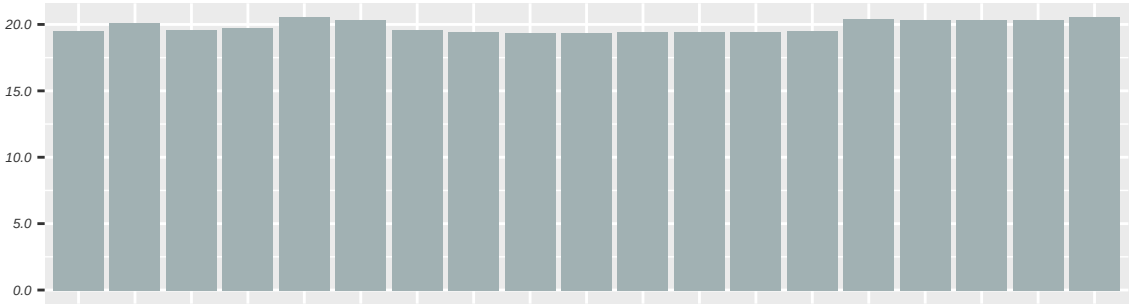
term	estimate	p.value
(Intercept)	17.1841515	0.0000000
as.factor(year_id)2016	0.5435012	0.1024311
agg_causeCancers	-2.5387252	0.0000000
agg_causeCardiovascular diseases	1.3846396	0.0000337
agg_causeChronic respiratory diseases	1.4047353	0.0000333
agg_causeCommunicable and nutrition disorders	1.7946444	0.0000001
agg_causeDiabetes and kidney diseases	-0.0843353	0.7998236
agg_causeDigestive diseases	1.9618318	0.0000000
agg_causeEndocrine disorders	-1.2554208	0.0001683
agg_causeInjuries	2.7768257	0.0000000
agg_causeMaternal and neonatal conditions	-3.2613820	0.0000000
agg_causeMusculoskeletal conditions	1.0383789	0.0018387
agg_causeNeurological disorders	0.9448387	0.0045739
agg_causeOther non-communicable diseases	1.6312963	0.0000011
agg_causePrevention and coordination	-2.8957096	0.0000000
agg_causeSkin and other sense organ disorders	1.1159233	0.0008182
as.factor(year_id)2016:agg_causeCancers	0.1119215	0.8119150
as.factor(year_id)2016:agg_causeCardiovascular diseases	-0.2261237	0.6307000
as.factor(year_id)2016:agg_causeChronic respiratory diseases	0.0952092	0.8417381
as.factor(year_id)2016:agg_causeCommunicable and nutrition disorders	-0.0600710	0.8983721
as.factor(year_id)2016:agg_causeDiabetes and kidney diseases	0.0396297	0.9328516
as.factor(year_id)2016:agg_causeDigestive diseases	0.1050241	0.8233082
as.factor(year_id)2016:agg_causeEndocrine disorders	0.3811605	0.4177841
as.factor(year_id)2016:agg_causeInjuries	-0.1029154	0.8267989
as.factor(year_id)2016:agg_causeMaternal and neonatal conditions	-0.3575102	0.5279227
as.factor(year_id)2016:agg_causeMusculoskeletal conditions	0.0857897	0.8552701
as.factor(year_id)2016:agg_causeNeurological disorders	0.0523592	0.9113610
as.factor(year_id)2016:agg_causeOther non-communicable diseases	-0.0299608	0.9492087
as.factor(year_id)2016:agg_causePrevention and coordination	-0.1469024	0.7547926
as.factor(year_id)2016:agg_causeSkin and other sense organ disorders	0.0201944	0.9657527

```
##    term                    estimate std.error statistic  p.value
##    <chr>                      <dbl>     <dbl>     <dbl>    <dbl>
##  1 (Intercept)                15.4      0.121    127.   0
##  2 age_group_name1 to 4        1.20     0.170      7.05 2.03e-12
##  3 age_group_name10 to 14      1.92     0.170     11.3  1.67e-29
##  4 age_group_name15 to 19      2.59     0.170     15.2  1.55e-51
##  5 age_group_name20 to 24      2.96     0.170     17.5  1.17e-66
##  6 age_group_name25 to 29      3.09     0.170     18.2  2.45e-72
##  7 age_group_name30 to 34      3.16     0.170     18.6  3.99e-75
##  8 age_group_name35 to 39      3.23     0.170     19.0  1.87e-78
##  9 age_group_name40 to 44      3.30     0.170     19.4  1.09e-81
## 10 age_group_name45 to 49      3.32     0.170     19.6  8.29e-83
## 11 age_group_name5 to 9        1.27     0.170      7.49 7.86e-14
## 12 age_group_name50 to 54      3.27     0.170     19.3  3.25e-80
## 13 age_group_name55 to 59      2.89     0.170     17.0  1.50e-63
## 14 age_group_name60 to 64      2.70     0.170     15.9  1.12e-55
## 15 age_group_name65 to 69      2.63     0.170     15.5  3.12e-53
## 16 age_group_name70 to 74      2.48     0.170     14.6  1.22e-47
## 17 age_group_name75 to 79      2.37     0.170     13.9  1.52e-43
## 18 age_group_name80 to 84      2.32     0.170     13.7  6.62e-42
## 19 age_group_name85 plus       2.39     0.170     14.1  3.11e-44
```

Emergency Department General Expenditures



Public Insurance Expenditures



Private Insurance Expenditures

Out−of−Pocket Expenditures

Table 4: R^2 Values for the Main Effects and Interaction Models Analyzing Gender and Age

Payer2	Main_Effects2	Interaction2
Public Spending	0.00251	0.00241
Private Spending	0.02899	0.02904
Out-of-Pocket Spending	0.02361	0.02363

Table 5: R^2 Values for the Main Effects and Interaction Models Analyzing Disease Type and Age

Payer	Main_Effects	Interaction
Public Spending	0.5068870	0.5293510
Private Spending	0.5054947	0.5149051
Out-of-Pocket Spending	0.5161683	0.5261024

Gender and Age Interaction In order to test the possibility that there is a joint interaction of gender and age, a main effects and interaction effects linear regression model has been fit to the data. As a whole, it shows that the interaction of gender and age slightly increases the accuracy of the regression for public and private spending as seen by the increased adjusted R^2 value. However, for out-of-pocket spending, it decreases the adjusted R^2 value. Nevertheless, overall, the adjusted R^2 values for all three types of spending are incredibly low, which further point to our conclusion that age may not affect the level of spending from different sources.

Age and Disease Interaction

```
## # A tibble: 16 x 5
##    term                                  estimate std.error statistic   p.value
##    <chr>                                    <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                           16.9      0.0713     237.    0
##  2 agg_causeCancers                      -2.69     0.0994     -27.1   1.45e-152
##  3 agg_causeCardiovascular diseases       1.14     0.0994      11.5   3.28e- 30
##  4 agg_causeChronic respiratory diseases  1.29     0.101       12.8   7.42e- 37
##  5 agg_causeCommunicable and nutrition d~ 1.61     0.0994      16.2   7.68e- 58
##  6 agg_causeDiabetes and kidney diseases  0.0569   0.0994       0.573 5.67e-  1
##  7 agg_causeDigestive diseases            1.66     0.0994      16.7   5.41e- 61
##  8 agg_causeEndocrine disorders          -1.25     0.0994     -12.6   7.61e- 36
##  9 agg_causeInjuries                      1.99     0.0994      20.0   2.81e- 86
## 10 agg_causeMaternal and neonatal condit~ -3.50    0.120      -29.2   9.83e-176
## 11 agg_causeMusculoskeletal conditions    0.816    0.0994       8.21  2.65e- 16
## 12 agg_causeNeurological disorders        0.780    0.0994       7.85  4.89e- 15
## 13 agg_causeOther non-communicable disea~ 1.25     0.0994      12.6   6.29e- 36
## 14 agg_causePrevention and coordination  -3.06     0.0994     -30.8   4.22e-193
## 15 agg_causeSkin and other sense organ d~ 0.892    0.0994       8.97  3.78e- 19
## 16 age_group_id                           0.00334  0.000556     6.01  2.02e-  9
```

```
## [1] 0.5726639
```

```
## # A tibble: 30 x 5
##    term                                  estimate std.error statistic   p.value
##    <chr>                                    <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                            17.1      0.0817    210.    0
##  2 agg_causeCancers                       -3.16     0.116     -27.3   4.41e-155
##  3 agg_causeCardiovascular diseases        0.610    0.116       5.28  1.35e-  7
##  4 agg_causeChronic respiratory diseases   1.08     0.116       9.31  1.70e- 20
##  5 agg_causeCommunicable and nutrition d~  1.44     0.116      12.5   2.49e- 35
```

```
##  6 agg_causeDiabetes and kidney diseases    -0.237    0.116      -2.06 3.99e-  2
##  7 agg_causeDigestive diseases               1.50     0.116      13.0  4.42e- 38
##  8 agg_causeEndocrine disorders             -1.42     0.116     -12.3  2.98e- 34
##  9 agg_causeInjuries                         1.74     0.116      15.1  2.31e- 50
## 10 agg_causeMaternal and neonatal condit~   -2.69     0.140     -19.2  6.58e- 80
## # ... with 20 more rows
```

```
## # A tibble: 0 x 0
```

```
## # A tibble: 16 x 5
##    term                                estimate std.error statistic   p.value
##    <chr>                                  <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                          16.2     0.0841      193.   0
##  2 agg_causeCancers                     -2.23    0.117       -19.0  2.32e- 78
##  3 agg_causeCardiovascular diseases      1.63    0.117        13.9  1.68e- 43
##  4 agg_causeChronic respiratory diseases  1.75   0.119        14.8  1.74e- 48
##  5 agg_causeCommunicable and nutrition d~  2.09   0.117      17.9  1.39e- 69
##  6 agg_causeDiabetes and kidney diseases  -0.208  0.117      -1.78 7.54e-  2
##  7 agg_causeDigestive diseases            2.46    0.117      21.0  2.66e- 94
##  8 agg_causeEndocrine disorders          -0.749   0.117      -6.39 1.74e- 10
##  9 agg_causeInjuries                      3.48    0.117      29.7  4.60e-181
## 10 agg_causeMaternal and neonatal condit~ -3.54   0.141      -25.1  2.40e-132
## 11 agg_causeMusculoskeletal conditions    1.52    0.117      13.0  3.16e- 38
## 12 agg_causeNeurological disorders        1.35    0.117      11.6  1.32e- 30
## 13 agg_causeOther non-communicable disea~  2.06   0.117      17.6  1.60e- 67
## 14 agg_causePrevention and coordination   -2.63    0.117     -22.4  3.83e-107
## 15 agg_causeSkin and other sense organ d~  1.44   0.117      12.3  1.90e- 34
## 16 age_group_id                          -0.0131  0.000655   -20.0  1.98e- 86
```

```
## [1] 0.5626007
```

```
## # A tibble: 30 x 5
##    term                                estimate std.error statistic   p.value
##    <chr>                                  <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                          16.5     0.0981     168.   0
##  2 agg_causeCancers                     -2.75    0.139      -19.8  6.48e- 85
##  3 agg_causeCardiovascular diseases      1.06    0.139        7.65 2.25e- 14
##  4 agg_causeChronic respiratory diseases  1.54   0.140       11.0  5.06e- 28
##  5 agg_causeCommunicable and nutrition d~  1.87   0.139      13.5  1.12e- 40
##  6 agg_causeDiabetes and kidney diseases  -0.611  0.139      -4.41 1.08e-  5
##  7 agg_causeDigestive diseases            2.33    0.139      16.8  5.58e- 62
##  8 agg_causeEndocrine disorders          -1.00    0.139      -7.21 6.47e- 13
##  9 agg_causeInjuries                      3.27    0.139      23.6  2.17e-117
## 10 agg_causeMaternal and neonatal condit~ -3.16   0.168      -18.8  1.61e- 76
## # ... with 20 more rows
```

```
## [1] 0.5734167
```

```
## # A tibble: 16 x 5
##    term                                estimate std.error statistic   p.value
##    <chr>                                  <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                          14.5     0.0786     184.   0
##  2 agg_causeCancers                     -2.72    0.110      -24.8  1.48e-129
##  3 agg_causeCardiovascular diseases      0.994   0.110        9.08 1.48e- 19
##  4 agg_causeChronic respiratory diseases  1.15   0.111       10.4  6.12e- 25
##  5 agg_causeCommunicable and nutrition d~  1.72   0.110      15.7  3.22e- 54
##  6 agg_causeDiabetes and kidney diseases  -0.395  0.110      -3.61 3.09e-  4
```

Table 6: Temp

term	estimate	p.value
(Intercept)	14.7092021	0.0000000
agg_causeCancers	-3.1442198	0.0000000
agg_causeCardiovascular diseases	0.4235641	0.0010880
agg_causeChronic respiratory diseases	0.9331922	0.0000000
agg_causeCommunicable and nutrition disorders	1.5405779	0.0000000
agg_causeDiabetes and kidney diseases	-0.7646196	0.0000000
agg_causeDigestive diseases	1.7105672	0.0000000
agg_causeEndocrine disorders	-1.1024696	0.0000000
agg_causeInjuries	2.4308631	0.0000000
agg_causeMaternal and neonatal conditions	-3.4564444	0.0000000
agg_causeMusculoskeletal conditions	0.6503271	0.0000005
agg_causeNeurological disorders	0.4510409	0.0005043
agg_causeOther non-communicable diseases	1.3397594	0.0000000
agg_causePrevention and coordination	-3.5027704	0.0000000
agg_causeSkin and other sense organ disorders	0.6936139	0.0000001
age_group_id	-0.0218172	0.0000000
agg_causeCancers:age_group_id	0.0193805	0.0000000
agg_causeCardiovascular diseases:age_group_id	0.0259313	0.0000000
agg_causeChronic respiratory diseases:age_group_id	0.0098494	0.0024985
agg_causeCommunicable and nutrition disorders:age_group_id	0.0079308	0.0148507
agg_causeDiabetes and kidney diseases:age_group_id	0.0167852	0.0000003
agg_causeDigestive diseases:age_group_id	0.0067519	0.0380775
agg_causeEndocrine disorders:age_group_id	0.0103193	0.0015291
agg_causeInjuries:age_group_id	0.0117393	0.0003125
agg_causeMaternal and neonatal conditions:age_group_id	-0.0191120	0.0000016
agg_causeMusculoskeletal conditions:age_group_id	0.0120678	0.0002110
agg_causeNeurological disorders:age_group_id	0.0145592	0.0000078
agg_causeOther non-communicable diseases:age_group_id	0.0117118	0.0003228
agg_causePrevention and coordination:age_group_id	0.0077166	0.0177767
agg_causeSkin and other sense organ disorders:age_group_id	0.0081909	0.0118748

```
##  7 agg_causeDigestive diseases             1.86    0.110        17.0  3.52e- 63
##  8 agg_causeEndocrine disorders           -0.875   0.110        -7.99 1.55e- 15
##  9 agg_causeInjuries                       2.69    0.110        24.6  5.35e-127
## 10 agg_causeMaternal and neonatal condit~ -3.89    0.132       -29.5  1.97e-178
## 11 agg_causeMusculoskeletal conditions     0.916   0.110         8.36 7.52e- 17
## 12 agg_causeNeurological disorders         0.771   0.110         7.04 2.08e- 12
## 13 agg_causeOther non-communicable disea~  1.60    0.110        14.6  2.16e- 47
## 14 agg_causePrevention and coordination   -3.33    0.110       -30.4  2.09e-189
## 15 agg_causeSkin and other sense organ d~  0.874   0.110         7.98 1.75e- 15
## 16 age_group_id                           -0.0112  0.000613    -18.3  3.42e- 73
```

```
## [1] 0.5759006
```

```
## [1] 0.5873628
```

Table 7: Hypothesis Testing for Significance

TestNumber	TestType	Analysis	PValue	CI	Decision
1	Two-sample t-test	M/F Overall Spending	0.2494	(-0.0316, 0.1996)	Fail to reject null hypothesis
2	Two-sample t-test	M/F Public Spending	0.128	(-0.0083, 0.2153)	Fail to reject null hypothesis
3	Two-sample t-test	M/F Private Spending	0.6329	(-0.0828, 0.1760)	Fail to reject null hypothesis
4	Two-sample t-test	M/F OoP Spending	0.4598	(-0.0616, 0.1847)	Fail to reject null hypothesis
5	ANOVA	Overall Spending by Disease	<2e-16		Reject null hypothesis
6	ANOVA	Overall Spending by Age	<2e-16		Reject null hypothesis

Appendix

References

Institute for Health Metrics and Evaluation (IHME). United States Healthcare Spending in Emergency Departments by Health Condition 2006-2016. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME), 2021.

Woody Scott K, Liu A, Chen C, Kaldjian AS, Sabbatini AK, Duber, HC, Dieleman JL. Healthcare Spending in U.S. Emergency Departments by Health Condition, 2006-2016. PLOS One. 27 October 2021.