

An Investigation of Social Factors Influencing Emergency Healthcare Expenditure

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Contents

Abstract	1
Background & Significance	2
Methods	2
Data Collection	2
Exploratory Data Analysis	2
ANOVA Assumption Violation	2
Gender	3
Age	3
Aggregate Cause	6
Gender and Age Interaction	7
Age and Disease Interaction	7
Appendix	12
References	12

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).

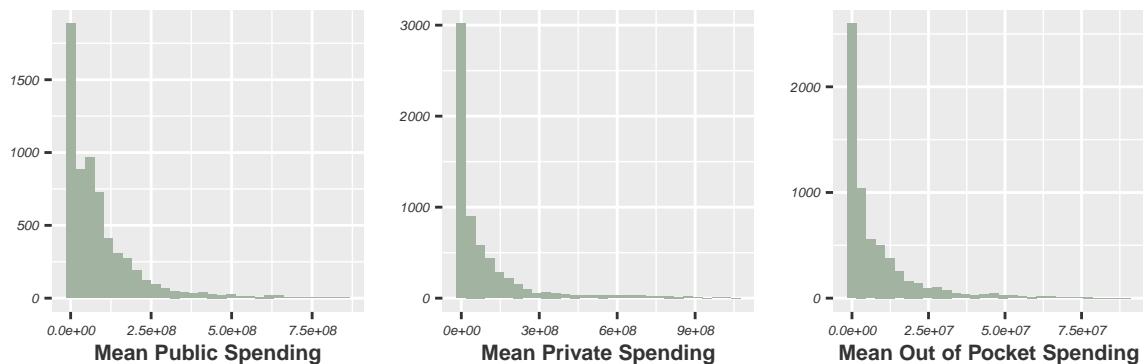
The data given includes summaries of identified gender and ages as ‘r “Both”’ and ‘r “All Ages”’ observations, respectively. In order to gauge accurate analysis of this data, we chose to exclude the aforementioned observations to avoid double counting.

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.

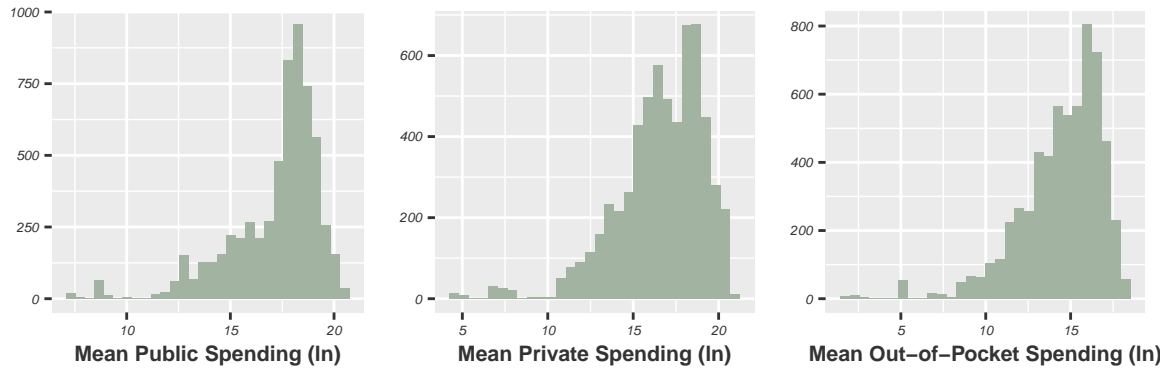
Exploratory Data Analysis

ANOVA Assumption Violation To confirm that our data could be evaluated under ANOVA assumptions, we visualized the distributions of payer groups. The distributions for all three groups showed severe right skewness in the data, thus not meeting the normal distribution assumption needed for ANOVA testing. We resolved this by applying a log transformation to the data (excluding any spending data with observation 0) to evaluate using a more normal distribution, shown below.

Distribution of Payer Groups



Distribution of Payer Groups, Log Scale



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.

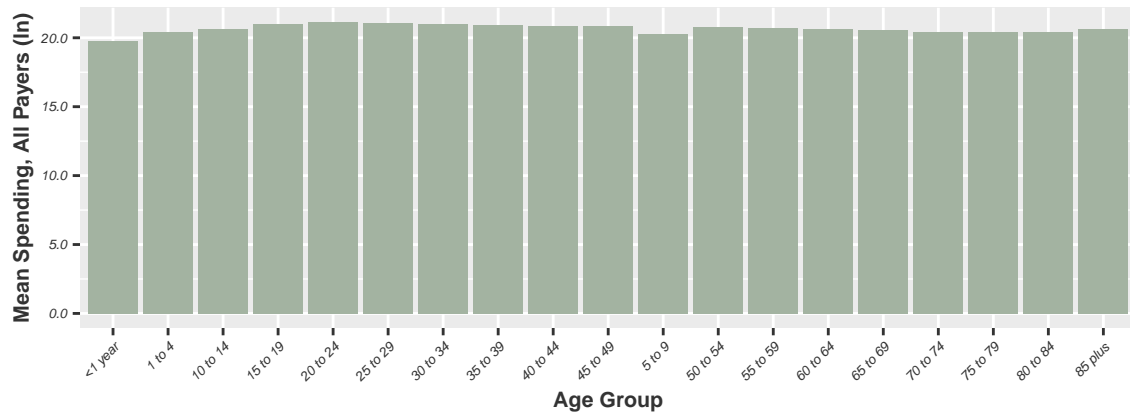
Age A secondary demographic factor that we were able to evaluate from this DEX data is age, through the lens of its relationship with ED healthcare expenditure. The 'r age_group_name' variable is split into 19 groups that generally increase by 5-year increments. We first used an overall test with ANOVA on the log scale to evaluate 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 our F-test ($ndf = 18$, $ddf = 6031$), a significant difference among age groups was identified. Therefore, we rejected our null hypothesis and designed step-down tests with a Holm correction to minimize Type I errors. The pairwise t-tests evaluated 99/171 differing combinations, which was consistent with our hypothesis that (a 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)
```

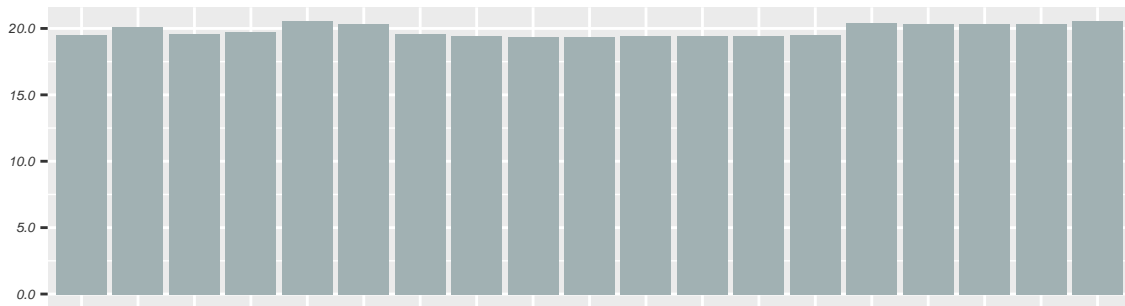
term	estimate	std.error	statistic	p.value
(Intercept)	15.4	0.121	127.	0
age_group_name1 to 4	1.20	0.170	7.05	2.03e-12
age_group_name10 to 14	1.92	0.170	11.3	1.67e-29
age_group_name15 to 19	2.59	0.170	15.2	1.55e-51
age_group_name20 to 24	2.96	0.170	17.5	1.17e-66
age_group_name25 to 29	3.09	0.170	18.2	2.45e-72
age_group_name30 to 34	3.16	0.170	18.6	3.99e-75
age_group_name35 to 39	3.23	0.170	19.0	1.87e-78
age_group_name40 to 44	3.30	0.170	19.4	1.09e-81
age_group_name45 to 49	3.32	0.170	19.6	8.29e-83
age_group_name5 to 9	1.27	0.170	7.49	7.86e-14
age_group_name50 to 54	3.27	0.170	19.3	3.25e-80
age_group_name55 to 59	2.89	0.170	17.0	1.50e-63
age_group_name60 to 64	2.70	0.170	15.9	1.12e-55
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

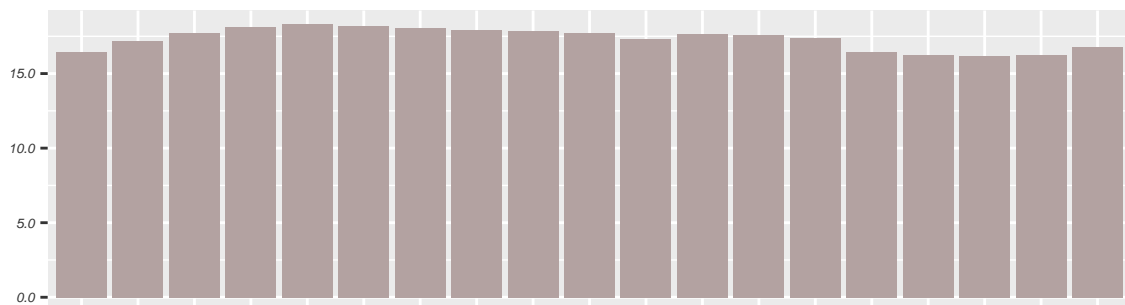


Table 1: Coefficient-Level Estimates for a Model Fitted to Estimate Variation in Mean Expenditure by Aggregate Cause Categories

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
Endocrine	-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.

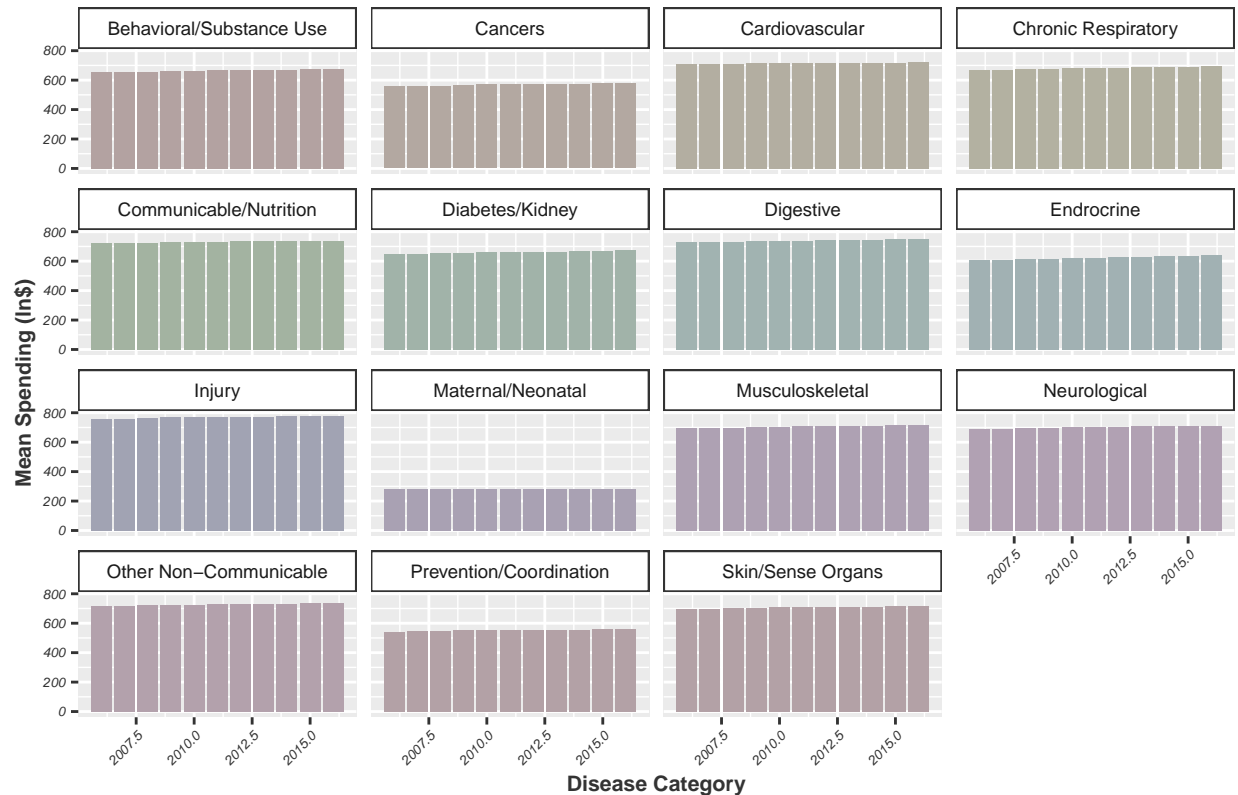
Table 2: Fit Values for Disease Type Analysis

Measure	Result
R ²	0.5973
Adjusted R ²	0.5964

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 6), 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.

Log Mean Spending by Disease



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

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
```

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

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


```

## 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
## 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 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

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 Age	<2e-16		Reject null hypothesis
6	ANOVA	Overall Spending by Disease	<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.