Healthy heart, healthy mind;
a study of the factors most directly influencing proper health in a
sampling of the nations of the world.

Abstract:
One of the most important issues facing the United States today is the subject of health care
reform. The number of uninsured Americans reached 47 million in 2008. While the United States
leads the world in healthcare spending at 15.6 percent of GDP, they are 50th in ranking for life
expectancy [Appendix C].

In this study, we take several parameters and measure their effects on the 'health' of a given
country. To quantify a country's 'health', we have chosen to use life expectancy, and both infant
and adult mortality as indicators. Once finding the factors that optimize a country's health, we will
create a 'Utopian' society (subsequently named "Country X"), and finally compare this Utopian
society to that of the United States with the intention of learning what will most greatly impact the
health of Americans.

In the outset, we wanted to compare directly the types of healthcare systems of countries of
interest, but upon beginning research, it quickly became apparent that there is no easy way to
classify the healthcare system of a given country. Most healthcare systems have developed with a
plurality of government planning and an organic growth, leaving an infinitely varied group of
systems. In lieu of this fact, we chose expenditure per capita (epc) to measure the relative
efficiency of a healthcare system. Expenditure as a percent of Gross Domestic Product (ehg) has
problems of its own when including countries of small economies.

Results:
The most direct effect one can have on a country's health is of course to spend money on
health. Our greatest correlations agree with this, suggesting that the best a country can do is to
spend about $2,500 per person to get the most effect of the money. Some countries (like the U.S.)
spend much more than this with no apparent benefit. We believe the excess monies could be
funneled into other programs to better maximize health, like education. Thus, we examined adult
literacy and Government Expenditure on Education per Pupil and also found a strong correlation.
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Description of Variables

These variables were chosen based on their direct relation to a given country's health.

Predictor Variables

-Urban Population This is the sum of the population of a nation's five largest cities as a ratio of total population.

-Adult Literacy This is defined as the percentage of citizens aged 15 and over who can read and write.

-Government Expenditure on Healthcare per capita (in US dollars)

-Government Expenditure on Education per pupil (in US dollars)

Response Variables

-Life Expectancy This is an average of life expectancy for males and females for each country.

-Infant Mortality Deaths of those less than 5 years of age per 1000 persons.

-Adult Mortality Deaths of those age 15-60 per 1000 persons

Countries of Interest

We have chosen 184 countries to get as large a base of data as possible. The exact number comes from obtaining reliable data sets for all included. This base includes all first world countries, and also contains a wide variety of religious and political affiliations so as not to accidentally
oversight these attributes as hidden factors.

**Statistical Analyses**

Relationships between each of the predictor variables and response variables individually were first analyzed to isolate any direct relationships. Attempting to find correlations between two or more predictor variables and a response variable yielded no appreciable results, and are thus omitted. Below is a list of all relevant data, using linear regression modeling (see Appendix). We found the 'Ideal Value' by looking graphically to where the predictor value should lie so that the response variable is maximized with the least waste in expenditure on health, education, etc. The 'Explicit Formula' is the best fit found for the data.

**Infant Mortality vs. Health Expenditure per Capita**

\[ R^2 = 0.7843 \]
\[ p-value = 2.2e-16 \]
Ideal Value: \(( $2500, \ .00198373 \text{ deaths per 1000} )\)

Explicit Formula: \[ y = x^{-624738} \]

**Adult Mortality vs. Health Expenditure per Capita**

\[ R^2 = .6291 \]
\[ p-value = 2.2e-16 \]
Ideal Value: \(( $2500, \ .0636337 \text{ deaths per 1000} )\)

Explicit Formula: \[ y = x^{-35207} \]

**Life Expectancy vs. Health Expenditure per Capita:**

\[ R^2 = .6441 \]
\[ p-value = 2.2e-16 \]
Ideal Value: \(( $2500, \ 78.721 \text{ years} )\)

Explicit Formula: \[ y = 6.776 \log x + 25.7053 \]

**Infant Mortality vs. Adult Literacy**

\[ R^2 = .5089 \]
\[ p-value = 2.2e-16 \]
Ideal Value: \(( 95 \text{ percent literacy, } .0264236 \text{ deaths per 1000})\)

Explicit Formula: \[ y = -.15705 \log x + .7416 \]

**Adult Mortality vs. Adult Literacy**

\[ R^2 = .3565 \]
\[ p-value = 2.2e-16 \]
Ideal Value: \(( 95 \text{ percent literacy, } .144628 \text{ deaths per 1000})\)
Explicit Formula: $y = e^{-0.1898x - 1.3049}$

**Life Expectancy vs. Adult Literacy**

$R^2 = .5089$

p-value = 2.2e-16

Ideal Value: (95 percent literacy, 70.9734 years)

Explicit Formula: $y = .4313x + 29.9970$

**Infant mortality vs. Population in Urban Areas**

$R^2 = .4175$

p-value = 2.2e-16

Ideal Value: (80 percent urban, .0112388 deaths per 1000)

Explicit Formula: $y = e^{-0.0349x - 1.69326}$

**Adult mortality vs. Population in Urban Areas**

$R^2 = .412$

p-value = 2.2e-16

Ideal Value: (80 percent urban, .119667 deaths per 1000)

Explicit Formula: $y = e^{-0.017156x - 750560}$

**Life Expectancy vs. Population in Urban Areas**

$R^2 = .4024$

p-value = 2.2e-16

Ideal Value: (80 percent urban, 73.6135 years)

Explicit Formula: $y = .32249x + 47.8143$

**Infant Mortality vs. Education Expenditure per Capita**

$R^2 = .8203$

p-value = 2.2e-16

Ideal Value: ($4500, .000902$ deaths per 1000)

Explicit Formula: $y = x^{-83340}$

**Adult Mortality vs. Education Expenditure per Capita**

$R^2 = .6579$

p-value = 2.2e-16

Ideal Value: ($4500, .0438633$ deaths per 1000)

Explicit Formula: $y = x^{-3717}$
Life Expectancy vs. Education Expenditure per Capita

\[ R^2 = .6333 \]
\[ p\text{-value} = 2.2e^{-16} \]
Ideal Value: \(( $4500, \quad 77.3223 \text{ years} )\)
Explicit Formula: \[ y = 6.9283\log x + 19.042 \]

**Major Findings**

**Infant mortality, adult mortality, life expectancy vs. Expenditure per Capita:**

Here were the largest correlations found, especially among infant and adult mortality. This again seems obvious, considering the effects of health spending in general. There seems to be an upper limit on the benefits of spending per capita, at $2,000 to lower infant mortality, and $3,000 to lower adult mortality and raise life expectancy. We chose $2,500 as the optimum expenditure per capita for country X.

At $6,714 per capita, there is an exorbitant amount of inefficiency in the health spending of the United States. While there are innumerable ways to lower this number (malpractice lawsuit restrictions, compulsory insurance, etc.), we are more interested in how the excess of $4,214.00 might be spend to directly or indirectly increase health. We then decided to analyze the benefits of an education, through measuring adult literacy, on a country's health. The findings for this predictor variable are discussed later.

**Expenditure as Percent of Gross Domestic Product (ehg):**

This variable showed no direct relationship to our response variables, so we will not use it in our analysis. The reason we think there is no correlation is because ehg has no relation to health care expenditure per capita. There may, for example, be a country whose ehg is really high, but the GDP is so low that it translates to a really low expenditure per capita. Conversely, there may be a country with a low ehg but the GDP is so large that the expenditure per capita is very large.

**Infant mortality, adult mortality, life expectancy vs. Adult literacy:**

Adult literacy did not yield as high a correlation with any response variables as might be
expected. This leads to the conclusion that education has a much smaller impact on general health than one might think. We found this hard to believe, proposing possible errors in data collection in constituent countries, and thus decided to search a new, similar indicator; Education Expenditure per Pupil.

Finding an optimal literacy rate was a little ambiguous, for one would think that 100 percent literacy is the best, but must also consider the cost-benefit on health of exerting the energy to reach this level. We choose 95 percent literacy for country X, and the United States exceeds this level with a literacy rate of 99 percent.

**Infant mortality, adult mortality, life expectancy vs. Percent Urban Population:**

Looking at the figures, there is some obvious relation, but so many outliers make for very small correlations. This was surprising; for we first postulated longer lives in urban areas based on access to healthcare, higher education, and a more organized system of health in general. Possible reasons for such small correlations between health and 'urban-ness' of a country are higher exposure to pollutants, lower water, air, food quality, easier transmission of disease, and sanitation issues.

We choose 80 percent urban for country X, for infant mortality is not decreased beyond this number, and both life expectancy and adult mortality show no appreciable change. The United States is 81 percent urban, and thus at an advantage.

**Infant mortality, adult mortality, life expectancy vs. Education Expenditure per Pupil:**

Here we found strong correlations for infant mortality and education expenditure. Adult mortality, and life expectancy yielded good, though not statistically strong results. Our hypothesis was thus correct in the fact that higher focus on education will increase a country's health. We attribute the reason for this correlation's greater statistical significance than that of literacy rate to the ease with which data is collected. This further underscores our belief that data on world literacy contains large amounts of error.

We choose $4,500 as the optimal expenditure per pupil for country X. This is much less than the spending by the United States, which comes up to $9,154. This was surprising, for we would suggest the excess spent on healthcare could be better used in education. We conclude that the United States should first become much more efficient in health-care spending, and the excess
monies are not readily spent in other areas of our analysis.

Discussion

The best way to increase a country’s health (from our choice of possibilities) is through direct spending on healthcare and education. The structure of a country in urban population, type of government, etc. seems not to have as large an impact as one might initially think. This may come from the fact that there are thousands of implications of being an urban society, or having a specific government, each facet providing a positive or negative impact on health. In largely populated nations with widely varying cultural standards, chaos is inevitable, making the task of a concrete statistical evaluation difficult, if not impossible. Well aware of this fact as we delved into the data sets, we are not highly surprised with so many inconclusive results, and are satisfied with the correlations retained.

The initial goal of this study was how to improve the state of healthcare in the United States. To this end, no concrete suggestions can be made. U.S. spending on both health and education far exceeds that needed by our model country X, and these spending figures have the highest impact on health in our data set. So the question is, why when we spend so much in both fields, are Americans so far behind in life expectancy? For one, many would agree that spending in both healthcare and education is massively inefficient, and much can be done to remedy this. Other reasons which are much more difficult to quantify are lifestyle and culture. What we eat, when we eat it, how we exercise, how we take care of ourselves, average days of vacation, and countless other things could be compared to get an idea of general health. Also, other indicators of health certainly branch much farther than life expectancy or mortality rates. This study is only a crack at the surface of the optimization of healthcare, and the only conclusions we can draw are the fact that the United States does not spend nearly as efficiently as it could on health and education.

We predicted that religion would be a useful predictor variable, but found it too hard of a statistic to quantify. We decided, therefore, to omit this variable from our list of predictors.

The type of government was also quite difficult to quantify on account of the wide variety of
governments. On examining a smaller group of twenty five nations, the top seven countries in life expectancy were also in the top ten countries for lowest infant mortality: Australia, Iceland, Italy, Japan, Spain, Sweden, and Switzerland. These countries host widely varied types of government, from constitutional monarchy to federal parliamentary democracy. This leads to the conclusion that the type of government has no bearing on life expectancy or infant mortality. Of special note is the fact that no communist countries were in the top 7, but as our survey of countries only included two, namely, China and Vietnam, nothing conclusive can be made of this fact. We thus chose no specific type of government for country X, and have no conclusions on the impact of the government of the United States on health.

Possible Further Study

There are several useful correlations in our analysis. However, were we to repeat this study with the initial goal in mind (improving health care in the United States), there are a few things which we could do differently. One of these is choosing more predictor variables. World Health Organization has data for immunizations, salary of a public school teacher, number of miles of paved versus unpaved roads and several more factors that we did not consider.