## SDGB 7844 HW 4: Chocolate & Nobel Prizes

Instructor: Prof. Nagaraja

Due: 11/16 in class

Submit two files: (a) solutions (explanations, plots, tables, etc. in .docx or .pdf file) and (b) code (in a .R file). Both parts should be (a) printed and brought to class and (b) emailed to fordhamRcomputing@gmail.com by the start of class. (See the Lecture 1 exercises on Blackboard for an example of how to format your files.)

In your email, use the subject heading: "HW 4: [Your name]-[Time of Class]" and include HW 4 and your name in the file names (time of class is either 1:15 PM or 3:30 PM). Please email your solutions only once! Complete your work individually and comment your code for full credit.

Read the New England Journal of Medicine article, "Chocolate Consumption, Cognitive Function, and Nobel Laureates" (Messerli, F.H., Vol. 367(16), 1562-1564; 2012) which is attached to the end of this assignment. We will be using a reconstruction of Messerli's data<sup>1</sup>. The variables in the data set you will use are (file: "nobel\_chocolate.txt" on Blackboard) are "country", "nobel\_rate", and "chocolate".

The information gathered in the data set you will be using is from several different sources. The number of Nobel prize winners is from Wikipedia and includes winners through November 2012, population information (used to compute the "nobel\_rate" variable) is from the World Bank, and chocolate market size is from the Euromonitor International's Passport Database.

<u>Goal:</u> In this assignment, you will be replicating Messerli's analysis.

<sup>&</sup>lt;sup>1</sup>Source: McClintock, S., Stangl, D., and Çetinkaya-Rundel, M. (2014). The real secret to genius? Reading between the lines. *CHANCE*. **27**(1).

- 1. According to Messerli, what is the variable "number of Nobel laureates per capita" supposed to measure? Do you think it is a reasonable measure? Justify your answer.
- 2. Are countries without Nobel prize recipients included in Messerli's study? If not, what types of bias(es) would that introduce?
- 3. Are the number of Nobel laureates per capita and chocolate consumption per capita measured on the same temporal scale? If not, how could this affect the analysis?
- 4. Construct a scatterplot of Nobel laureates per capita vs. chocolate consumption. Label Sweden on your plot (on the computer, not by hand). Compute the correlation between these two variables and add it to the scatterplot. How would you describe this relationship? Is correlation an appropriate measure? Why or why not?
- 5. What is Messerli's correlation value? (Use the correlation value that includes Sweden.) Why is your correlation different?
- 6. Why does Messerli consider Sweden an outlier? How does he explain it?
- 7. Regress Nobel laureates per capita against chocolate consumption (include Sweden):
  - (a) What is the regression equation? (Include units of measurement.)
  - (b) Interpret the slope.
  - (c) Conduct a residual analysis to check the regression assumptions. Make all plots within one figure. Can we conduct hypothesis tests for this regression model? Justify your answer.
  - (d) Is the slope significant (conduct a hypothesis test and include your regression output in your answer)? Test at the  $\alpha = 0.05$  level and remember to specify the hypotheses you are testing.
  - (e) Add the regression line to your scatterplot.
- 8. Using your model, what is the number of Nobel laureates expected to be for Sweden? What is the residual? (Remember to include units of measurement.)
- 9. Does increasing chocolate consumption cause an increase in the number of Nobel Laureates? Justify your answer.

#### OCCASIONAL NOTES

# Chocolate Consumption, Cognitive Function, and Nobel Laureates

Franz H. Messerli, M.D.

Dietary flavonoids, abundant in plant-based foods, have been shown to improve cognitive function. Specifically, a reduction in the risk of dementia, enhanced performance on some cognitive tests, and improved cognitive function in elderly patients with mild impairment have been associated with a regular intake of flavonoids.<sup>1,2</sup> A subclass of flavonoids called flavanols, which are widely present in cocoa, green tea, red wine, and some fruits, seems to be effective in slowing down or even reversing the reductions in cognitive performance that occur with aging. Dietary flavanols have also been shown to improve endothelial function and to lower blood pressure by causing vasodilation in the peripheral vasculature and in the brain.3,4 Improved cognitive performance with the administration of a cocoa polyphenolic extract has even been reported in aged Wistar-Unilever rats.5

Since chocolate consumption could hypothetically improve cognitive function not only in individuals but also in whole populations, I wondered whether there would be a correlation between a country's level of chocolate consumption and its population's cognitive function. To my knowledge, no data on overall national cognitive function are publicly available. Conceivably, however, the total number of Nobel laureates per capita could serve as a surrogate end point reflecting the proportion with superior cognitive function and thereby give us some measure of the overall cognitive function of a given country.

#### METHODS

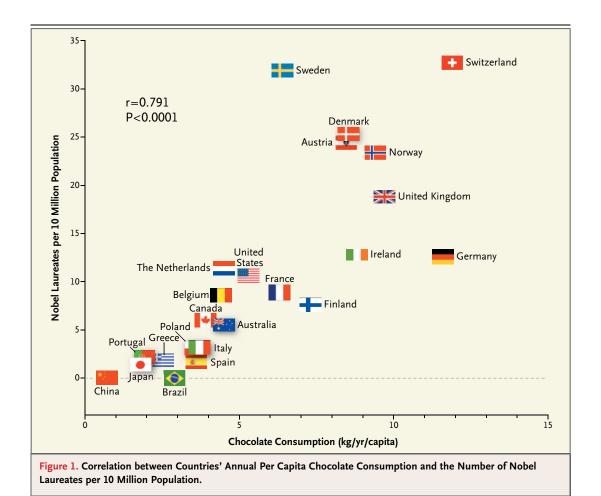
A list of countries ranked in terms of Nobel laureates per capita was downloaded from Wikipedia (http://en.wikipedia.org/wiki/List\_of\_countries\_by\_Nobel\_laureates\_per\_capita). Be-

cause the population of a country is substantially higher than its number of Nobel laureates, the numbers had to be multiplied by 10 million. Thus, the numbers must be read as the number of Nobel laureates for every 10 million persons in a given country.

All Nobel Prizes that were awarded through October 10, 2011, were included. Data on per capita yearly chocolate consumption in 22 countries was obtained from Chocosuisse (www.chocosuisse.ch/web/chocosuisse/en/home), Theobroma-cacao (www.theobroma-cacao.de/wissen/wirtschaft/international/konsum), and Caobisco (www.caobisco.com/page.asp?p=213). Data were available from 2011 for 1 country (Switzerland), from 2010 for 15 countries, from 2004 for 5 countries, and from 2002 for 1 country (China).

#### RESULTS

There was a close, significant linear correlation (r=0.791, P<0.0001) between chocolate consumption per capita and the number of Nobel laureates per 10 million persons in a total of 23 countries (Fig. 1). When recalculated with the exclusion of Sweden, the correlation coefficient increased to 0.862. Switzerland was the top performer in terms of both the number of Nobel laureates and chocolate consumption. The slope of the regression line allows us to estimate that it would take about 0.4 kg of chocolate per capita per year to increase the number of Nobel laureates in a given country by 1. For the United States, that would amount to 125 million kg per year. The minimally effective chocolate dose seems to hover around 2 kg per year, and the dose–response curve reveals no apparent ceiling on the number of Nobel laureates at the highest chocolate-dose level of 11 kg per year.



### DISCUSSION

The principal finding of this study is a surprisingly powerful correlation between chocolate intake per capita and the number of Nobel laureates in various countries. Of course, a correlation between X and Y does not prove causation but indicates that either X influences Y, Y influences X, or X and Y are influenced by a common underlying mechanism. However, since chocolate consumption has been documented to improve cognitive function, it seems most likely that in a dose-dependent way, chocolate intake provides the abundant fertile ground needed for the sprouting of Nobel laureates. Obviously, these findings are hypothesis-generating only and will have to be tested in a prospective, randomized trial.

The only possible outlier in Figure 1 seems to their consumption. That receiving the Nobel be Sweden. Given its per capita chocolate consumption of 6.4 kg per year, we would predict countrywide seems unlikely, although perhaps that Sweden should have produced a total of celebratory events associated with this unique

about 14 Nobel laureates, yet we observe 32. Considering that in this instance the observed number exceeds the expected number by a factor of more than 2, one cannot quite escape the notion that either the Nobel Committee in Stockholm has some inherent patriotic bias when assessing the candidates for these awards or, perhaps, that the Swedes are particularly sensitive to chocolate, and even minuscule amounts greatly enhance their cognition.

A second hypothesis, reverse causation — that is, that enhanced cognitive performance could stimulate countrywide chocolate consumption — must also be considered. It is conceivable that persons with superior cognitive function (i.e., the cognoscenti) are more aware of the health benefits of the flavanols in dark chocolate and are therefore prone to increasing their consumption. That receiving the Nobel Prize would in itself increase chocolate intake countrywide seems unlikely, although perhaps celebratory events associated with this unique

honor may trigger a widespread but most likely transient increase.

Finally, as to a third hypothesis, it is difficult to identify a plausible common denominator that could possibly drive both chocolate consumption and the number of Nobel laureates over many years. Differences in socioeconomic status from country to country and geographic and climatic factors may play some role, but they fall short of fully explaining the close correlation observed.

#### STUDY LIMITATIONS

The present data are based on country averages, and the specific chocolate intake of individual Nobel laureates of the past and present remains unknown. The cumulative dose of chocolate that is needed to sufficiently increase the odds of being asked to travel to Stockholm is uncertain. This research is evolving, since both the number of Nobel laureates and chocolate consumption are time-dependent variables and change from year to year.

#### CONCLUSIONS

Chocolate consumption enhances cognitive function, which is a sine qua non for winning the Nobel Prize, and it closely correlates with the number of Nobel laureates in each country. It remains to be determined whether the consumption of chocolate is the underlying mechanism for the observed association with improved cognitive function.

Dr. Messerli reports regular daily chocolate consumption, mostly but not exclusively in the form of Lindt's dark varieties.

Disclosure forms provided by the author are available with the full text of this article at NEJM.org.

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