MA103 - Math Modeling and Introduction to Calculus
Fall 2007
Project: Analysis of Diabetes in America
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Diabetes is a disorder that affects the way your body uses food for energy. Normally, the sugar you take in is digested and broken down into a simple sugar known as glucose. The glucose then circulates in your blood where it waits to enter cells to be used as fuel. Insulin, a hormone produced by the pancreas, helps move the glucose into cells. A healthy pancreas adjusts the amount of insulin based on the level of glucose in your body. But if you have diabetes, this process fails to control the glucose level, and blood sugar levels increase without control.

There are two main types of diabetes. People with Type 1 diabetes are completely unable to produce insulin. People with Type 2 diabetes can produce insulin, but their cells don't respond to it. In either case, the glucose can't move into the cells, and blood glucose levels can become high. Over time, these high glucose levels can cause serious complications, such as kidney failure and blindness.[1] Although diabetes can be associated with serious complications and premature death, people with diabetes can take steps to control the disease and lower the risk of complications.

Why do we care about the cost of diabetes in America?

An estimated 7% of the United States population, about 20.8 million children and adults have diabetes. While an estimated 14.6 million have been diagnosed, 6.2 million people (or nearly one-third) are unaware that they have the disease.

The cost of diabetes in America is staggering. The cost is a result of both direct and indirect costs of the disease. The annual costs of health care for each person in America with diabetes rose more than 30% between 1997 and 2002. The direct economic costs of the disease are those generated by the resources used in treating or coping with the disease, including expenditures for medical care and the treatment of the illness. Common examples are hospital care, physician services, home nursing services, medical devices, drugs and other medical costs. Indirect economic costs address the potential resources that are lost as a result of the disease. They include the societal costs of morbidity (death), disability, and premature death. Indirect costs represent the impact, present and future, of opportunities

[1] "An Overview of Diabetes." Learn About Diabetes, Joslin Diabetes Center. 16 Jan 2007.

lost to the individual as a consequence of diabetes.[2]

Groups and organizations use cost figures to gather support, government and private, for research and programs addressing their diseases. The mission of each of these groups is based on the idea that persons with a given disease will gain improved health and quality of life only if more resources are devoted to its research and treatment. The American Diabetes Association (ADA), for example, has sponsored three recent cost-of diabetes studies. Additionally, in an effort to increase financial support from private and public agencies, pharmaceutical companies are increasingly turning to these mathematical estimates to promote the costs of the specific diseases in which they have a financial interest.[3]

PART I (Parts II and III will be handed out later in the semester.)

The purpose of this part of the project is to enhance your ability to evaluate a complex topic and use an appropriate problem solving technique to address a real-world issue. Your group is tasked to develop a model that will estimate the annual cost of diabetes in America for persons over the age of 20; ultimately, you will use your mathematical model to estimate the cost of diabetes in the year 2020. This project is not designed to simply discover your ability to conduct research on the Internet. For example, consider the statement, "diabetes care was estimated in 1997 as $3,212 per person, and in 2002 this increased to $4,500...therefore in the year 2020, we will assume the cost increases linearly."' This statement is an example of an over-simplified model and demonstrates little problem solving techniques; it is not what is expected for this project.

Model estimating cost of diabetes: The model on the following page will be the foundational model that will be used for this requirement.

1. **Known:**
   (a) An estimated 7% of American citizens have diabetes.
   (b) The cost of diabetes can be attributed to direct and indirect costs.
2. **Unknown:** The cost of diabetes in America for all persons 20 years or older in the year 2020.
3. **Assumptions:**
   (a) Our analysis will consider only the costs for persons 20 years and older.

[2]Songer T. Studies on the Cost of Diabetes, Centers of Disease Control and Prevention. Washington: GPO, June 1998.

[3]Ibid.

(b) A person between the ages of 20-65 will be considered an adult.

(c) People older than 65 will be considered elderly; a large majority of this group no longer work due to retirement.

(d) Affected adults of all ethnic backgrounds will have equal costs. Although one could argue that different ethnic groups historically have different access to health care, we make this observation based on the cost of providing health care, not necessarily the amount charged by insurance companies, or the additional costs that an uninsured individual would pay out of pocket.

(e) Affected elderly of all ethnic backgrounds will have equal costs.

(f) Care will be reported in terms of 2007 dollars.

Devise a Plan For this portion of the analysis, we choose to only consider what we believe are the most costly factors associated with diabetes. We believe that a simple model that accounts for the most dramatic factors serves to provide a valid estimate while maintaining an ease of use for potential uses in both the private and public sector. Through insightful thought and research on the Internet, we determined (NOTE: This is our personal observation!) that the primary causes of these costs occur due to treatment of the disease (physician care and pharmaceutical expenditures) and lost work time due to effects of the disease. In a report written by Dr. Sandeep Vijan and Dr. Kenneth Langa,[4] the authors suggested that diabetic work absenteeism (indirect cost) and permanent disability (indirect cost) cost Americans an estimated $54 billion annually. Additionally, according to the American Diabetic Association, diabetes alone represents 11% of the U.S. health care expenditure. People with diabetes have medical expenditures 2.4 times higher than they would if they did not have diabetes. With this knowledge and desire to maintain an accurate but fairly manageable model, we have elected to initially model costs with the following function:

$$Cost(Adult, Elderly) = A_1(Adult) + A_2(Elderly) + B_1(Adult) + B_2(Elderly)$$

Model Definition The above model defines the cost of diabetes in America in 2020.

1. The independent variables for this analysis are Adult and Elderly. Adult is defined as the number of diabetic adults in America in 2020 between the ages of 20 and 65 years old. Similarly, Elderly is defined as the number of diabetic adults in America in 2020 older than 65. The domain of both these variables will be $[0, 300 \text{ million}]$ persons.

[4] Vijan, S, and Langa, K. The impact of diabetes on work-force participation,The University of Michigan Retirement Research Center, January 2003

2. The dependent variable for this analysis is Cost. Cost is defined as the cost, in dollars, for diabetes in America. The range of this variable is $(0, \inf)$.

3. B_1 and B_2 represent placeholders for your group to add define and estimate parameters. You must have a minimum of 2 additional parameters (B_1 and B_2).

4. A_1 represents the annual cost of lost work for an adult employee with diabetes in the year 2020.

5. A_2 represents the annual cost of lost work for an elderly employee with diabetes in the year 2020.

Pursuant to the requirements of developing an accurate model, you must compute actual values for the defined parameters.

Requirement 1: Your group must submit a type written technical report that incorporates your complete analysis and requisite discussion in meeting the following tasks:

1. Develop a minimum of five valid and necessary assumptions as part of your analysis. This is in addition to the ones given above during model development.

2. Complete the given model that will estimate the cost of diabetes in America for persons over the age of 20. The provided model shows work absenteeism as a major indirect cost (shown for both Adult and Elderly). We have defined work absenteeism for adults and shown a detailed example of a possible process for developing an appropriate estimate of the parameter for that variable. Your group will estimate the remaining parameters for this model. This will ultimately include two parameters that your group defines, in addition to the parameter A2, defined in the given model.

3. Your group must select the most critical direct cost factors that would assist in modeling the cost of diabetes. Limit your work to include a minimum of 2 additional terms (B_1 and B_2). The estimates of the parameters will be a result of problem solving techniques and research conducted by your group.

In the example below, we will discuss the development of the parameterA_1; a similar technique would be applied toward estimating the remaining parameters.

For the parameterA_1, we assume that every lost work day due to complications of diabetes, is equal to the daily salary of the individual. This cost may be felt by the employer through the hiring of additional persons (temporary employees), payment of overtime to account for the lost labor, or other unknown costs. Therefore, our plan will be to make an

estimate of how many work days the average diabetic loses due to his/her disease. Subsequently, we will assume that the cost of a lost work day is the daily salary of the individual. Thus, the total cost per person is the product of lost days and the cost of each lost day.

According the the United States Census Bureau,[5] the measured median household income in the United States in 2005 was \$46,242. Since we are interested in modeling the effect of work absenteeism in the year 2020, we must adjust this cost for the effects of inflation. While future inflation is difficult to estimate, a quick search on the Internet demonstrates that historical inflation has centered around 3% annually; we will use this inflation factor for our model. Thus in the year 2020, we will predict that the median income will be \$72,043.53.

Since A_1 is designed to measure the cost effect of absenteeism, we must make a determination of the cost of each individual day. Assuming that the average American works 20 days per month, we expect that the average American works 240 days per year. Using the median salary as our baseline, we estimate each lost work day has a cost of $\frac{\$72.043.53}{240 \text{ days}}$. This equates to an estimated cost of \$300.18 per day.

Now, we must make an assessment of how many work days an adult diabetic loses each annual work period. Clearly, without significant research and study, this term is difficult to assess, so we will simply make a broad estimation that each employee misses 1 work day per month, or 12 days annually. We think it is realistic to assume that a diabetic will lose 1 day of work per month due to appointments, illness or other factors. Therefore, we assume that the parameter A_1, which represents the annual cost of absenteeism for an adult with diabetes in 2020, is equal to $(\frac{\$300.18}{\text{day}})(12 \text{ days}) = \$3,602.17$ per year.

[5] Webster, B., and Bishaw, A. Income, Earnings, and Poverty Data From the 2005 American Community Survey. US Census Bureau. Washington: GPO, August 2006., pg. 2

Requirement 2: The next step of your analysis will be to predict the populations of individuals that will have diabetes in the year 2020. Using the data provided in Appendix 1, Appendix 2, and individual research, provide population models for the following groups of American populations:[6]

1. Non-Hispanic Whites
2. Non-Hispanic Blacks
3. Hispanic/Latino Americans
4. American Indians and Alaska Natives
5. Asian Americans and Pacific Islanders

You may find the following websites useful to your analysis and research:

1. www.diabetes.org/diabetes-statistics/cost-of-diabetes-in-us.jsp
2. care.diabetesjournals.org/cgi/content/full/26/3/917
3. http://www.cdc.gov/diabetes/statistics/pubs.htm
4. http://www.census.gov/prod/2006pubs/acs-02.pdf
5. http://www.census.gov/ipc/www/usinterimproj/natprojtab02a.xls

Specified Tasks:

1. Develop a mathematical model to estimate the diabetic population sizes for each ethnic group in 2020. **NOTE**: You might consider using the percentages of race/ethnicity groups to provide a more accurate estimate of the diabetic population.
2. Use your models from requirements 1 and 2 to determine an estimate of the total cost of diabetes in the year 2020.
3. Discuss how this model and/or estimate could be improved given more time to complete the analysis.
4. Discuss how these findings might be important to you.

[6]The data provided in this Appendix can be found on the course website adjacent to the project link.

APPENDIX 1: 2004 Total prevalence of diabetes by race/ethnicity[7]

1. **Non-Hispanic Whites:** 13.1 million, or 8.7% of all Non-Hispanic Whites aged 20 years or older have diabetes.

2. **Non-Hispanic Blacks:** 3.2 million, or 13.3% of all Non-Hispanic Blacks aged 20 years or older have diabetes. Non-Hispanic Blacks are 1.8 times as likely to have diabetes as Non-Hispanic Whites.

3. **Hispanic/Latino Americans:** Mexican Americans, the largest Hispanic/Latino subgroup, are 1.7 times as likely to have diabetes as Non-Hispanic Whites. If the prevalence of diabetes among Mexican Americans were applied to the total Hispanic/Latino population, about 2.5 million (9.5%) Hispanic/Latino Americans aged 20 years or older would have diabetes. Sufficient data are not available to derive estimates of the total prevalence of diabetes (both diagnosed and undiagnosed diabetes) for other Hispanic/Latino groups. However, residents of Puerto Rico are 1.8 times as likely to have diagnosed diabetes as U.S. Non-Hispanic Whites.

4. **American Indians and Alaskan Natives:** 99,500, or 12.8% of American Indians and Alaska Natives aged 20 years or older who received care in 2003 had diagnosed diabetes. 118,000 (15.1%) of American Indians and Alaskan Natives aged 20 years or older have diabetes (both diagnosed and undiagnosed). American Indians and Alaska Natives are 2.2 times as likely to have diabetes as Non-Hispanic Whites.

5. **Asian Americans and Pacific Islanders:** The total prevalence of diabetes (both diagnosed and undiagnosed) is not available for Asian Americans or Pacific Islanders. However, in Hawaii, Asians, Native Hawaiians, and other Pacific Islanders aged 20 years or older are more than 2 times as likely to have diagnosed diabetes as whites after adjusting for population age differences. Similarly, in California, Asians were 1.5 times as likely to have diagnosed diabetes as Non-Hispanic Whites. Other groups within these populations also have increased risk for diabetes.

[7] http://diabetes.niddk.nih.gov/dm/pubs/statistics/index.htm#7

APPENDIX 2: Population of the United States by Ethnicity[8]

Ethnicity	July 1, 2006	July 1, 2005	July 1, 2004	July 1, 2003
White, Non-Hispanic	239,746,254	237,885,464	236,036,395	234,190,714
Black	38,342,549	37,904,619	37,472,889	37,045,265
American Indian Alaska Natives	2,902,851	2,863,696	2,824,946	2,786,400
Asian	13,159,343	12,756,578	12,354,426	11,970,145
Pacific Islander Native Hawaiian	528,818	517,491	506,586	495,570
Hispanic	43,692,745	42,266,250	40,827,316	39,444,617

Ethnicity	July 1, 2002	July 1, 2001	July 1, 2000
White, Non-Hispanic	232,464,989	230,589,080	228,637,204
Black	36,676,149	36,259,742	35,814,967
American Indian Alaska Natives	2,750,466	2,712,506	2,673,624
Asian	11,566,615	11,134,053	10,697,440
Pacific Islander Native Hawaiian	485,963	475,609	465,124
Hispanic	38,057,880	36,603,913	35,163,005

[8]These population estimates are provided through the US Census Bureau, and are estimates provided between the 10-year census reports. We will assume that the total US population for each annual report is simply the sum of the group data provided. This information was extracted from the following: http://www.census.gov/popest/national/asrh/NC-EST2006/NC-EST2006-03.xls

Works Cited

1. Songer T. Studies on the Cost of Diabetes, Centers of Disease Control and Prevention. Washington: GPO, June 1998.

2. "National Diabetes Statistics." National Diabetes Statistics fact sheet, National Institute of Diabetes and Digestive and Kidney Diseases. 2005. <http://diabetes.niddk.nih.gov/dm/pubs/statistics/index.htm#7>

3. "An Overview of Diabetes." Learn About Diabetes, Joslin Diabetes Center. 16 Jan 2007.

4. Vijan, S, and Langa, K. The impact of diabetes on work-force participation, The University of Michigan Retirement Research Center, January 2003.

5. Webster, B., and Bishaw, A. Income, Earnings, and Poverty Data From the 2005 American Community Survey. US Census Bureau. Washington: GPO, August 2006. <http://www.census.gov/prod/2006pubs/acs-02.pdf>

6. US Census Bureau. Annual Estimates of the Population by Sex, Race, and Hispanic Origin for the United States. August, 2006. <http://www.census.gov/popest/national/asrh/NC-EST2006/NC-EST2006-03.xls>