Using Math to Understand Our World
Project 6
Making and Using Childhood Growth Charts

Instructions: Read through this project and work through the questions (especially the ones in boldface). When prompted, read the designated parts of the CDC report and answer the questions in the "Reading Guide". Use all that you have learned to prepare the materials listed on the "What to Hand In" sheet.

1 Introduction

Most of you are probably familiar with pediatricians' practice of plotting children's weight and height on a growth chart. But where do these growth charts come from and what information does the pediatrician get from them?

Typically a growth chart has age along the horizontal axis and either height or weight along the vertical axis, and the pediatrician will plot the child's data on both of these. Some pediatricians instead use a single weight-to-stature chart, where stature is on the horizontal axis and weight is on the vertical axis. Each chart usually has curves that show the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentile curves. If a child's weight lies along the 95th percentile curve, for example, on an age-to-weight chart, that means that 95 percent of other children of the same age have a lower weight. Printable examples of weight-to-age, height-to-age, and weight-to-stature charts for children ages birth to 36 months or ages 2 to 20 years can be found at

`http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/clinical_charts.htm.`

Examples of these charts can be found in the *Growth Charts* section of this packet. The CDC (*Center for Disease Control* - remember them from the smallpox article in Project 3!) growth-chart homepage is

`http://www.cdc.gov/growthcharts.`

Tracking a child's position on the growth charts is a valuable tool. A sudden change of percentiles, or consistent 5th or 95th percentile measurements can indicate a problem.

Until recently, the charts that pediatricians used for children 3 years of age and older were constructed using data gathered between 1963 and 1974. The charts for children under three were constructed using data from a small sample of white middle-class children who lived near

Yellow Springs, Ohio during the period 1929-1975. Once the data was gathered, fairly simple statistical techniques were used to turn the data into smooth curves like those found in the charts. Since the development of these charts, a number of concerns have been expressed about various aspects of the sampling and statistical procedures used.

To respond to these concerns, the CDC came out with new charts in 2000, using larger and more diverse sample sizes as well as more advanced statistical techniques. The CDC also added a new chart to the previous ones of height-to-age, weight-to-age, and weight-to-stature. They added BMI-to-age. *BMI* stands for *body-mass-index* and is computed by taking weight (in kg) and dividing by height (measured in meters) squared (i.e., $BMI = w/h^2$, but remember to use metric units). The CDC encourages pediatricians to switch to using BMI charts for several reasons:

- Children at different ages have different body shapes. For example, two year olds, on the whole, are a lot chubbier than four year olds. On a weight-to-height or weight-to-age chart, a tall two year old might come across as overweight, but on a BMI-to-age chart he might come out as average.
- It has been discovered (using data obtained by following people from childhood into adulthood - called a *longitudinal study*) that childhood BMI is a slightly better indicator of future obesity in adulthood.
- Since adult obesity (or lack thereof) is measured using BMI, using BMI as the measure for children allows continuity as the child progresses from teens to 20's.

In this project, we will learn more about the CDC project to produce new growth charts, how the growth charts were made, and how BMI is used to identify children at risk for obesity. We will read parts of the original CDC Report, located at

`www.cdc.gov/nchs/data/series/sr_11/sr11_246.pdf`,

we will use the data to produce our own growth chart, and we will view a CDC PowerPoint presentation to learn more about BMI.

There are many aspects of this project that you might be able to share with your students. If you think it would be acceptable to students and their families, you could even take BMI data from your students and compare it to the national data. Or perhaps you could find data about Nebraska students on-line.

Before going on to the rest of the project, I would like you to read the first four pages of the CDC report (before getting to the first four pages, you have to scroll through about a million pages of the table of contents). Use the "Reading Guide" questions to help you synthesize your reading. You might also want to reference the "What to Hand In" sheet as you continue.

2 Constructing the Charts

In this section we will explore the methods for constructing BMI-to-age curves using the CDC data. The CDC data set is huge with literally hundreds of thousands of data points. It takes a computer to organize that sort of data. Let's use the CDC data and a computer program to help us generate the 75th percentile curve for BMI-to-age for girls ages 2 to 20 years. The CDC recorded data for girls of ages 2, 2.5, 3, 3.5, 4, 4.5, and so on every six months until age 20. Thus, the horizontal axis for our curve will be age marked by half years. A computer program was generously developed for us and will allow you to find the 75th percentile points for each age. The program allows you to input an age and a BMI and then it will output the CDC sample size for that age and the number of children who had a BMI equal to or lower than the one you put in. The URL for this computer program is

`http://www.math.unl.edu/~ghines1/bmi-program`

Get some graph paper and carefully plot the 75th percentile points. You might want to split this task amongst a group of 4 or 5 of you. It can get tedious after awhile to check every age and half age between 2 and 20.

Now that you have a bunch of points, how do you turn this into a nice *smooth* curve that looks like the ones on the pediatricians' charts? Can you draw a pretty good looking curve that fits this data pretty well? It doesn't have to go through all the data points, it just has to be close to all the data points, and it has to be smooth without corners or points. **Try it**. In the 1977 charts, this is exactly how the graphs were drawn - computers plotted the data points and then a person sat down and drew a smooth curve that looked like it fit the points pretty well. Then mathematics was used to get a *best-fit formula* for this hand drawn curve (a formula was needed in order to have computers reproduce the curve or to use it in any mathematical analysis). In the new 2000 charts, however, fairly advanced statistical methods were used (via computers) to draw the curves.

Now compare your 75th percentile curve with the CDC's. The CDC charts for BMI-to-age for girls 2 to 20 years, along with the original plotted points, is on pages 79 and 80 of the report (these are also included in the *Growth Charts* section of this packet - the last two pages). **How did you do? Does the minimum of your curve occur at the same place as the minimum of the CDC curve? We'll see soon that the location of the minimum is important.**

In the CDC chart, notice that the high and low percentile curves, like the 5th and 95th for example, fit the data points less well. **Why do you think that is?**

The mathematics that the CDC used to generate the curves from the data is pretty sophisticated, but you can get a feel for some of it by reading parts of the report. Read the sections: *Data Exclusions*, *Statistical Curve Smoothing Procedures*, *Age and Length Groupings*, *Curve Smoothing Stage*, and the first column of *The Transformation Stage*. In the *Detailed Procedures by Chart* section, read the subsection *Length-for-Age and Stature-for-Age* (it has a few subsubsections). You won't be able to understand much of what you read, but the "Reading Guide" questions will help you to identify a few of the major points. And you will get an idea as to how much mathematics (in this case statistics) can go into something as simple as creating childhood growth charts.

3 Using BMI to Indicate Risk of Adulthood Obesity

What are the chances that an overweight child will become an overweight adult? It stands to reason that overweight children are *more likely* to become overweight adults, but how much more likely? At what point does a child's weight become a concern?

The CDC has produced a PowerPoint presentation about the new 2000 charts and about using BMI in children to predict adulthood obesity. In this section we will investigate parts of the presentation. You can view the entire presentation at

`www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint`

or you can just view the slides that I refer you to. Along the way, I'll include questions for you to think about. The answers to these questions will help you in preparing your answers for the questions on the "What to Hand In" sheet. Let's get started......

Dr. Robert Whitaker at the *Children's Hospital Medical Center* in Cincinnati did a longitudinal study to find out to what degree childhood BMI is related to adult obesity. To see what he found out, go to

`www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/020.htm`

Summarize his findings.

Read about other risk factors associated with high BMI-to-age at

`www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/021.htm`

Weight-to-stature charts are also good predictors of adulthood risks, but not quite as good as BMI-to-age. Look at the weight-to-stature chart for girls ages 2 to 20 years, which is included in the *Growth Charts* section of this packet. Compare this to the BMI-to-age (also in the *Growth Charts* section). What do you notice about the difference in the shapes of the graphs? View slides 24-27 at

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www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/024.htm
www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/025.htm
www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/026.htm
www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/027.htm
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What is known about the relationship between adult obesity and age of adiposity rebound? If future research indicates that this is a strong link, how might that help in efforts to identify at-risk children? What are the current recommendations for overweight and at-risk categories?

You may wonder what all the fuss is about when it comes to measuring and plotting children's BMI. Isn't it easy to tell just by looking at a child whether or not he or she is at risk for adulthood obesity? Let's try it! View the three slides 33, 35, and 37 (but DO NOT VIEW slides 34, 36, or 38 yet) at

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www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/033.htm
www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/035.htm
www.cdc.gov/nccdphp/dnpa/growthcharts/training/powerpoint/slides/037.htm
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Can you guess which of these children are at risk?

The first child is a 3-year old boy whose height is 39.7 inches and weight is 41 pounds. **Calculate his BMI ($weight/(height)^2$ - remember to change to metric units) and plot it on the BMI-to-age chart for boys ages 2 to 20 years (included in the *Growth Charts* section)**. The second child is a 4-year old girl. She is 41.9 inches tall and weighs 34.5 pounds. **Calculate and plot her BMI.** The last child is also a 4-year old girl. She is 39.2 inches tall and weighs 38.6 pounds. **Calculate and plot her BMI**. **Which of these children are at risk? How does the last girl compare to the first boy? What would her risk status be if she were three and not four? Why is it useful to use BMI-to-age rather than weight-to-stature?**

How important is it to take precise measurements? How precise do we need to be? We've all had the experience of weighing five pounds more on the doctor's scale than on our own (how does that happen anyway?). Suppose the last girl was weighed again the next day on a different scale and weighed 37.1 pounds. What would her BMI be? Her risk factor?

Suppose a 5 year-old boy is 43 inches tall and 42.7 pounds. On what percentile curve is his BMI? What magnitude of error can this measurement tolerate? **In particular, what sort of error in height and weight would cause him to be classified as "at-risk" instead of "healthy"?**