Spring 6-2022

Addressing the Body Mass Index Using a Teaching Math for Social Justice Lens

Riley J. Wolfe
Portland State University

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by

Riley Wolfe

An undergraduate honors thesis submitted in partial fulfillment of the

requirements for the degree of

Bachelor of Science

in

University Honors

and

Mathematics

Thesis Advisor

Eva Thanheiser

Portland State University

2022

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Introduction

Accepted notions surrounding American education have been in a state of change for over 200 years (Ravitch & Viteritti, 2001). The once prized mission of civic assimilation is slowly being replaced by a mission of celebrating diversity (Ibid.). Throughout this change, shaping the next generation of voters has been a prominent goal of American education (Ibid.).

In his book, *Dear Citizen Math*, Karim Ani discusses organizing math education to impact how future adults approach social and political issues. He writes that students should be taught to "use math to clarify [their] understanding of the world and inform how [they] participate in it" (Ani, 2021). He describes the math classroom as an appropriate place to explore complicated social and political problems because many can be better understood using math–which he calls the "language of logic" (Ibid., 3).

Ani is one advocate of a new approach to math education called Teaching Math for Social Justice (TMSJ). Despite the noble goals of TMSJ and its many advocates, available TMSJ content remains sparse. Many social and political contexts which could be understood though the 'language of logic' are yet to be addressed through a TMSJ lens. Conversely, TMSJ is yet to provide lessons for teaching certain Common Core learning targets.

Among contexts not yet addressed by TMSJ is the body positivity movement, which seeks to fight weight bias, an issue which includes racial and gender subtexts. Body positivity is an excellent candidate for a TMSJ lesson through the Body Mass Index (BMI).

BMI is a mathematical formula which purports to predict susceptibility to disease from a person's weight and height (CDC, 2021). However, the science behind BMI is dubious at best (Nordqvist, 2013) (Hainer & Aldhoon-Hainerová, 2013) (Tomiyama et al., 2016). BMI is a tool used to justify weight discrimination, which can lead to problems ranging from teasing on playgrounds (Puhl & King, 2013) to denial of medical operations (Amy et al., 2006).

There are already many existing math lessons which explore the math of the formula. One, found on the *National Council of Teachers of Mathematics* website, is called *What Is Your Body Mass Index?*, and deputizes 6th grade students to assign weight loss goals to fictional subjects based on their calculated BMI (Yanik & Memis, 2016). Another existing option is a lesson plan by Joanne Abramson, in which students weigh and measure themselves in front of their classmates and then are publicly sorted to be 'healthy', 'overweight', 'obese', or 'morbidly obese' (Abramson, n.d.). Lessons like these can distract weight conscious students from focusing on the math content of the lesson. Many other lessons exist which delve into the Body

Mass Index, but almost all accept BMI as a good measure of health on an individual level, despite the fact that the inventor of BMI did not believe the tool should be used to measure individuals' health (Eknoyan, 2008). Further investigation has yielded no superior options for teaching about BMI with a TMSJ approach. For this reason, I have created a high school, algebra lesson plan which studies the math content in BMI using the practices of TMSJ.

After a test-run of my own lesson it was clear that simply recognizing the distress that can come from discussing BMI was less than adequate in preventing new trauma for those who had experienced it in the past. For this reason, the lesson introduction emphasizes Trauma Informed Teaching practices and includes time to discuss weight and weight stigma to prime students who have suffered from or perpetrated weight discrimination.

The lesson outlined on the following pages is inspired by the lessons in the book *High School Lessons to Explore, Understand, and Respond to Social Injustice (Berry et al., 2020)*. This teacher resource provides an outline for designing class content around a social justice framework. The book provides a list of core mathematical learning targets and provides lessons for many. Note that the book provides no resource fulfilling its second *Algebra and Functions* learning target, nor their second *Connecting Algebra to Functions* learning target. The following lesson is designed to fulfill both of these learning targets while addressing the social justice context surrounding BMI.

Lesson Exploring the Historical Use for the Body Mass Index

Learning Targets

Social Justice Standards:

- *Action 18*: I have the courage to speak up to people when their words, actions, or views are biased or hurtful, and I will communicate with respect even when we disagree.
- *Action 19*: I stand up to exclusion, prejudice, and discrimination, even when it's not popular or easy or when no one else does.
- *Justice 12*: I can recognize, describe, and distinguish unfairness and injustice at different levels of society.
- *Justice 14*: I am aware of the advantages and disadvantages I have in society because of my membership in different identity groups, and I know how this has affected my life.
- *Diversity 9*: I relate to and build connections with other people by showing them empathy, respect, and understanding, regardless of our similarities or differences.

Mathematics Essential Concepts:

- *Algebra and Functions (A.2)*: Finding solutions to an equation, inequality, or system of equations or inequalities requires checking of candidate solutions, whether generated analytically or graphically, to ensure that solutions are found and that those found are not extraneous.
- *Connecting Algebra to Functions (CAF.2)*: Graphs can be used to obtain exact or approximate solutions of equations, inequalities, or systems of equations and equalities. Including systems in two variables […].

Mathematical Practices:

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Use appropriate tools strategically.

Weight, Health, and Weight Stigma

Starting in 1972, American insurance companies began adjusting rates around a pre-existing formula called the Body Mass Index (BMI). The formula considers weight and height and insurance companies claim that it predicts likelihood of developing certain cardiovascular and metabolic conditions. This calculation reinforces an existing belief that heavier people are less healthy than their lighter counterparts. Children in classrooms everywhere are affected by this belief and resulting prejudices.

BMI's ability to predict health outcomes come under scrutiny as large studies have shown that life expectancy is not greatly diminished in those with higher BMI and that lower scores may be more dangerous. Additionally, mortality risks associated with obesity (the highest category of BMI scores) may have confounding variables such as stress and the ways doctors treat heavier patients. Children are not aware of these facts. In fact, many classroom lessons about BMI feed

into these prejudices. The following lesson plan discusses the history of BMI and the math behind the formula to educate about weight bias and its repercussions. Certain pedagogic choices have been made (specifically using adult, male, European examples) to try to show that the way BMI is used differs from its historical context. Only very recently was this formula applied to women and non-Europeans, and only even more recently has it been used to diagnose individual health. The lesson is meant to impress upon students that these practices are not an effective way to determine health.

Deep and Rich Mathematics

After being introduced to its historical origin, students will explore the Body Mass Index and its associated chart. Students will consider and categorize hypothetical examples. Students will adjust the height and weight of example subjects to understand how each variable in the formula effects its output. In a homework assignment following the first day of the lesson, students will explore a graphical approach to determining BMI. In the second half of the lesson, groups of students will define the different regions of the BMI chart using systems of inequalities.

About the Lesson

The lesson is designed to be launched, explained, explored, and discussed over two 90-minute class blocks. Using fictional examples, students will explore bivariate formulas and use algebra skills to define regions using quadratic systems of inequalities.

Teacher Preparation

Discussion of weight can be traumatizing to students due to past experiences of injustice. Additionally, one meta-analysis showed that weight was related to poor school performance in one group and subject: girls categorized as 'overweight' in math. For this reason, special care must be taken so as not to compound existing performance disparities. As a teacher, you must consider if your class can appropriately discuss this subject. To make sure that your language does not contribute to trauma, consider exploring the resources provided by the American Psychological Association. These resources can be found here: https://www.apa.org/obesity-guideline/discussing-weight, and are included in the *Resources* section.

A goal of this lesson is to challenge the assumption that heavier people are necessarily unhealthy. An excellent piece of scholarship debunking this belief is *Misclassification of Cardiometabolic Health when using Body Mass Index Categories* by Tomiyama and colleagues. The authors of this study, published in the International Journal of Obesity, found that from a sample of 40,420 Americans described as overweight or obese by the Body Mass Index, nearly half had metabolic data which categorize them as healthy. Even among people categorized as obese, 30% had data indicating they were healthy. Further readings are included below:

- Mortality does not strictly increase with BMI. Lower BMI scores are also associated with shorter life expectancy and the 'overweight' category is associated with longer life expectancies than those in the 'normal' category: https://care.diabetesjournals.org/content/36/Supplement_2/S276.
- BMI may be especially inaccurate for Black people: https://doi.org/10.1093/ajcn/71.6.1392.
- For additional arguments and proposals for more accurate formulas for estimating individual health: https://www.medicalnewstoday.com/articles/265215.

Lesson Resources

American Psychological Association Discussion Standards:
https://www.apa.org/obesity-guideline/discussing-weight,

Video about history of BMI:
https://youtu.be/koexrmCw06s

Class Article about the flaws of BMI:
https://www.medicalnewstoday.com/articles/265215#An-example-of-the-biggest-flaw-in-using-BMI

Article to explain categorization failures:
https://www.nature.com/articles/ijo201617 (Tomiyama, et al. 2016)

National Institute of Health, BMI calculator:
https://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmicalc.htm

Ted Talk about Fat Bias:
https://www.youtube.com/watch?v=Gak58BcuPh0

Lesson Facilitation

Launch (up to 60 Minutes)

- Introduce weight bias and prime class for discussion. This lesson is intended to deter future trauma related to weight-bias. However, it presents an opportunity for trauma to be incurred. For this reason, a comprehensive introduction and consideration of language is important before beginning this lesson.
    - Telling students that the following lesson is related to weight and that you understand this is sensitive to many will show self-conscious students that they are being considered.
    - Likewise, appealing to the whole class for empathy and social-awareness might help curb possible thoughtless or intentionally hurtful comments. Prompts like,

"think of something you are self-conscious about and how you feel when people are talking about that thing around you" and "consider how the words you use over the next two days might be heard by your classmates" can start this conversation.
    - If a student feels comfortable talking about how their weight has affected them it might help students to understand the impact of their words.
    - Discuss appropriate and inappropriate vocabulary and why some terms might be offensive or not. There is no set list of offensive and inoffensive terms related to weight discrimination. Some people find the word "fat" offensive, while other advocates wear the term with pride. Agreeing on at least a few sensitive terms to refer to heavier people will help the lesson run smoothly.
    - Remind students that when people feel attacked it is hard to focus on complex problems. The problems in the following lesson are challenging and will involve teamwork. It will benefit everyone if the whole class feels safe and able to participate in problem-solving.
    - Weight is a category of identity that students do not often see represented. For this reason the lesson can potentially have long lasting positive impacts, but negative impacts are also possible. If it becomes clear to you that the class will not be capable of conducting themselves respectfully during the lesson, one-on-one discussions may be necessary. Throughout the lesson, monitor group discussions and be prepared to interject.
- Introduce the Body Mass Index to the whole class.
    - Ask, "Have any of you heard of the BMI or Body Mass Index before?", "What does BMI claim to measure?", "Does the doctor take your height and weight when you go for a checkup?", "Why does she or he do that?"
- Introduce History of the Body Mass Index by watching the video by Patrick Kelly.
    - First, consider asking emotional questions:
        - "What stood out to you?"
        - "How did the video make you feel?"
    - Next, try to refocus on finer details about BMI that have not been covered yet:
        - "What was the original context of the BMI?", "Who was using it and why?"
        - "What group was Quetelet studying?", "Is that group representative of people in the US today?"
        - Give quote from Adolphe Quetelet "This is not to be used, or intended to measure one's health."
        - "Who started using BMI to predict health?", "Why did they do this?"
- Have students read the Medical News Today article *An Example of the Biggest Flaw in Using BMI* or read the article as a class (included in the *Resources* section).
    - "What does the article say is the biggest flaw with BMI?"
    - "What group does it use for an example?"
    - "Do you think that only athletes with lots of muscle are categorized as unhealthy by BMI? Does it categorize non-athletes correctly?"

    - Explain to them the findings of the Tomiyama 2016 study: 50 million Americans are categorized as unhealthy and obese even though they have good cardio-metric data (i.e. blood pressure, cholesterol, etc.). Almost half of those categorized as overweight have healthy cardio-metric scores in everything else, and 30% of people categorized as obese have otherwise healthy scores.
    - "If this index miscategorizes about half of the people it says are unhealthy: is it a good way to measure health?"
- Let students explore the online calculator on the NIH website.
    - It is not encouraged that you would suggest students use their own weight and height. Instead, providing example numbers may be helpful to students. BMI is a flawed metric and one that almost always upsets people unfamiliar with it. When choosing an example data set consider what you want to communicate: perhaps values that will give a 'healthy' result, the measurements of the average American man or woman, or another interesting set of values.
    - Encourage students to change values and share observations: "Do you notice anything interesting about the calculator when you change only height or weight?", "Does increasing weight lower or raise the BMI?", "Does increasing height lower or raise the BMI?"
    - Close the program, then ask the students to make a hypothesis: "What do you think would happen if you doubled height and weight? Will the BMI go up, down, or stay the same?"
    - Conclude the *Launch* section without checking this together, let the students sit with their hypotheses.

Explore (95 minutes, divided over 2 class periods)

- Private Work Time (20 minutes)
    - Distribute the attached worksheet to students.
    - In this time students will complete work on section 1 problems of the worksheet.
    - Move throughout the room to monitor work and give clarification.
- Homework Introduction (10 minutes)
    - Class will likely finish sometime during the *Explore Phase*, possibly after the *Private Work* period of the activity. Be sure to leave some time to talk as a class and introduce the homework before class is excused.
- Homework Debrief (15 minutes)
    - At the beginning of the next class, time should be set aside to debrief the homework.
    - Select some students to show how they graphed the historical categories.
    - Ask the class what differences they saw between the graph they created and the standard BMI chart.
    - Hopefully, they notice the following: the range of the graph is different, the independent and dependent variables are swapped, and that there are a different number of sections. Discuss the meaning of each difference as a class.

- Group Work Time (15 minutes)
    - Divide students into at least four groups (3-5 members): assign each group one region of the BMI chart to explore.
    - Move throughout the room to help students who need clarification. Questions to help them along may include:
        - "How have we defined ranges in previous lessons?"
        - "How can we find an equation to represent this line?"
        - "What will be the x and y intercepts for this line?"
        - "Which side of this line is your range on? How does this relate to inequalities?"
    - Select one group per each BMI category to present their findings. Try to select groups who approached the problem in different ways: ensure that the class sees a variety of methods used to solve the problem.
- Presentation Time (20 minutes)
    - Allow selected groups to first describe how they defined their region, then to give their answers.
    - Encourage other students to ask questions and explore the math together.
- Addressing hypothesis (15 minutes)
    - Before students begin the final page of the activity, ask them about their hypotheses. If possible, have many students with each perspective explain and defend their assumption about the hypothetical from the beginning of the activity. Without settling the debate yourself, ask the students to begin the final page of the activity. Completion of this page could be used as a "check out" ticket at the end of the class following the *Summarize* section of the lesson.

Summarize (15 Minutes)

- Once BMI has been explored mathematically, the discussion should shift to the social justice issues related to fat bias.
- Watch the Ted Talk by Professor Madison A. Krall discussing fat bias and thin privilege. (Warning: the presenter mentions sex at the 8:55 mark).
- For a discussion about weight bias and body acceptance, use questions such as the following:
    - "How did what she say make you feel?"
    - "Where does the professor say heavier people face discrimination?"
    - "Is it okay to treat people badly because of how they look?", "Why do some people think it is okay to treat bigger people poorly?"
    - "What does the speaker compare weight bias to?"
    - "Can any of you think of examples at our school where there might be weight bias or privileges related to thinness?"

Taking Action

- Thin people have a big role to play in body acceptance as allies. This can be related to other lessons covered in the year.
- Once students understand the harmful effects of weight stigmatization and the role they can have in mitigation, time might be spent on how to recognize and address the bias. Have them consider where they see weight bias and how they could address it.
- Relate fat stigmatization to roots in capitalism, sexism, and racism:
    - "With all of this critique out there why do insurance companies still use BMI?"
    - "How are fat men and fat women portrayed differently in movies and on television?"
    - "Do other systems exist that were designed specifically for white men, but are now everyone must use?"
- Now that kids understand the math and history behind the BMI chart, they are able to explain it to others. Empower them to be advocates:
    - A hallway poster or presentation may be a way to expand the lesson and give more focus to its social justice context.
- There are other issues related to weight stigmatization which can be explored with geometry, statistics, and algebra. Depending on class behavior and interest, it might be brought back in further lessons for further explanation.

Worksheets and Homework

(see next page)

Day 1: Deciphering the Body Mass Index

In 1839 Adolphe Quetelet defined an index which we now call the 'Body Mass Index' or *BMI* as follows:

$$BMI = \frac{mass\ in\ kilograms}{(height\ in\ meters)^2}$$

Today people still use the Body Mass Index, but as we have discussed in class, it is not always a very accurate way to measure health.

Predict: Imagine that you measured someone's height and weight at age 4 when they were 1 meter tall. If you measured their height at 18 when they were 2 meters tall and their weight had doubled, how would their BMI have changed?

I think that their BMI would (circle one): **Stay the same** **Go up** **Go down**

Explain your reasoning:

_____

_____

_____

When Quetelet designed the Body Mass Index, he only surveyed adult men from France and Scotland.

Let's consider some hypothetical examples with names like the original subjects:

<u>Pierre</u>
Age: 45 Height: 1 meter 90 cm Weight: 107 kilograms

<u>Hamish</u>
Age: 62 Height: 1 meter 98 cm Weight: 97 kilograms

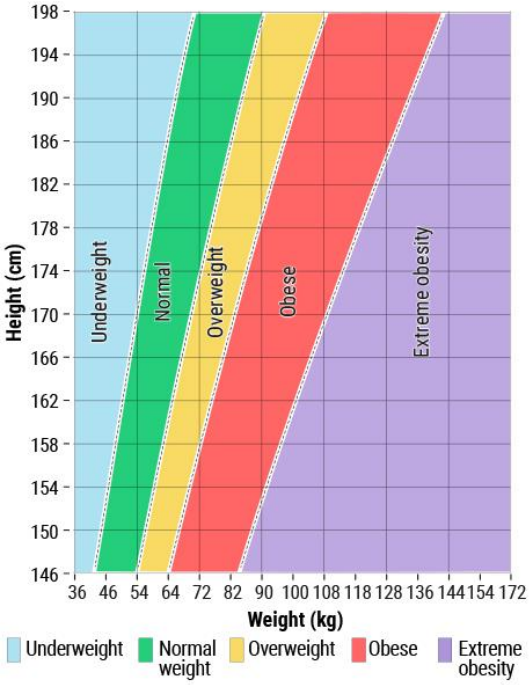
<u>Ronan</u>
Age: 33 Height: 1 meter 65 cm Weight: 67 kilograms

Using the Body Mass Index formula at the top of the page to calculate the 3 men's' BMI scores:

Pierre's BMI is: _____ *Hamish's BMI is*:_____ *Ronan's BMI is*: _____

Use the space below to show your work:

Places that calculate the Body Mass index often display the following chart:



The regions of the chart are defined as follows:

Underweight: BMI scores below 18.5

Normal: BMI scores above 18.5, but less than 25

Overweight: BMI scores above 25, but less than 30

Obese: BMI scores above 30, but less than 40

Extreme Obesity: any BMI score of 40 or more

Answer one of the following:
What do you notice about this chart? How did the designer use color to communicate their own prejudices? How does the creator define 'normal'?
Use the space below to answer one of the questions:

Using the chart above, explain how the chart categorizes our subjects:

Pierre's BMI is _____ which places him in the _____ category of the BMI chart.

Hamish's BMI is _____ which places him in the _____ category of the BMI chart.

Ronan's BMI is _____ which places him in the _____ category of the BMI chart.

Use the space below to show your work:

How do the categories from the chart change how you think about the men? Does it make sense to treat these men any differently based on this new knowledge?

People's bodies are always changing. People get shorter as they get older and everyone's weight is different each day: weight can change slowly or very quickly.

Recall our subjects' original measurements:

Pierre	Hamish	Ronan
Age: 45	Age: 62	Age: 33
Height: 1 meter 90 cm	Height: 1 meter 98 cm	Height 1 meter 65 cm
Weight: 107 kilograms	Weight: 97 kilograms	Weight: 67 kilograms

Consider the following changes in measurements and how they would affect our subjects:

a. Imagine that Pierre gained 2 kilograms between two doctor's appointments.

After this change, Pierre would weigh _____ and his BMI score would change to

_____, the BMI chart would categorize him as _____ now.

b. Imagine that Hamish lost 14 kilograms (about 31 pounds) in one month. When he noticed this change, he used BMI to address if he was still healthy.

After this change, Hamish would weigh _____ and his BMI score would change to

_____, the BMI chart would categorize him as _____ now.

c. Imagine that Ronan's height decreased 2 cm after his 63rd birthday. What news is he going to get the next time he visits the doctor?

After this change, Ronan's height would be _____ and his BMI score would change to

_____, the BMI chart would categorize him as _____ now.

Use the space below to show your work:

Which of these changes surprised you most? If you were a doctor, which change would make you most concerned for your patient? Did the BMI change help you make this decision?

Homework: Getting Familiar with BMI

In class, we categorized some hypothetical examples by calculating their BMI. However, this calculation is not the only way to categorize people using BMI. Many people use the BMI chart to categorize themselves instead of calculating a value. In this assignment, you will explore how this is done.

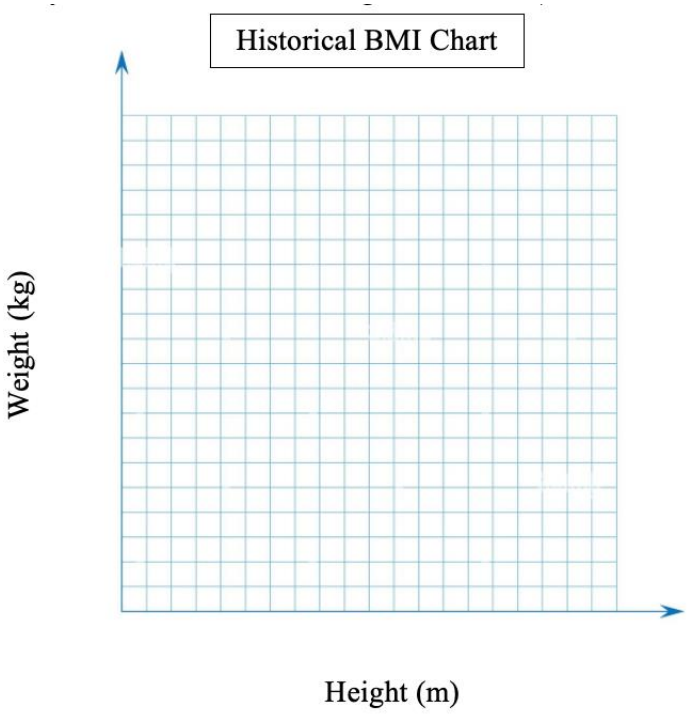
Historically, different values were used to divide the categories of the Body Mass Index. Graph the following equations and label the regions for the historical BMI categories. Label your axes up to at least 150kg and 3 meters.

People to the left of the line: $\mathbf{w = 18.5*h^2}$ were categorized as 'underweight'

People between the lines: $\mathbf{w = 18.5*h^2}$ *and* $\mathbf{w = 27.8*h^2}$ were categorized as 'normal'

People to the right of the line: $\mathbf{w = 27.8*h^2}$ were categorized as 'overweight'

Does your graph look like the graph we saw in class? What is something different about this chart from the one in class?



Using the following examples, label a point on the graph representing each person's height and weight. Next, calculate their BMI using the formula learned in class.

Antoine: 168 cm, 55 kg

Category: _____ BMI: _____

Ewan: 210 cm, 100 kg

Category: _____ BMI: _____

François: 175 cm, 90 kg

Category: _____ BMI: _____

Keithen: 200 cm, 102 kg

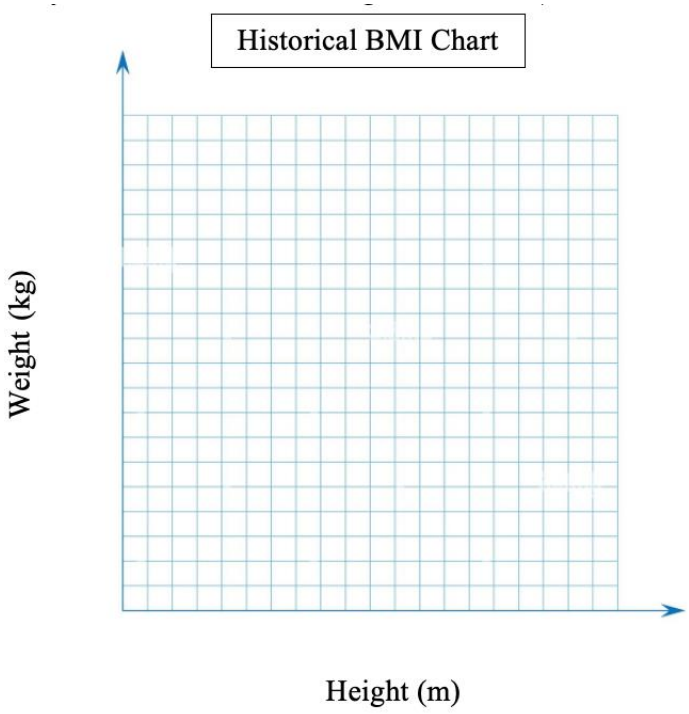
Category: _____ BMI: _____

Do you see any challenges with sorting based on a graph compared to calculating BMI? Which do you prefer?

In 1998, the United States changed how BMI was categorized. The value dividing ‘normal’ and ‘overweight’ was lowered from 27.8 to 25. How would this change affect our example subjects? Would anyone’s BMI category change? How does this make you feel?

When this change was made, about 29 million Americans went from being called ‘normal’ to being called ‘overweight’ without gaining even one pound.

How would this change affect your BMI chart? Draw what you think the new chart would look like, or explain in words what would be different with this new threshold.

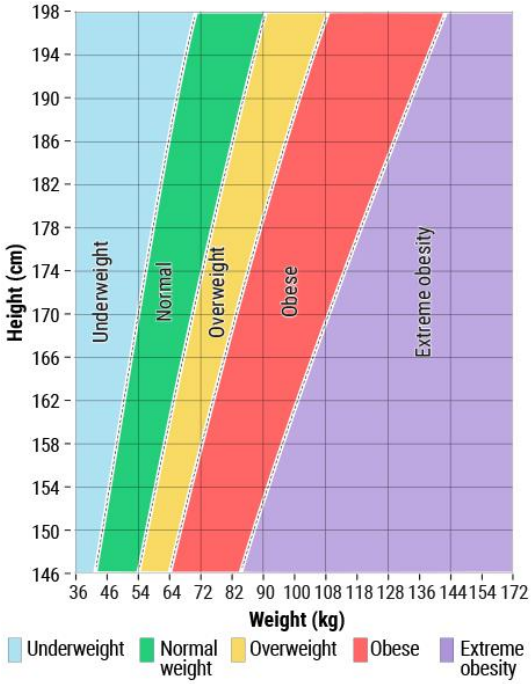


Brainstorm:

Next class, we will find equations to describe all the regions of the modern BMI chart. If you would like to practice, use the space below to define the region of the current overweight category on the BMI chart (values between 25 and 30) using equations. (**Hint: how can inequalities be used to describe this section of the graph?**)

Day 2: Group Work

Like any graph, the BMI chart can be defined using equations.



Recall the boundaries of each region of the BMI chart from before:

Underweight: $0 < BMI < 18.5$

Normal: $18.5 \leq BMI < 25$

Overweight: $25 \leq BMI < 30$

Obese: $30 \leq BMI < 40$

1) Which section of the BMI chart has your group been asked to define?

   _____

2) Let's think about this region together:

   a- The lowest BMI in this region is: _____

   b- The highest BMI in this region is: _____

3) How can we define the bounds of this region using an expression?

   a- What is the dependent variable? _____
   *(*Clue: *did Adolphe Quetelet believe that height changed based on weight or that weight changed based on height?)*

   b- What is the independent variable? _____

4) Now you have all the tools needed to define your region of the BMI chart. Use the area below to write a system of inequalities defining your region:

Returning to Your Hypothesis

At the beginning of this exercise you were told to make the following prediction:

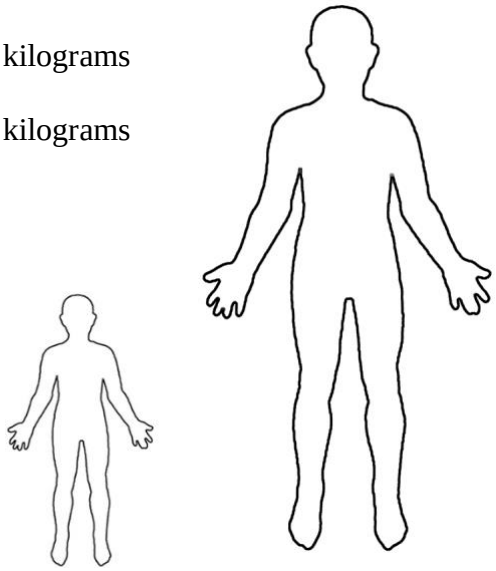
Predict: Imagine that you measured someone's height and weight at age 4 when they were 1 meter tall. If you measured their height at 18 when they were 2 meters tall and their weight had doubled, how would their BMI have changed?

How did you predict their BMI would change? _____

Do you want to change your prediction? _____

Here are the individual's measurements:

Age: 4	Height: 1 meter 0 cm	Weight: 18 kilograms
Age: 18	Height: 2 meters 0 cm	Weight: 36 kilograms



Use the space below to calculate the BMI scores at both ages:

How did the BMI scores change? Can you explain why this happened using the BMI formula to explain the change?

If you are curious why the change was so extreme, you might try converting the measurements to feet and pounds. Do these measurements make a lot of sense? What part of the BMI formula causes this large change?

Running the Lesson and Different Solution Paths

This lesson was test run to a virtual classroom of eight perspective math teachers to determine appropriate pacing, check clarity of wording, understand reactions, and observe different problem-solving approaches.

While running the lesson, participants were eager and productive. The math was described as challenging, but not inaccessible. Students also learned the history of BMI and some changed their opinions on the subject. However, during the final debrief period, it was made clear the lesson had been an emotional roller coaster for multiple participants and even ended in tears for at least two.

Ultimately, this experience led to several suggestions for change. For instance, in the draft lesson, it was encouraged that participants calculate their own BMI. This was distressing for some class members who were concerned they'd be called on to share their score with the group. One peer wisely observed, "calculating your own BMI can only disappoint people." Another suggested that we should not give validity to a tool that we were ultimately trying to deconstruct. Insights like these led to an expanded emphasis on Trauma Informed Teaching practices.

Discussing weight can be traumatic to adults and children alike. Trauma Informed Teaching strategies are not just an option, but a necessary part of running this lesson. The lesson demands students perform precise calculations, use critical thinking, and engage in discussion: all of these are hampered when a student is emotionally distressed. For this reason, I again stress that the lesson must be handled carefully and discussions must be closely supervised by teachers so that everyone feels safe and can focus on the lesson .

Along with insight into the different emotional interpretations people have to this lesson, different mathematical interpretations were also observed. Below I will describe some of the different pathways allowed by this lesson.

Hypothesis Differences

The first question on the worksheet asks students to predict how doubling weight and height would change someone's BMI. Depending on their interpretation, a student might assume the BMI would increase, decrease, or stay the same. After group work, but before the *Returning to Your Hypothesis* section of the activity, students should be asked to elaborate on why they felt that way and if their hypotheses have changed.

There are many potential explanations why BMI would decrease (the correct hypothesis), increase, or stay the same. Allowing students to discuss their own perspectives will demonstrate how they understand the relationship which BMI measures.

Independent and Dependent Variables

During group work, students are asked to find a system of inequalities to represent a region of the BMI chart. Before describing their system, they must identify which variable (either height or weight) is dependent on the other. The two groups in the class had different arguments for which variable was which. One group stated that Quetelet believed weight depended on height and that weight was therefore the independent variable. The other group argued that the standard BMI chart places height on the x-axis, and therefore it must be the independent variable. The homework assignment may lead to more arguments for either interpretation.

Ultimately, either interpretation is valid. The class should debate and decide among themselves which they prefer based on arguments from either side. After this process, allow student volunteers to adjust the shared equations which do not use the agreed upon variables.

Separation vs. Combination of Inequalities

As a group, students are asked to generate systems of inequalities to describe each category of the BMI chart. Assuming that weight is accepted as the independent variable, the 'normal' category of the chart can be described by the following system: $18.5h^2 \leq w \leq 25h^2$. Some students prefer to keep dependent variables on the left side of equations and will instead give two inequalities: $w \geq 18.5h^2$ and $w \leq 25h^2$. Students might also not be aware that equations can have more than two expressions.

Recognizing that the pair of inequalities can be combined is a key math learning from this lesson. Showing why these two interpretations are equivalent is important: give students a chance to explain their thinking to each other before stepping in.

Conclusion

Weight stigmatization remains a form of discrimination which gets very little attention and (unlike most forms of discrimination) is even sometimes regarded as a positive thing to do. A math lesson can be an appropriate way to introduce this issue and begin a conversation very relevant to high schoolers similar to other topics discussed in Teaching Math for Social Justice curriculums. The lesson will also empower students to approach future conversations about weight with the 'language of logic' that is usually missing from these conversations.

BMI represents a clear way to bring these issues into the math classroom. The lesson offered above requires sensitivity, just like all discussion relating to weight. It also offers a great connection between graphing systems of inequalities and a complicated social context: necessarily leading to learning about both.

Annotated Bibliography

Abramson, J. (n.d.). *Body Mass Index (BMI) Lesson Plan*. Study.Com. Retrieved January 14, 2022, from https://study.com/academy/lesson/body-mass-index-bmi-lesson-plan.html

Amy, N. K., Aalborg, A., Lyons, P., & Keranen, L. (2006). Barriers to routine gynecological cancer screening for White and African-American obese women. *International Journal of Obesity*, *30*(1), 147–155. https://doi.org/10.1038/sj.ijo.0803105

Obese women are reported to be at higher risk from gynecological cancers than nonobese women, yet these women are less likely to get cancer-screening tests. The specific factors that contribute to obese women not obtaining timely cancer screening have not been identified.

Ani, K. (2021). *Dear Citizen Math: How Math Class Can Inspire a More Rational and Respectful Society*. Damascus Rodeo.

Berry, R. Q., Conway, B. M., Lawler, B. R., & Staley, J. W. (2020). *High School Mathematics Lessons to Explore, Understand, and Respond to Social Injustice*. https://www.nctm.org/Store/Products/High-School-Mathematics-Lessons-to-Explore,-Understand,-and-Respond-to-Social-Injustice/

This teacher resource provides a starting point to build class content around a social justice framework. Asides from providing many math lessons to meet high school math standards, the book introduces social justice education and provides several arguments for why a social justice framework is superior to a traditional lesson structure.

CDC. (2021, September 1). *What Is My BMI?* Centers for Disease Control and Prevention. https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/english_bmi_calculator/bmi_calculator.html

Use this simple tool to calculate an adult's body mass index (BMI).

Eknoyan, G. (2008). Adolphe Quetelet (1796-1874)—The average man and indices of obesity. *Nephrology, Dialysis, Transplantation: Official Publication of the European Dialysis and Transplant Association - European Renal Association*, *23*(1), 47–51. https://doi.org/10.1093/ndt/gfm517

This short biography looks at Adolphe Quetelet's search to describe the "normal man". It discusses his foundational role in the social sciences in the 19th century and his moral philosophy. The paper also briefly describes how his index became the Body Mass Index which was championed by Ancel Keys in 1972 and eventually adopted by insurance companies.

Hainer, V., & Aldhoon-Hainerová, I. (2013). Obesity Paradox Does Exist. *Diabetes Care*, *36*(Supplement 2), S276–S281. https://doi.org/10.2337/dcS13-2023

This literature review describes the "obesity-mortality paradox". Contrary to common belief, there are many measures of mortality which decrease with rising BMI scores. Among the 15 manifestations described in the review are the likelihood to survive surgery, stroke, and diabetes with increasing BMI, perhaps most surprising is that individuals categorized as obese by the BMI chart have longer life expectancy than those categorized healthy.

Nordqvist, C. (2013, August 25). *Why BMI is inaccurate and misleading*. https://www.medicalnewstoday.com/articles/265215
In this article, Nordqvist aggregates several arguments against the use of BMI as a measure of health, citing when BMI fails to accurately describe people's health and some benefits of being overweight. Additionally, he proposes using a waist to height ratio as a superior measure of health to the Body Mass Index.

Puhl, R. M., & King, K. M. (2013). Weight discrimination and bullying. *Best Practice & Research Clinical Endocrinology & Metabolism*, *27*(2), 117–127. https://doi.org/10.1016/j.beem.2012.12.002
Yale Professor and PhD, Rebecca Puhl, summarizes the stereotypes and stigmatization faced by obese Americans in this review. Puhl also describes the negative ramifications of these attitudes on social, psychological, and physical health of those effected. Among many documented biases, the review states that teachers have significantly lower expectations of obese students and that attitude leading to weight discrimination are developed in childhood. Both facts point to the importance of addressing the problem in a classroom setting.

Ravitch, D., & Viteritti, J. P. (2001). *Making Good Citizens: Education and Civil Society*. Yale University Press. http://ebookcentral.proquest.com/lib/psu/detail.action?docID=3420336
This 2001 collection of essays addresses what public education has been and what it has become in the United States. The collection focuses on how education teaches children to participate in democracy as informed citizens.

Tomiyama, A. J., Hunger, J. M., Nguyen-Cuu, J., & Wells, C. (2016). Misclassification of cardiometabolic health when using body mass index categories in NHANES 2005–2012. *International Journal of Obesity*, *40*(5), 883–886. https://doi.org/10.1038/ijo.2016.17
The authors of this study, published in the International Journal of Obesity found that from a sample of 40,420 Americans described as overweight or obese by the Body Mass Index, nearly half had metabolic data which categorize them as healthy. even among people categorized as obese, 30% had data indicating they were healthy.

Yanik, H. B., & Memis, Y. (2016). What is your body mass index? *Teaching Children Mathematics*, *22*(7), 442–446. https://doi.org/10.5951/teacchilmath.22.7.0442
Written by two Math Education PhDs, this is the only lesson plan addressing the Body Mass Index on the National Council of Teachers of Mathematics (NCTM). While the lesson effectively utilizes the math of the Body Mass Index, it fails to responsibly handle the subject. When listing lesson goals, the authors make it clear that they believe the BMI is a good tool for understanding health and deputizes children to judge other peoples' health. This is dangerous in a classroom.