Quantifying Obesity in Economic Research: How Misleading is the Body Mass Index?

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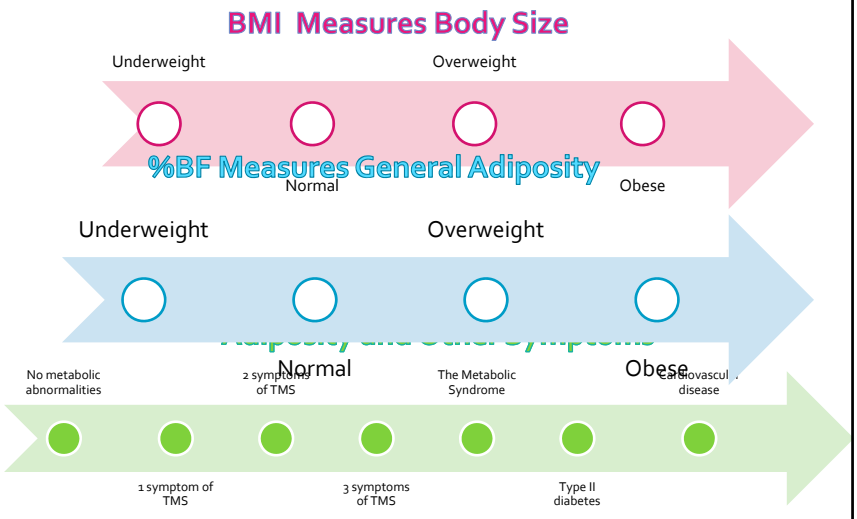
BMI is Ubiquitous

- Economists and epidemiologists use BMI to :
  - Estimate relative risk of death and disease for overweight and obese.
  - Calculate costs of obesity and related conditions.
  - Estimate effect of economic factors on obesity.
- *Q:* But what if BMI poorly predicts obesity and negative health outcomes?
- *Q:* How might economist's estimates be biased when BMI used as a proxy for obesity?

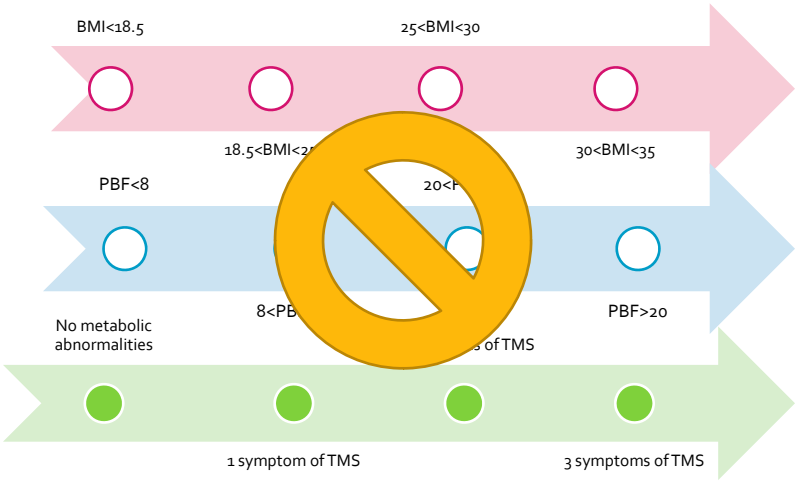
What We Do

- Evaluate BMI as a predictor of obesity as measured by percent body fat (%BF).
  - Quantify nature and magnitude of measurement error bias.
- Evaluate BMI as a predictor of morbidity and mortality relative to our obesity index.
  - Quantify nature and magnitude of measurement error bias.
  - Identify variables associated with bias in models that use BMI.

Obesity Measures Differ



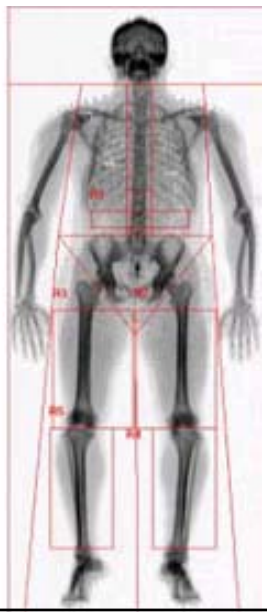
Obesity Measures Differ



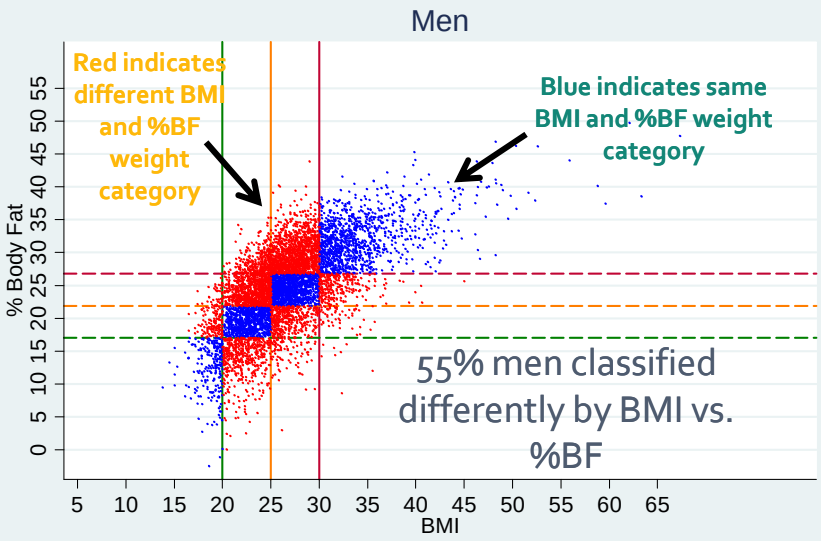
Same BMI, but Twice the Percent Body Fat

← Man A:
BMI = 31.74
%BF = 13
Wt(kg) = 106.3
Ht (m) = 1.83 m

Man B →:
BMI = 31.67
%BF = 26.3
Wt(kg) = 98.1
Ht (m) = 1.76



BMI as a Proxy for %BF



Note: The implied healthy/normal % body fat range for men is 17.1-21.9%.

Data: NHANES III

- Third National Health and Nutrition Examination Survey, conducted 1988-1994.
  - Individual and household characteristics
  - Lab tests and exam measurements
  - Mortality follow-up (December, 2006)
  - Diet recall
- Bioelectrical impedance analysis (BIA) readings allow for the calculation of %BF.
- 30,818 observations w/ exam data.
  - Have PBF and all other variables for 14,958 respondents.

BMI as Proxy for %BF

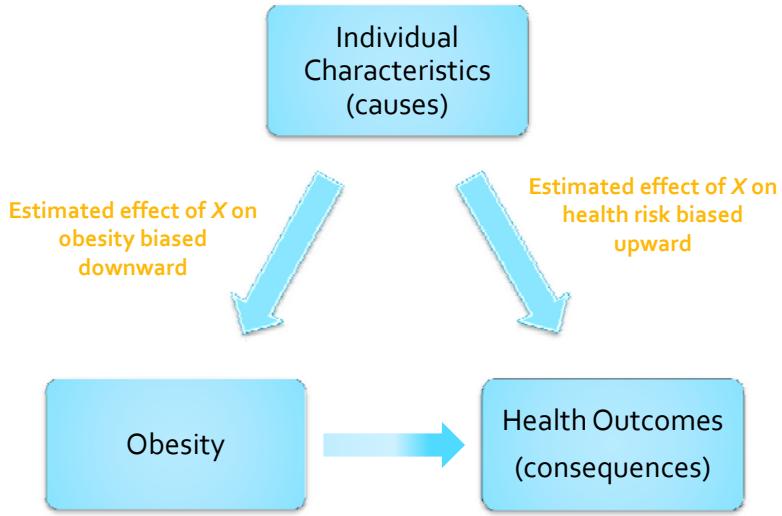
- Would like to model determinants of obesity and estimate:
  1. $\%BF_i = \beta' X_i + \varepsilon_i$
  - Xs are individual characteristics,
  - βs are the coefficients of interest.
- But economist (usually) does not observe %BF, so they estimate:
  2. $BMI_i = \gamma' X_i + u_i$

Measurement Error Bias

- Measurement error bias exists when X_i contains more or different information about BMI than it does about %BF
- Measurement error bias present if $\delta \neq 0$ in the regressions:

3. $\%BF_i = \alpha BMI_i + \delta' X_i + \nu_i$

Interpreting Measurement Error Bias: $\delta > 0$



Percent Body Fat Measurement Error Regressions

	Women	*Men*
BMI	0.94**	0.77**
Age	0.21**	0.11
Age^2	-0.002**	-0.001
Black	0.80**	0.31
Current Smoker	-0.57*	-0.41
Ex-Smoker	0.15	0.10
Menopause	0.63*	
< 5 Yrs HRT	0.37	
> 5 Yrs HRT	0.91**	
Family History T2D	-0.01	-0.01
Insomnia Spells	0.2	0.91
Hypersomnia Spells	-0.73	0.14
Constant	4.36*	0.03
Observations	4,012	3,814
R^2	0.69	0.39
Null F-Stat	18.63	7.67
Null p-value	0.00	0.00

Notes: **p<0.01, *p<0.05. HRT=hormone replacement therapy (estrogen).

$$\%BF_i = \alpha BMI_i + \delta' X_i + \nu_i$$

Measuring Obesity as Increased Health Risk from Excess Fat

- $\bar{F}_i$ is a "healthy" amount of fat
- D_i equals one in the event of a bad health outcome.
  - Type 2 diabetes, CVD, death, death from obesity related cause.
- Then obesity index for *i* is:

$$OB_i = Pr\left(D_i = 1 \middle| F_i, X_i\right) - Pr\left(D_i = 1 \middle| \bar{F}_i, X_i\right)$$

The Obesity Index

- Combines the effects of excess adipose tissue, abdominal obesity, and metabolic abnormalities on the risk of disease and death.

$$\begin{aligned}\Pr\left(D_i = 1 \middle| X_i, F_i\right) = {} & \beta_0 + \beta_1 \%BF_i + \beta_2 \left(\%BF_i\right)^2 + \beta_3 \%BF_i^{t-10} + \beta_4 \left(\%BF_i^{t-10}\right)^2 \\ & + \beta_5 Female_i \times \%BF_i + \beta_6 Female_i \times \left(\%BF_i\right)^2 \\ & + \beta_7 Black_i \times \%BF_i + \beta_8 Black_i \times \left(\%BF_i\right)^2 \\ & + \beta_9 WC_i + \beta_{10} TRG_i + \beta_{11} HDL_i + \beta_{12} BP_i \\ & + \beta_{13} QUICKI_i + \beta_{14} QUICKI_i \times AbOB_i \\ & + \beta_{15} BP_i \times QUICKI_i + \beta_{16} BP_i \times AbOB_i + \theta' X_i\end{aligned}$$

Measurement Error Bias

5. $Pr(D_i = 1 | F_i, X_i) = [\text{Obesity Index}_i] + \theta' X_i$

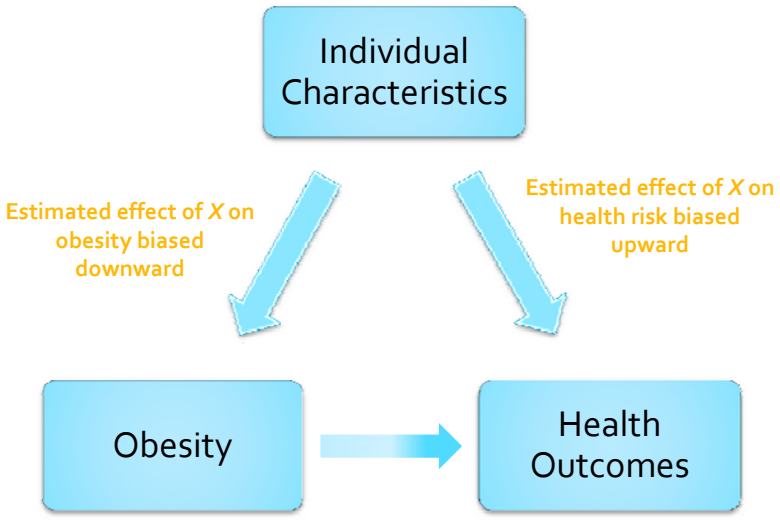
6. $Pr(D_i = 1 | F_i, X_i) = \phi_{0i} + \alpha BMI_i + \eta' X_i$

- Measurement error bias problem if :

$$\eta - \theta = \delta \neq 0$$

- i.e., when the coefficients on *X* differ depending on which measure of fatness is used to predict health outcomes.

Interpreting Measurement Error Bias: $\delta > 0$



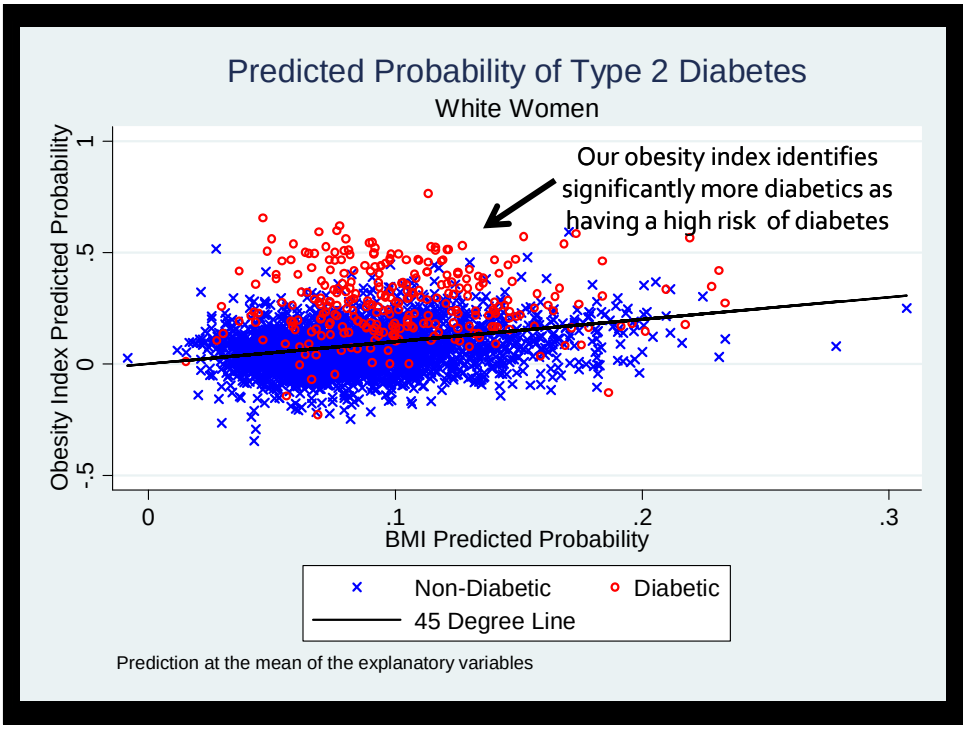
BMI vs. Obesity Index Effects on Type 2 Diabetes and CVD

	Type 2 Diabetes		*Cardiovascular Disease*	
	(1)	(2)	(3)	(4)
BMI		0.006**		0.003**
%BF	-0.006		0.002	
$\%BF^2$	0.000		0.000	
$\%BF_{t-10}$	0.001		-0.004*	
$(\%BF_{t-10})^2$	0.0001**		0.00006*	
Female*%BF	0.005		-0.002	
Female*$(\%BF)^2$	0.000		0.000	
Black*%BF	-0.007		-0.007	
Black*$(\%BF)^2$	0.000		0.000	
Waist Circumference	0.00136*		-0.001	
Criteria for Metabolic Syndrome:				
Triglycerides	-0.012*		0.026*	
HDL Cholesterol	0.001		0.046**	
Blood Pressure	0.625**		0.492**	
QUICKI	-5.450**		0.162	
(Blood Pressure)*(QUICKI)	-4.025**		-3.074**	
(Abdominal Obesity)*(QUICKI)	-0.144*		0.049	
(BP)*(Abdominal Obesity)	-0.038**		-0.032	
R^2	0.230	0.069	0.080	0.060

Measurement Error Bias in BMI vs. Obesity Index Effects on Health Outcomes

	δs			
	Type 2 Diabetes	*CVD*	*Mortality*	*Obesity Related COD*
Female	-0.01994	-0.04751	-0.14213	-0.05444
Black	-0.07193	-0.10068	-0.17422	0.04697
Age	0.00303**	0.00226**	0.00144**	0.00516**
Age^2	-0.00001	-0.00002**	0.00000	-0.00003
Current Smoker	0.00244	0.00519	0.00124	0.01212
Former Smoker	0.00636	0.00731**	0.00229	0.01093
Alcohol Cal Share	-0.00167**	-0.00091**	-0.00028	-0.00115**
$(\text{Alcohol Cal Share})^2$	0.00001	0.00001	0.00000	0.00002
Family History T2D	0.02279**	0.00881**	0.00739**	0.01094**
Income to Poverty Ratio	-0.00324**	-0.00091	-0.00166**	-0.00102**
Insomnia Spells	-0.0002	0.0036	-0.00008	-0.01525
Hypersomnia Spells	0.00156	-0.00156	0.00072	0.01276
F-Stat	9.595	4.051	3.423	1.369
p-value	0.000	0.000	0.000	0.173

Notes: Standard errors in parentheses, ** p<0.01, * p<0.05



Conclusion

- BMI not closely related to obesity as measured by PBF or our obesity index.
  - Low R^2 and many people misclassified by BMI vs. PBF.
- Age, sex, race, smoking and alcohol affect BMI and PBF differently.
  - Bias in estimated causes of obesity
  - Might misinterpret of the causes and their relative importance in explaining obesity.
- The measurement error is more than just noise, it is systematically related to specific variables.
  - Misleading results for causes and consequences of obesity.

Thank You!