BMI may predict adiposity, but not well enough for valid population inference

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PAA 2025 ANNUAL MEETING

Session on Obesity, Behavior, and Novel Weight-Loss Medications

The Team

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CENTER for STATISTICS and the SOCIAL SCIENCES

1. “in **population** studies BMI is a **reasonable** surrogate measure of body and visceral fat, but it lacks sensitivity and specificity when applied to individuals.”

- Nature, International Journal of Obesity (2009)

2. “BMI remains the most commonly used metric for **population-level** assessments and provides the most extensive data.”

- the Lancet, Volume 405 March 08, 2025

Contributions:

1. We test the assumption that BMI is “good enough” for population-level inference, and find that **it is not**.

Contributions:

1. We question the assumption that BMI is “good enough” for population-level inference, and find that **it is not**.

2. We offer a practical solution (with caveats):

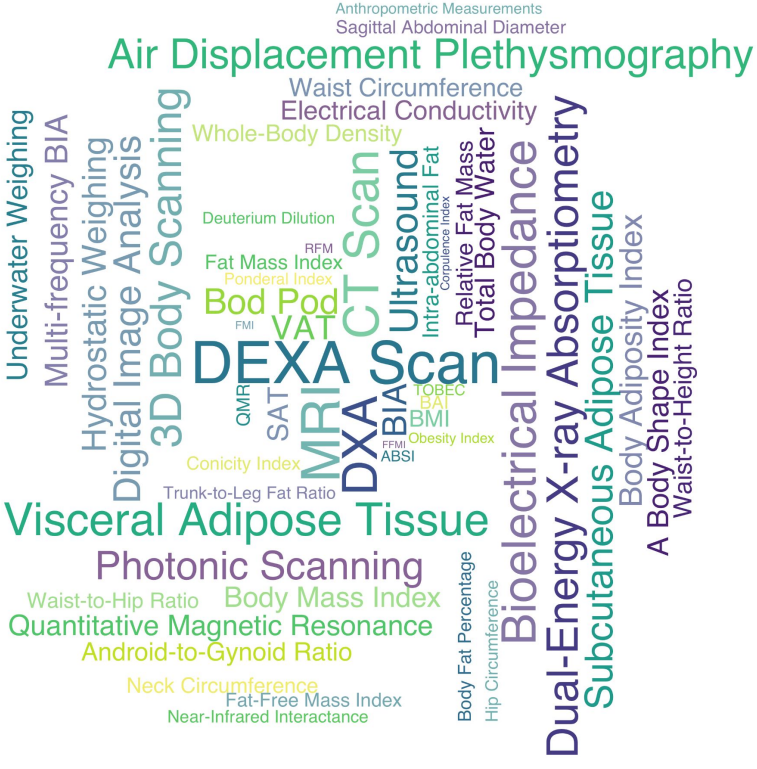
   a **statistical calibration** from inexpensive BMI-based measures of obesity towards better but less accessible measures.

Obesity

excessive fat accumulation that presents a risk to health

- World Health Organization

Obesity

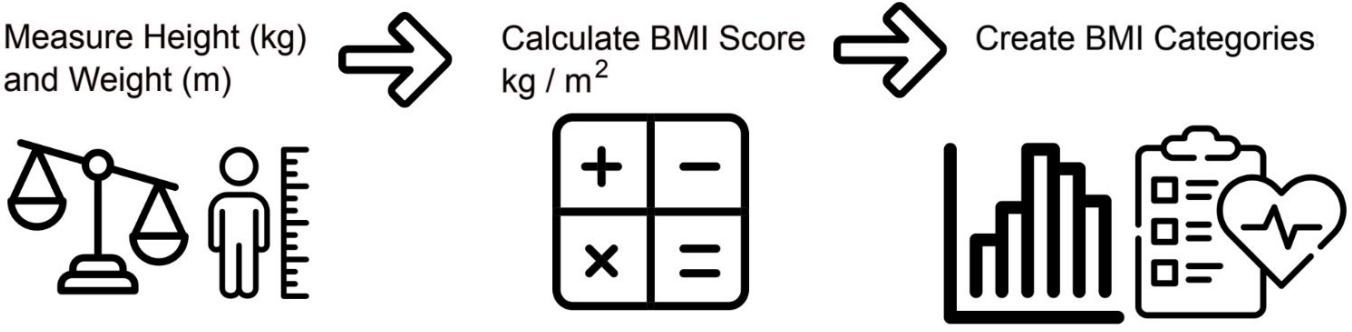


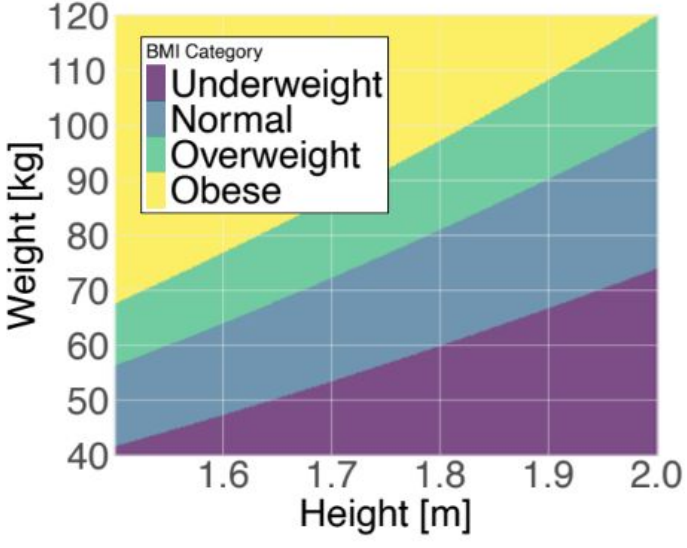
excessive ***fat accumulation*** *that presents a risk to health*

aka **Adiposity**

- World Health Organization

BMI is a cheap adiposity prediction algorithm





The Body Mass Index: the Good, the Bad, and the Horrid

BARRY BOGIN AND INES VARELA-SILVA

OPEN ACCESS

GAVIN PUBLISHERS

Journal of Obesity and Nutritional Disorders

Research Article

Abrahim M and Hand B. J Obes Nutr Disord 06: 145.

DOI: 10.29011/2577-2244.100045

Is it Time to Consider Body Mass Index to be Bad Medical Information (BMI)?

Mohammed Abrahim*, Brittany Hand

NUTRITION RESEARCH

Body Mass Index

Obesity, BMI, and Health

A Critical Review

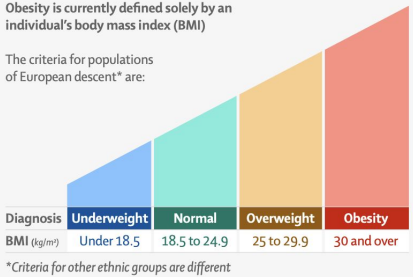
Nuttall, Frank Q. MD, PhD

Diagnosing clinical obesity

Limitations of the current definition of obesity

Obesity is currently defined solely by an individual's body mass index (BMI)

The criteria for populations of European descent* are:



*Criteria for other ethnic groups are different

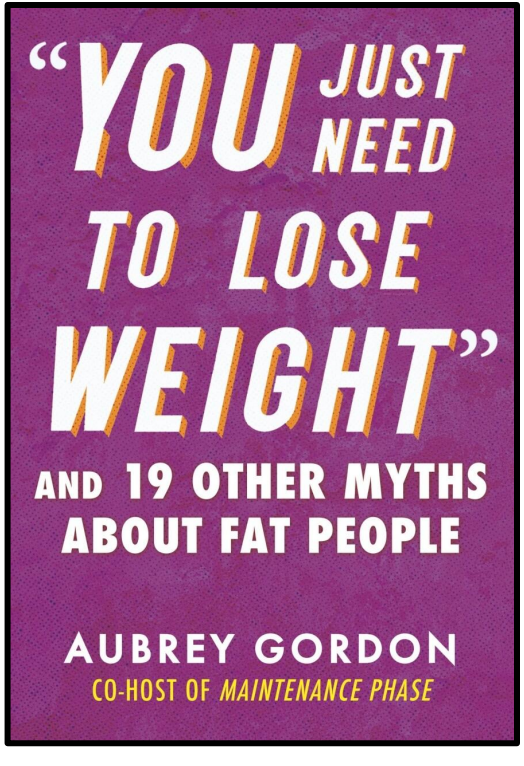
- Although BMI is **useful** for identifying individuals at increased risk of health consequences...
- It **is not** a direct measure of fat
- It **does not** establish the distribution of fat around the body
- It **cannot** determine when excess body fat is a health problem

Why You Shouldn't Rely on BMI Alone

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Home / News / BMI a poor metric for measuring people's health, say experts

BMI a poor metric for measuring people's health, say experts



The Body Mass Index: the Good, the Bad, and the Horrid

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Home / News / BMI a poor metric for measuring people's health, say experts

BMI is discussed everywhere.

Ubiquity legitimates its use in research.

but BMI ≠ Adiposity!

Why You Shouldn't Rely on BMI Alone

AUBREY GORDON
CO-HOST OF *MAINTENANCE PHASE*

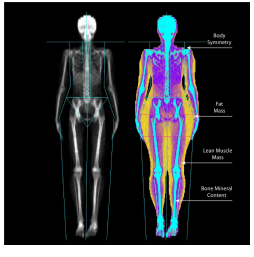
What is the “gold standard” measure of adiposity?

Dual-Energy X-Ray Absorptiometry

DXA scans are the “gold standard” measure of adiposity.

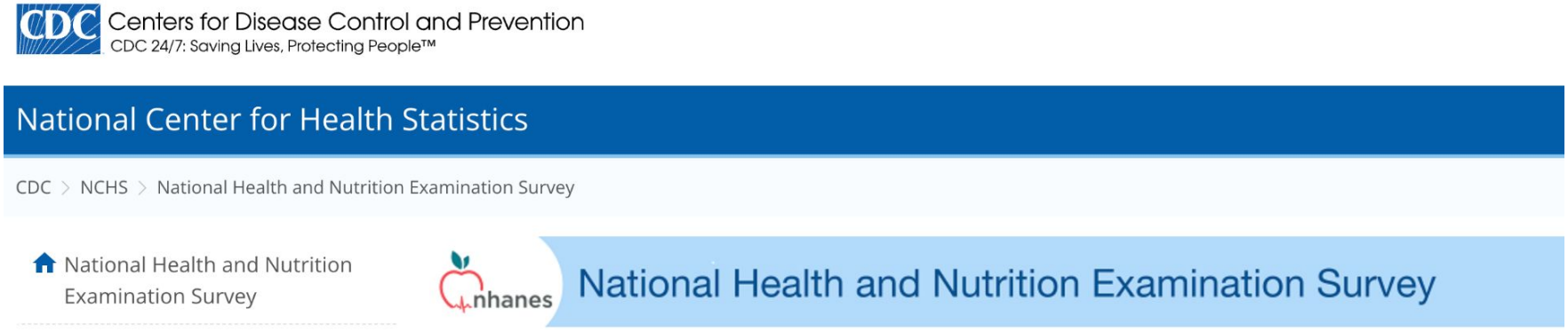
- Encyclopedia of Human Nutrition (Fourth Edition), 2013

As opposed to BMI and WC which measure **body proportions**, DXA measures **body composition** directly.



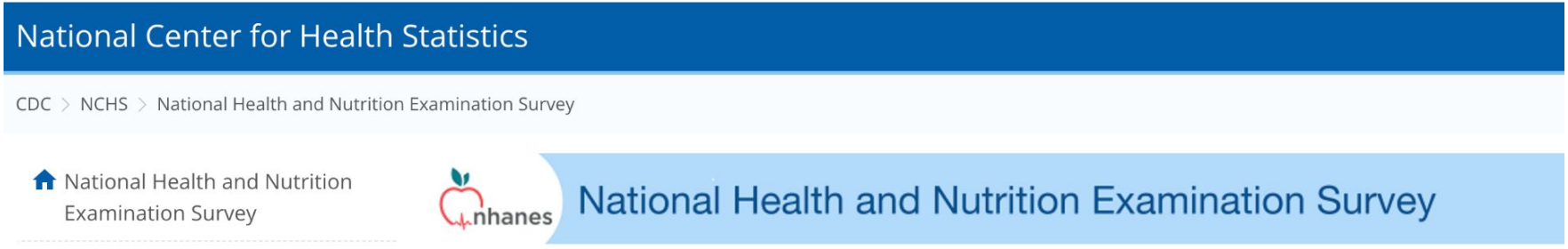
Whole-body percentage fat

Data



2011-2017	2021-2023
✅ BMI	✅ BMI
✅ Waist circumference (WC)	✅ Waist circumference (WC)
✅ Whole-body fat % (DXA)	❌ Whole-body fat % (DXA)

Data



Obesity Threshold

BMI	> **30 kg/m^2** for females and males
Waist circumference (WC)	> **88cm** (female) or **102cm** (male)
Whole-body fat % (DXA)	> **42%** (female) or **30%** (male)

Inference with Predicted Data (IPD)

arXiv > stat > arXiv:2401.08702

Statistics > Methodology

[Submitted on 14 Jan 2024 (v1), last revised 2 Feb 2024 (this version, v2)]

Do We Really Even Need Data?

Kentaro Hoffman, Stephen Salerno, Awan Afiaz, Jeffrey T. Leek, Tyler H. McCormick

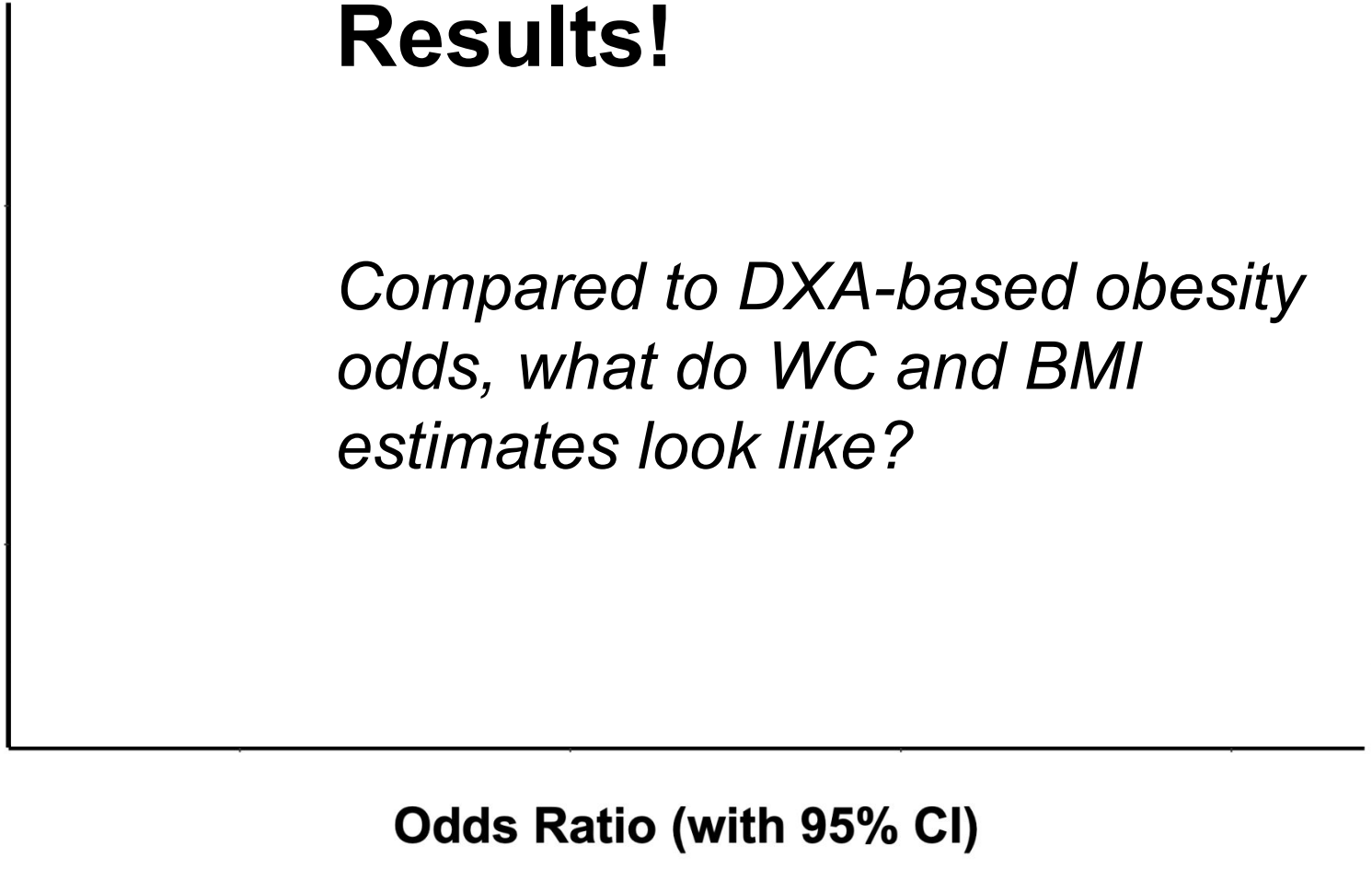
Inference with Predicted Data (IPD)

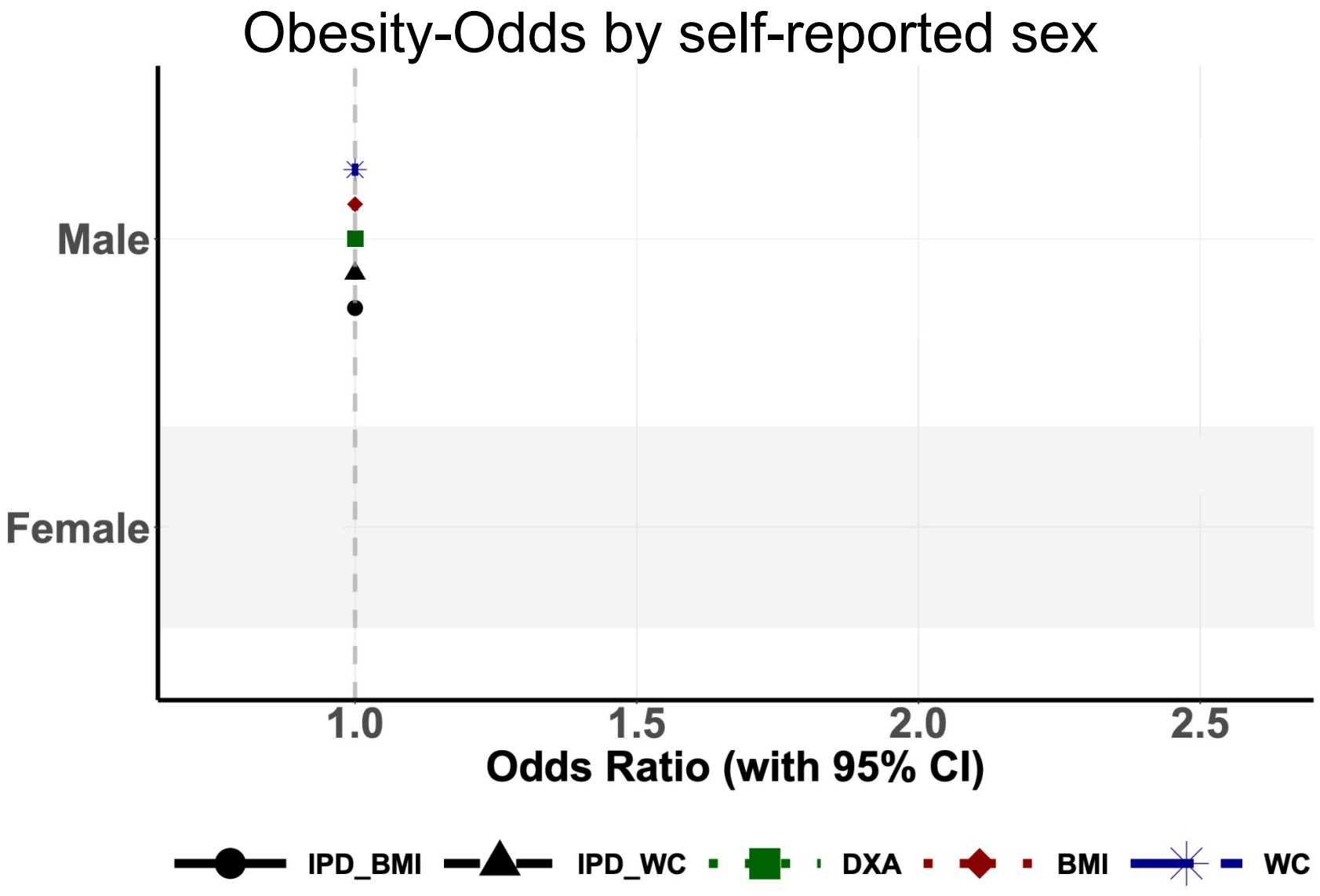
Session on Machine Learning Approaches in Mortality Research

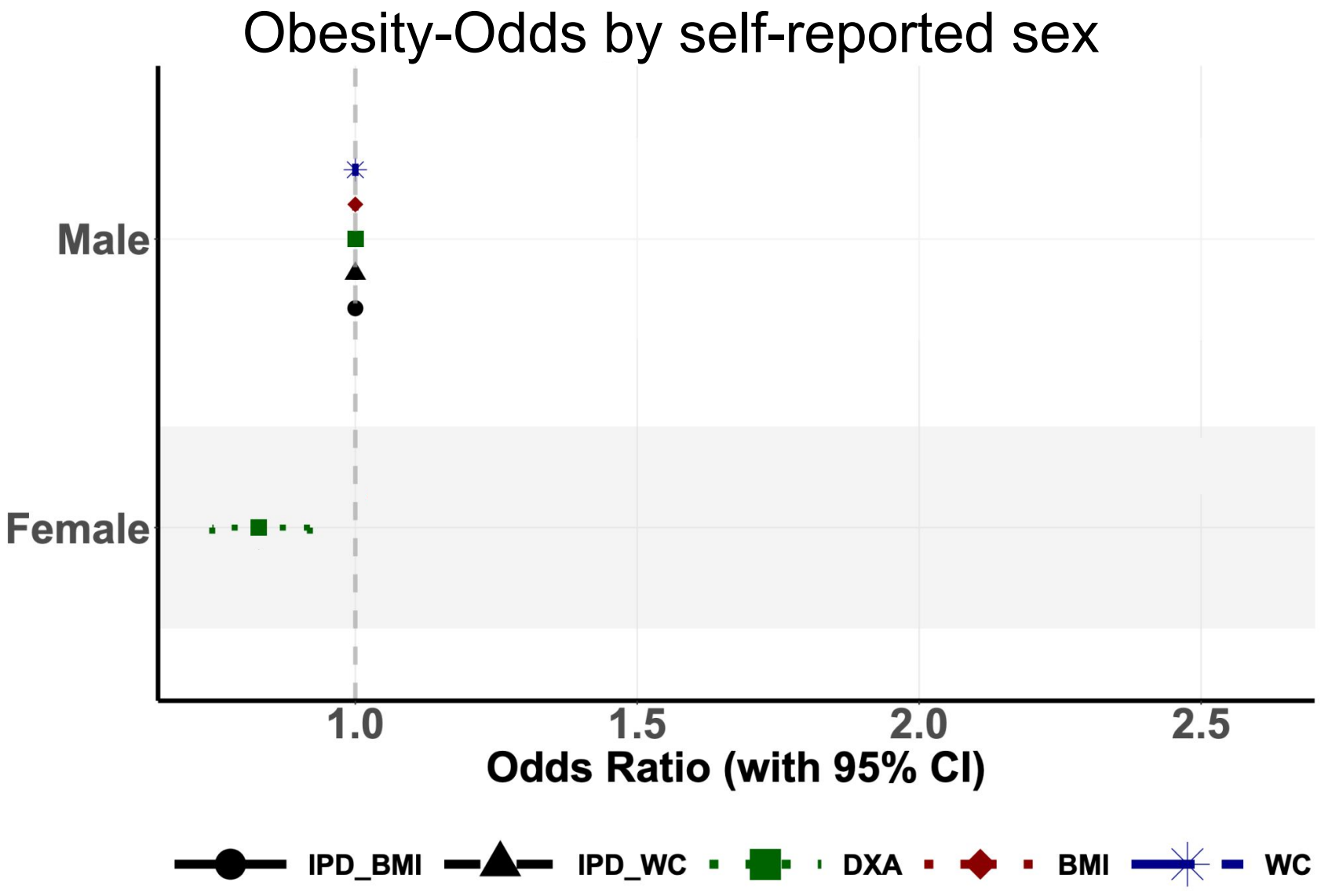
3:30 PM - 4:45 PM
Magnolia

Results!

Compared to DXA-based obesity odds, what do WC and BMI estimates look like?




Obesity-Odds by self-reported sex
Male
Female
1.0
1.5
2.0
2.5
Odds Ratio (with 95% CI)
IPD_BMI
IPD_WC
DXA
BMI
WC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1.0
1.5
2.0
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Odds Ratio (with 95% CI)
IPD_BMI
IPD_WC
DXA
BMI
WC


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IPD_BMI
IPD_WC
DXA
BMI
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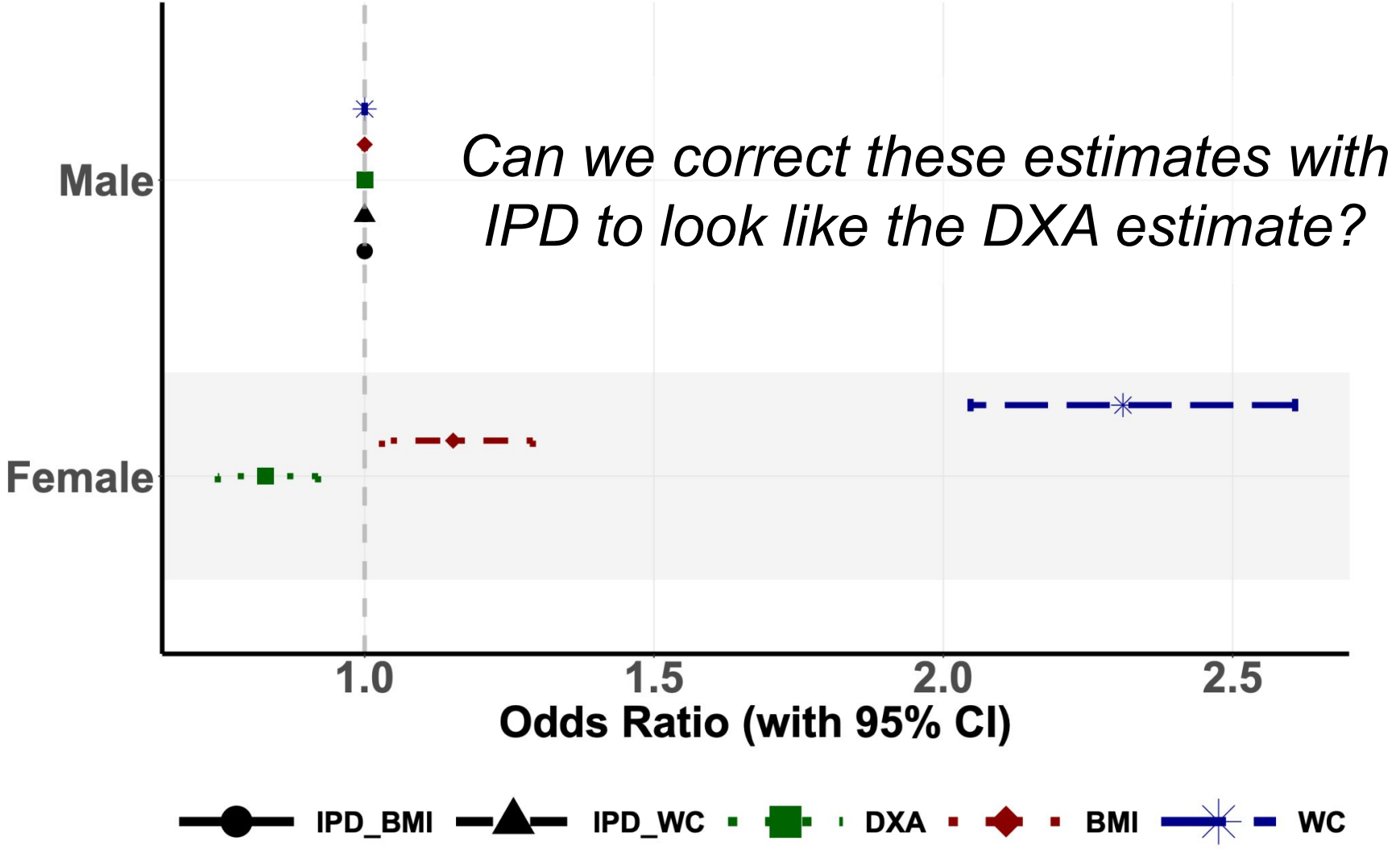
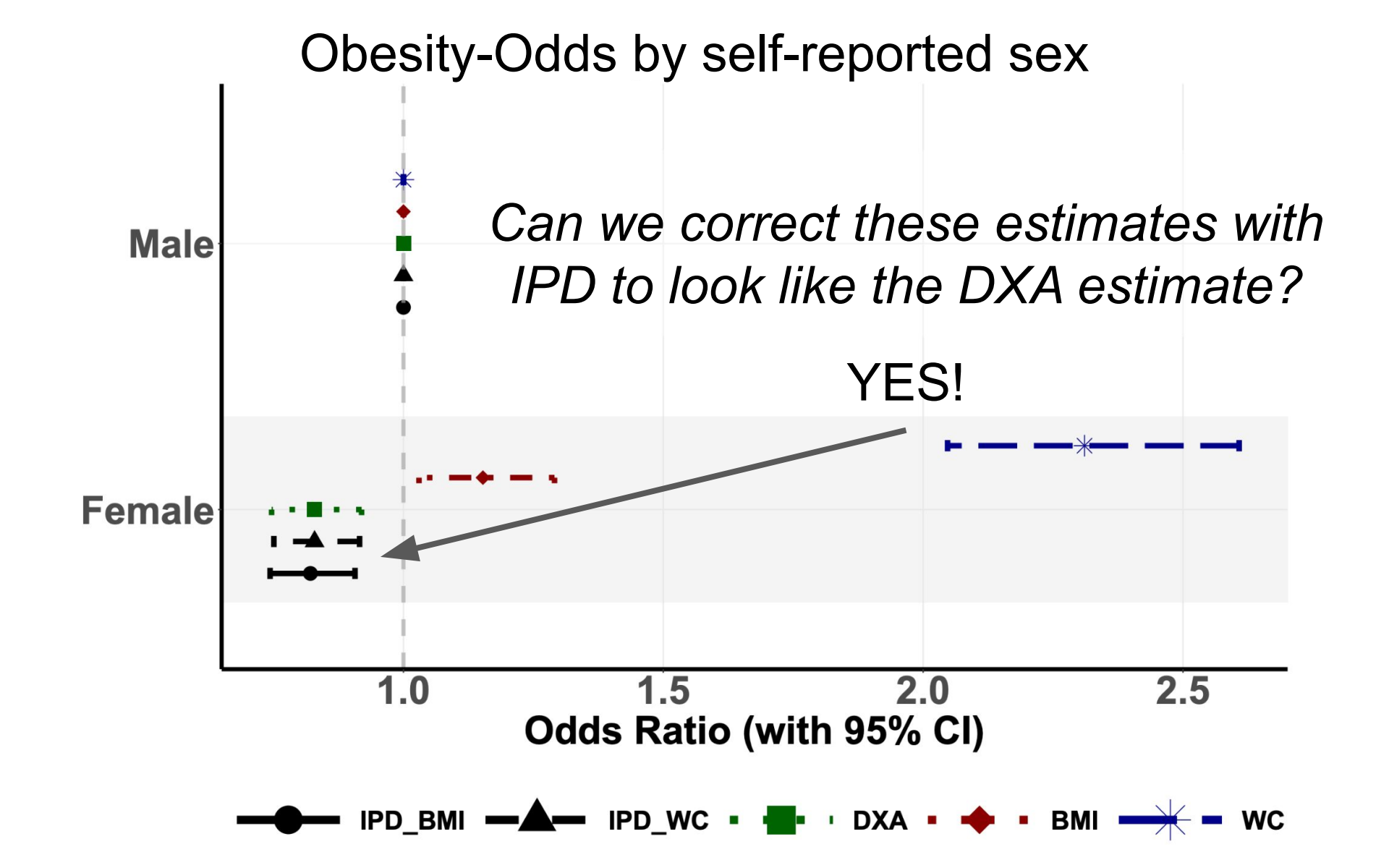
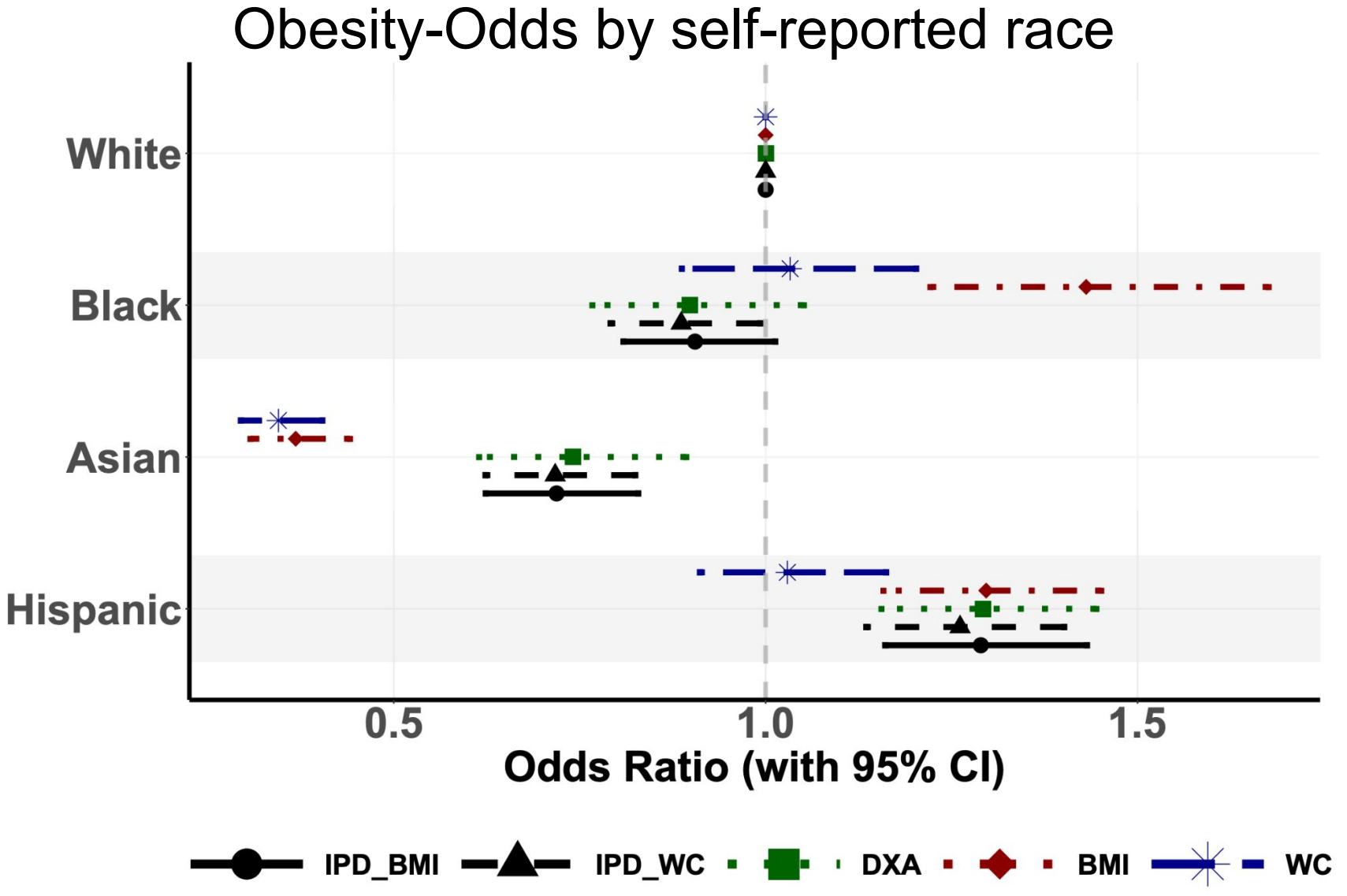
2.0
2.5
Odds Ratio (with 95% CI)
IPD_BMI
IPD_WC
DXA
BMI
WC

Obesity-Odds by self-reported sex




Obesity-Odds by self-reported sex
Male
Female
Can we correct these estimates with IPD to look like the DXA estimate?
YES!
1.0
1.5
2.0
2.5
Odds Ratio (with 95% CI)
IPD_BMI
IPD_WC
DXA
BMI
WC


Obesity-Odds by self-reported race
White
Black
Asian
Hispanic
0.5
1.0
1.5
Odds Ratio (with 95% CI)
IPD_BMI
IPD_WC
DXA
BMI
WC

Takeaways:

1. Obesity is a difficult concept to measure. We can measure adiposity directly, but its expensive

2. BMI alone is not a reliable measure of adiposity for individuals OR for population inference, but its cheap

3. Using a statistical calibration can get you estimates from cheap measures (BMI) that are aligned with an expensive “ground truth” measure (DXA)

Acknowledgements:

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How to measure obesity in public health research? Problems with using BMI for population inference

Adam Visokay, Kentaro Hoffman, Stephen Salerno, Tyler H McCormick, Sasha Johfre

doi: https://doi.org/10.1101/2025.04.01.25325037

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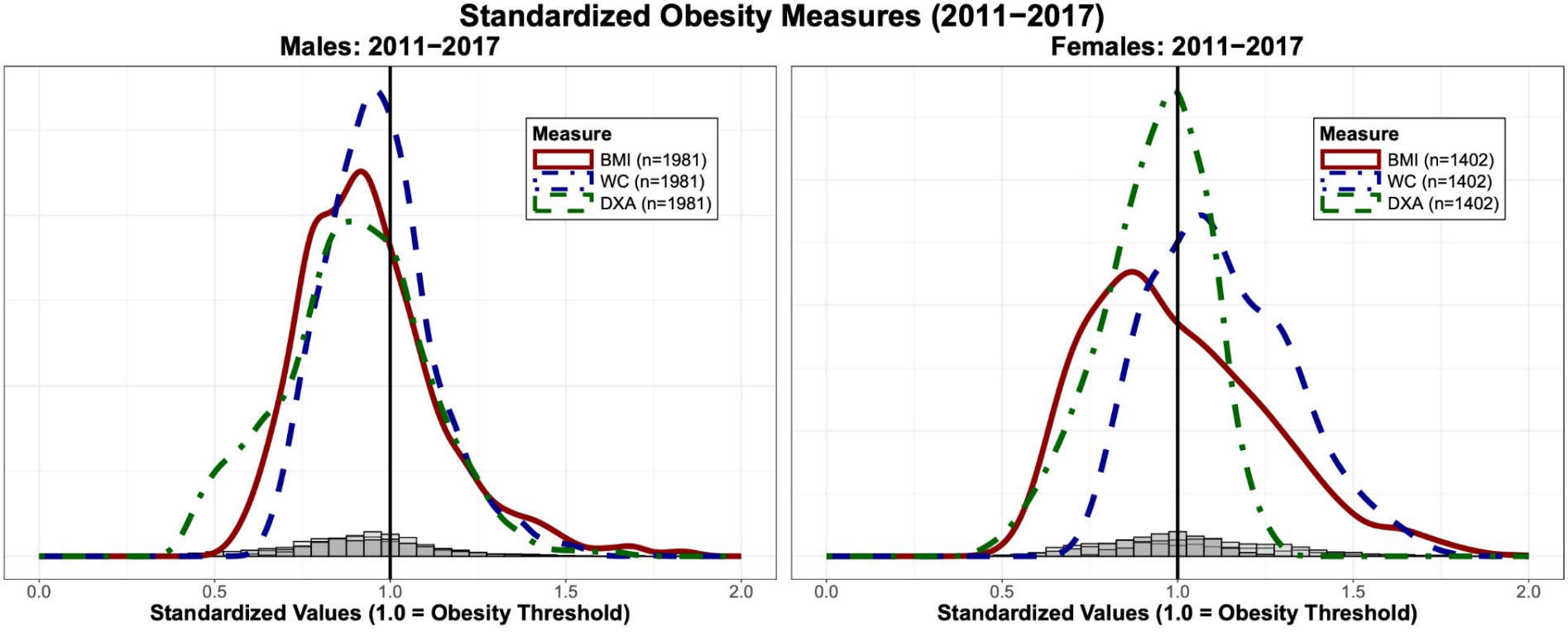
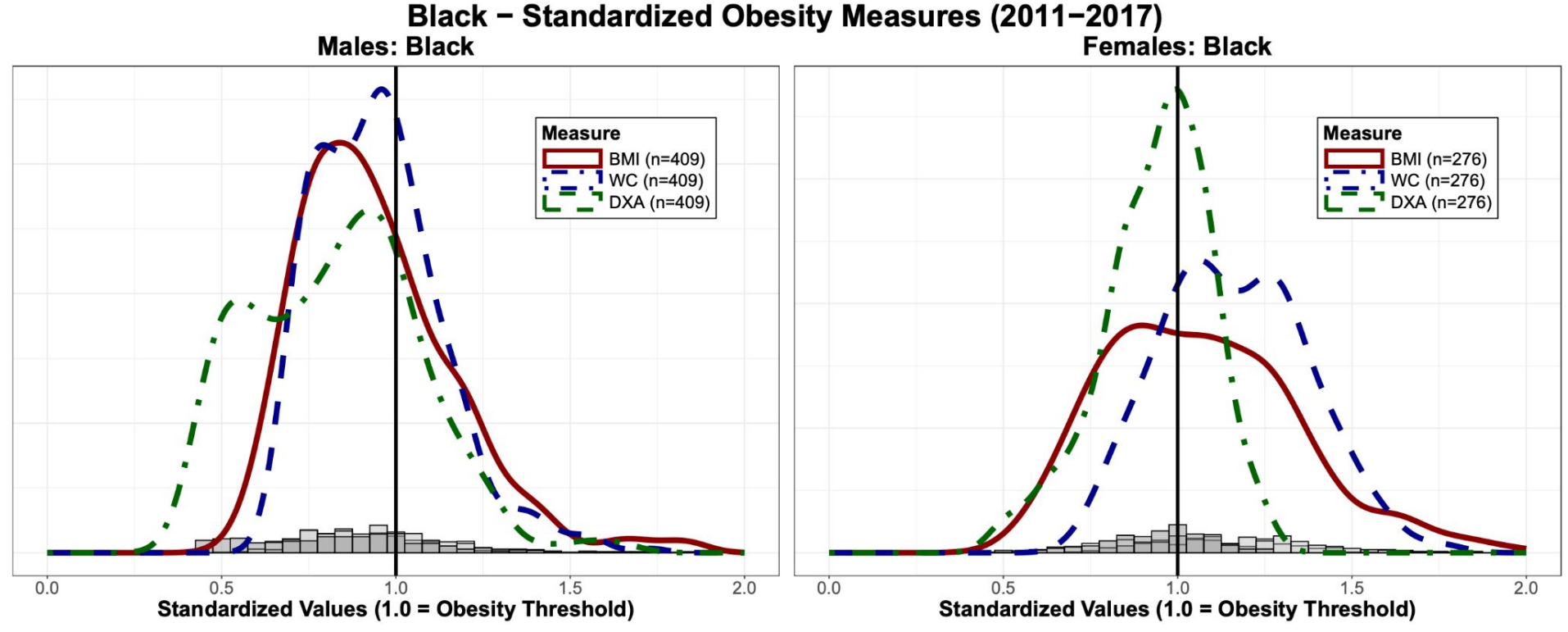
https://avisokay.github.io/
avisokay.bsky.social

Thank you!!

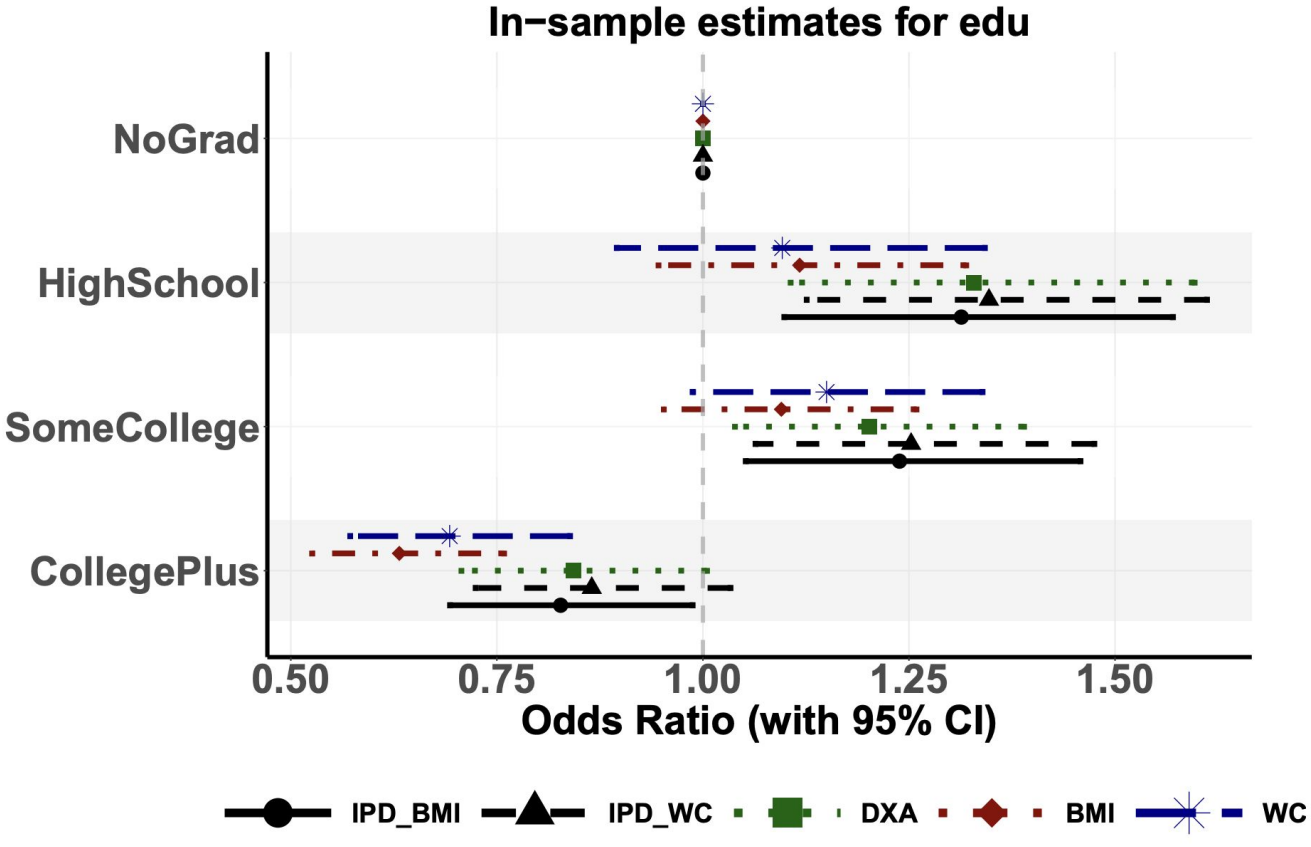
Appendix


Standardized Obesity Measures (2011−2017)
Males: 2011−2017
Females: 2011−2017
Measure
BMI (n=1981)
WC (n=1981)
DXA (n=1981)
BMI (n=1402)
WC (n=1402)
DXA (n=1402)
0.0
0.5
1.0
1.5
2.0
Standardized Values (1.0 = Obesity Threshold)

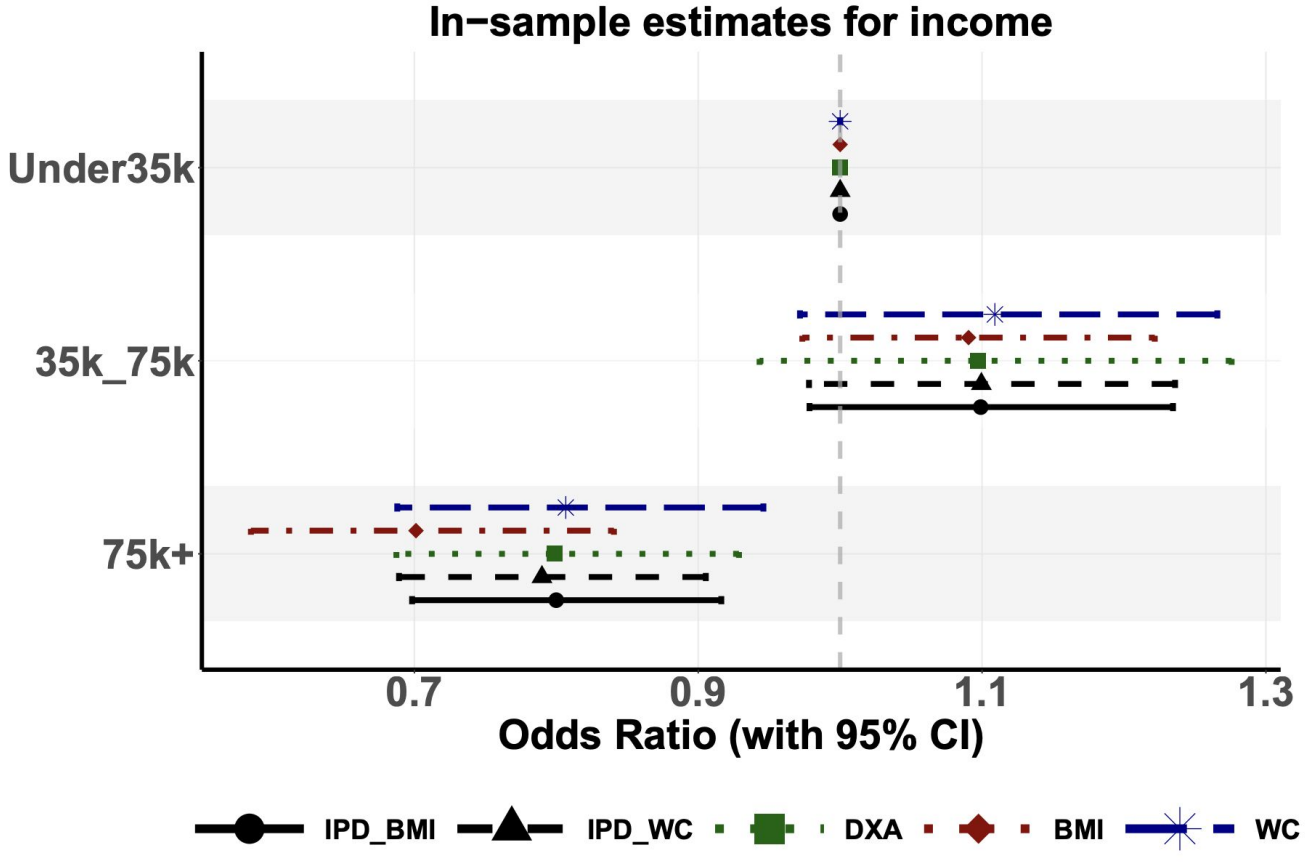
Appendix


Black − Standardized Obesity Measures (2011−2017)
Males: Black
Females: Black
Measure
BMI (n=409)
WC (n=409)
DXA (n=409)
Measure
BMI (n=276)
WC (n=276)
DXA (n=276)
0.0
0.5
1.0
1.5
2.0
Standardized Values (1.0 = Obesity Threshold)
Standardized Values (1.0 = Obesity Threshold)

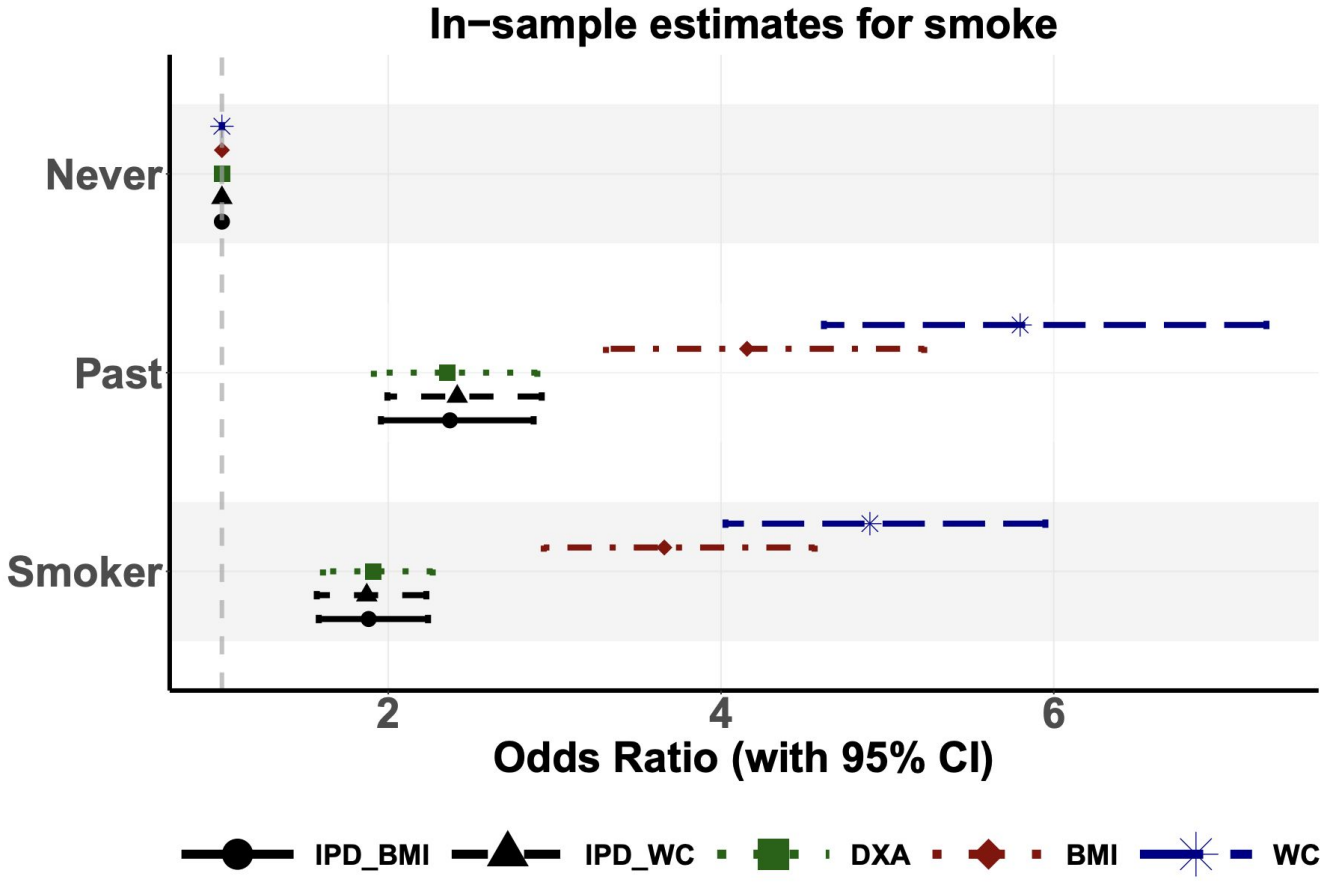
Appendix


In−sample estimates for edu
NoGrad
HighSchool
SomeCollege
CollegePlus
0.50
0.75
1.00
1.25
1.50
Odds Ratio (with 95% CI)
IPD_BMI
IPD_WC
DXA
BMI
WC

Appendix


In−sample estimates for income
Under35k
35k_75k
75k+
0.7
0.9
1.1
1.3
Odds Ratio (with 95% CI)
IPD_BMI
IPD_WC
DXA
BMI
WC

Appendix


In−sample estimates for smoke
Never
Past
Smoker
2
4
6
Odds Ratio (with 95% CI)
IPD_BMI
IPD_WC
DXA
BMI
WC