

# Anthropometry: What Can We Measure & What Does It Mean?

Anne McTiernan, MD, PhD

Fred Hutchinson Cancer Research Center  
Seattle, Washington, U.S.A.

I have no conflicts to disclose.



**FRED HUTCH**  
CURES START HERE®

# Anthropometry in Human Studies

- Height
- Weight
- Circumferences
  - Waist
  - Hip
- Indices
  - Body mass index (BMI):  $\text{kg/m}^2$
  - Waist-to-hip ratio
  - Waist-to-height ratio
  - A body shape index (ABSI)
- Change over time
- Duration of overweight/obesity

# Body Mass Index (BMI)

- Classifications (WHO)
  - Obese  $\geq 30$ ; overweight  $25 < 30$ ; normal  $18.5 < 25$ ; underweight  $\leq 18.5$
  - Obesity classes
    - 1:  $30.0 - 34.99$
    - 2:  $35.0 - 35.99$
    - 3:  $\geq 40.0$
  - Correlates with mortality, heart disease, diabetes
  - Cutpoints for cancer risk not established
- Race/ethnicity/gender considerations
- Physical fitness, lean mass

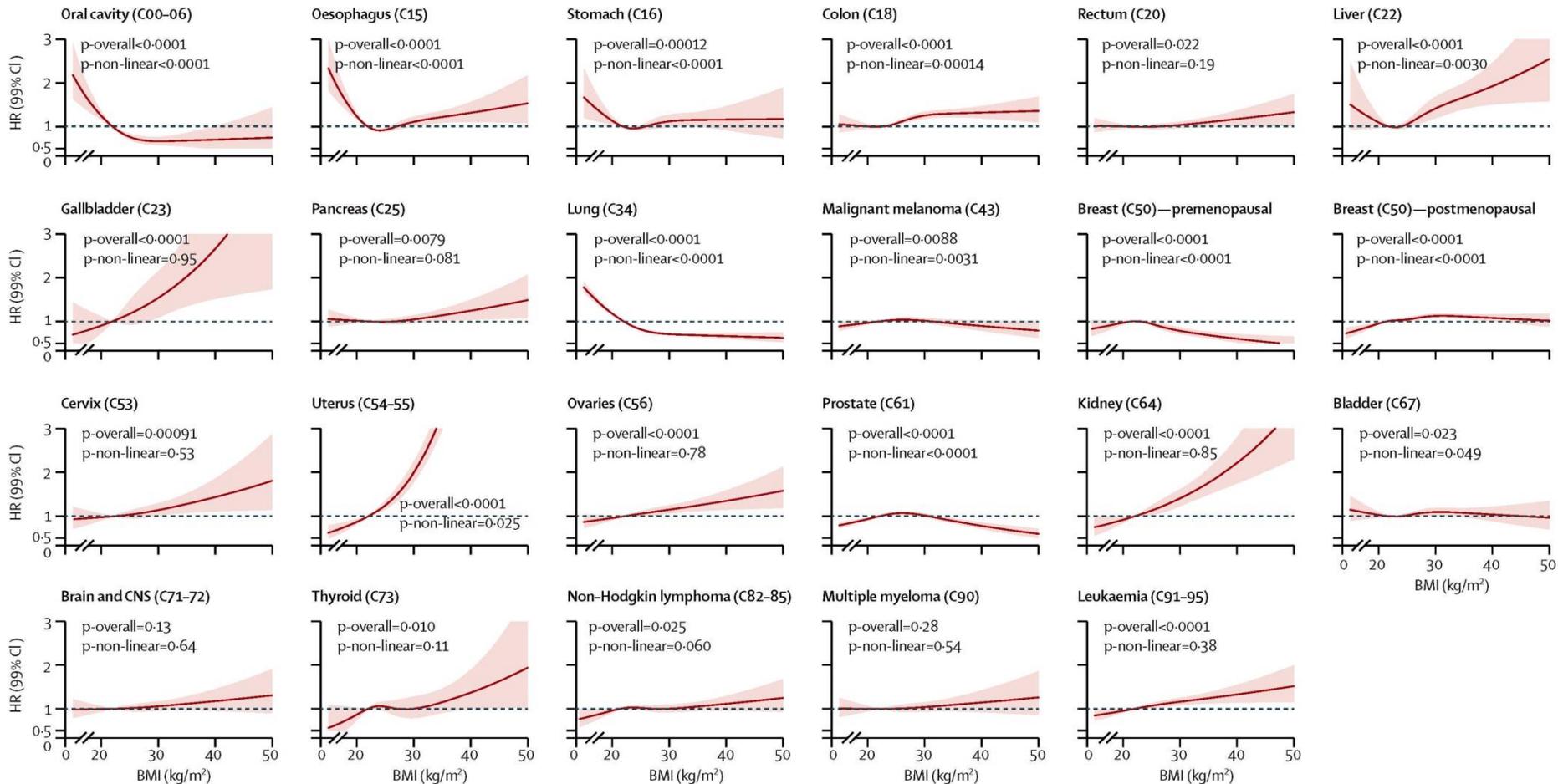
# Cancer Risk & Adiposity, Adult Weight Gain & Height: WCRF Continuous Update Project

Cancer site	BMI	Waist	Waist-hip	Wt gain	Height
Stomach (cardia)	↑				
Kidney	↑↑	↑↑	↑↑		↑
Gallbladder	↑				
Liver	↑↑				
Prostate (advanced)	↑	↑	↑		
Ovarian	↑				↑↑
Endometrial	↑↑	↑		↑	
Pancreatic	↑↑	↑↑	↑↑	↑↑	↑
Colorectal	↑↑	↑↑	↑↑		↑↑
Breast (postmeno)	↑↑			↑	↑↑
Breast (premeno)	↓				↑
Oesophageal (adenoca)	↑↑				

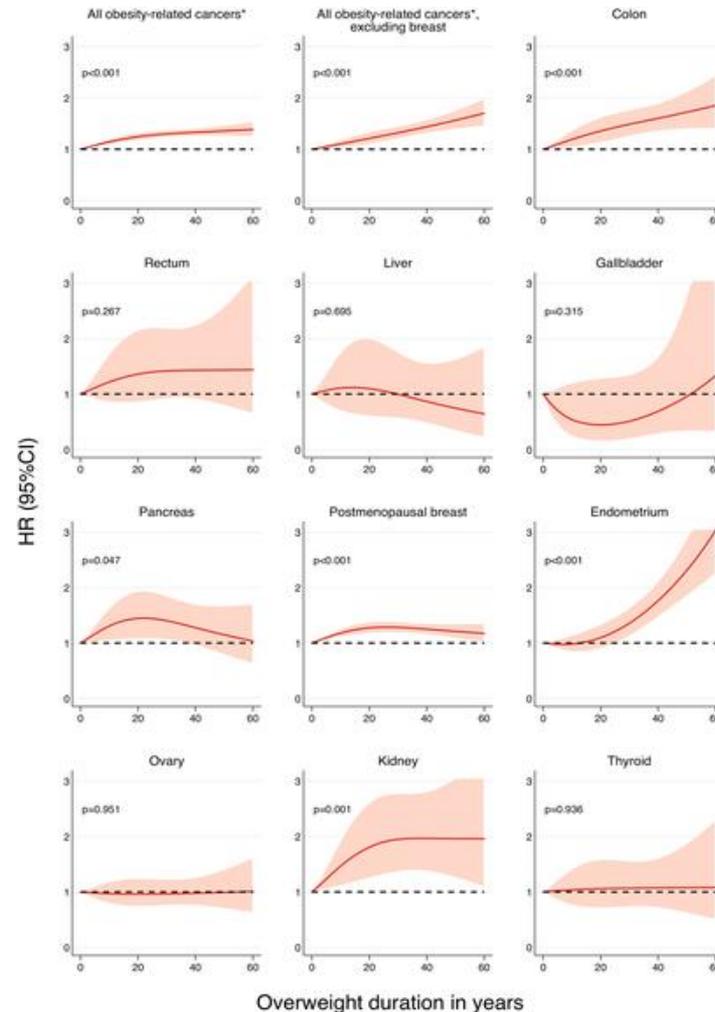
↑↑convincing increased, ↑ probable increased, ↓ probable decreased risk

Bandera et al for WCRF International CUP Panel. Int J Ca 2016 June 28 (epub)

# Clinic Measured BMI & Risk of Cancer: population-based cohort study of 5.24 million UK adults

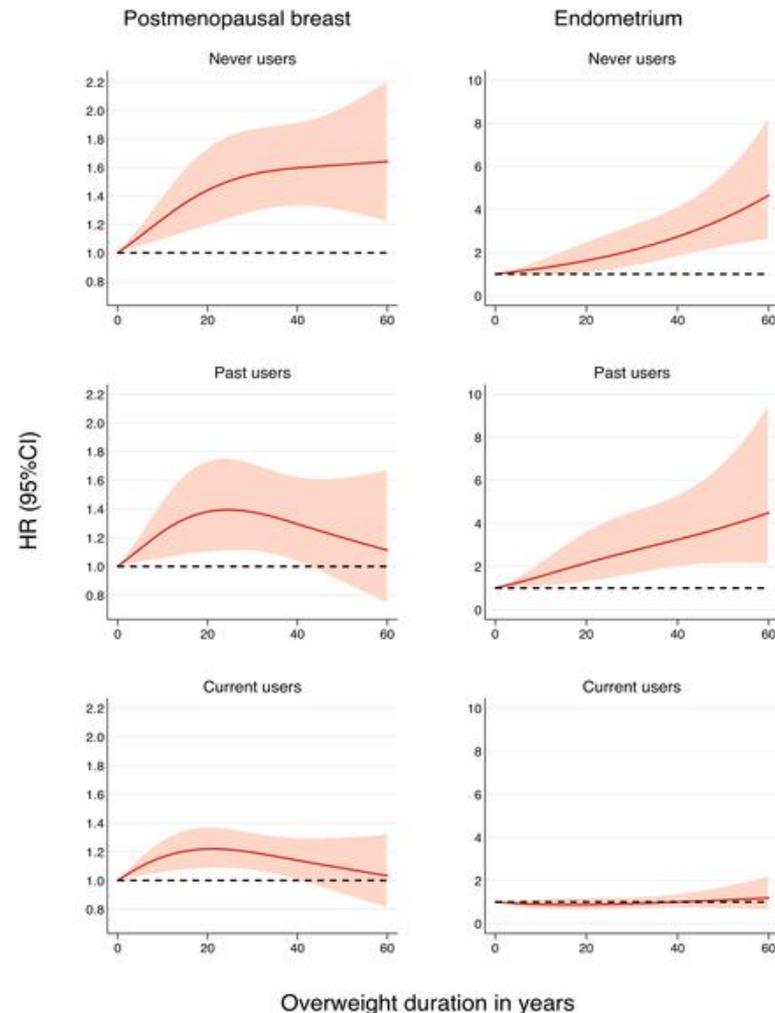


# Overweight (BMI $\geq 25$ kg/m<sup>2</sup>) Duration Since Age 18 y & Risk of Cancer: Women's Health Initiative



Arnold M, Jiang L, Stefanick ML, Johnson KC, Lane DS, et al. (2016) Duration of Adulthood Overweight, Obesity, and Cancer Risk in the Women's Health Initiative: A Longitudinal Study from the United States. PLoS Med 13(8): e1002081.

# Overweight (BMI $\geq 25$ kg/m<sup>2</sup>) Duration Since Age 18 y & Risk of Postmenopausal Breast and Endometrial Cancer by Postmenopausal Hormone Use: WHI



Arnold M, Jiang L, Stefanick ML, Johnson KC, Lane DS, et al. (2016) Duration of Adulthood Overweight, Obesity, and Cancer Risk in the Women's Health Initiative: A Longitudinal Study from the United States. PLoS Med 13(8): e1002081.

# Overall and Tumor Specific Incidence of Invasive Breast Cancer and Other Breast Cancer Outcomes (No., Annualized %) and Multivariable<sup>a</sup> Adjusted HRs by Baseline BMI in the WHI Clinical Trial

Table 2. Overall and Tumor Specific Incidence of Invasive Breast Cancer and Other Breast Cancer Outcomes (No., Annualized %) and Multivariable<sup>a</sup> Adjusted HRs by Baseline BMI in the WHI Clinical Trial

Cancer	Normal, <25	Overweight, 25 to <30	HR (95% CI)	Obese, Grade I, 30 to <35	HR (95% CI)	Obese, Grade 2 + 3, ≥35	HR (95% CI)	P Value <sup>b</sup>
All invasive breast cancer	823 (0.37)	1183 (0.41)	1.17 (1.06-1.29)	828 (0.47)	1.37 (1.23-1.53)	554 (0.51)	1.58 (1.40-1.79)	<.001
Receptor status								
ER+/PR+	489 (0.22)	734 (0.25)	1.21 (1.07-1.37)	544 (0.31)	1.52 (1.33-1.74)	376 (0.35)	1.86 (1.60-2.17)	<.001
ER+/PR-	125 (0.06)	169 (0.06)	1.07 (0.83-1.38)	97 (0.05)	1.09 (0.82-1.45)	61 (0.06)	1.01 (0.71-1.44)	
ER-/PR-	112 (0.05)	156 (0.05)	1.22 (0.93-1.60)	93 (0.05)	1.15 (0.84-1.57)	54 (0.05)	1.15 (0.79-1.67)	
HER2								
Positive	95 (0.04)	143 (0.05)	1.31 (0.99-1.74)	103 (0.06)	1.59 (1.17-2.17)	57 (0.05)	1.37 (0.94-2.00)	.52
Negative	494 (0.22)	715 (0.25)	1.17 (1.04-1.33)	493 (0.28)	1.36 (1.18-1.56)	347 (0.32)	1.72 (1.47-2.01)	
Triple negative								
Yes	60 (0.03)	84 (0.03)	1.23 (0.86-1.77)	40 (0.02)	0.90 (0.57-1.41)	33 (0.03)	1.42 (0.89-2.28)	.12
No	517 (0.23)	753 (0.26)	1.19 (1.05-1.34)	542 (0.30)	1.45 (1.27-1.66)	365 (0.34)	1.71 (1.46-1.99)	
Tumor size, cm								
<1	232 (0.10)	321 (0.11)	1.20 (1.00-1.45)	219 (0.12)	1.35 (1.10-1.66)	145 (0.13)	1.58 (1.25-1.99)	.02
1 to <2	333 (0.15)	461 (0.16)	1.09 (0.93-1.26)	328 (0.18)	1.32 (1.12-1.56)	189 (0.17)	1.29 (1.06-1.58)	
≥2	187 (0.08)	303 (0.10)	1.34 (1.09-1.63)	206 (0.12)	1.55 (1.25-1.93)	163 (0.15)	2.12 (1.67-2.69)	
Positive lymph node								
Yes	168 (0.08)	245 (0.08)	1.22 (0.98-1.52)	184 (0.10)	1.50 (1.19-1.89)	138 (0.13)	1.89 (1.46-2.45)	.06
No	579 (0.26)	825 (0.28)	1.16 (1.03-1.30)	547 (0.31)	1.31 (1.15-1.49)	345 (0.32)	1.45 (1.25-1.68)	
Histologic type								
Ductal	521 (0.23)	759 (0.26)	1.20 (1.06-1.35)	554 (0.31)	1.48 (1.29-1.69)	349 (0.32)	1.56 (1.34-1.83)	.92
Lobular	69 (0.03)	130 (0.04)	1.41 (1.03-1.93)	63 (0.04)	1.07 (0.73-1.57)	62 (0.06)	1.90 (1.29-2.80)	
Ductal and lobular	126 (0.06)	139 (0.05)	0.95 (0.73-1.23)	109 (0.06)	1.28 (0.97-1.70)	66 (0.06)	1.35 (0.97-1.88)	
Other	102 (0.05)	153 (0.05)	1.17 (0.89-1.54)	95 (0.05)	1.17 (0.86-1.59)	70 (0.06)	1.72 (1.24-2.40)	
Grade								
Well differentiated	237 (0.11)	302 (0.10)	1.02 (0.85-1.23)	192 (0.11)	1.12 (0.91-1.38)	127 (0.12)	1.30 (1.03-1.65)	.14
Moderately differentiated	312 (0.14)	457 (0.16)	1.21 (1.03-1.42)	337 (0.19)	1.50 (1.27-1.79)	214 (0.20)	1.66 (1.33-2.02)	
Poorly differentiated	216 (0.10)	299 (0.10)	1.13 (0.93-1.36)	204 (0.11)	1.29 (1.04-1.59)	142 (0.13)	1.58 (1.25-2.00)	
Stage								
Local	622 (0.28)	902 (0.31)	1.17 (1.05-1.31)	602 (0.34)	1.33 (1.17-1.51)	383 (0.35)	1.48 (1.28-1.72)	.05
Regional/distant	187 (0.08)	271 (0.09)	1.21 (0.99-1.49)	206 (0.12)	1.51 (1.21-1.89)	156 (0.14)	1.94 (1.52-2.47)	
Other cancer outcomes								
In situ breast cancer	230 (0.10)	305 (0.10)	1.00 (0.83-1.21)	178 (0.10)	0.96 (0.77-1.19)	129 (0.12)	1.32 (1.03-1.68)	.12
Total breast cancer	1038 (0.47)	1471 (0.51)	1.13 (1.04-1.24)	996 (0.56)	1.29 (1.17-1.42)	671 (0.62)	1.52 (1.36-1.70)	<.001
Breast cancer deaths	64 (0.03)	82 (0.03)	0.93 (0.65-1.34)	61 (0.03)	1.08 (0.72-1.62)	67 (0.05)	2.25 (1.51-3.36)	<.001
Deaths after breast cancer	137 (0.06)	185 (0.06)	1.12 (0.87-1.44)	147 (0.07)	1.37 (1.04-1.79)	120 (0.10)	2.11 (1.57-2.84)	<.001

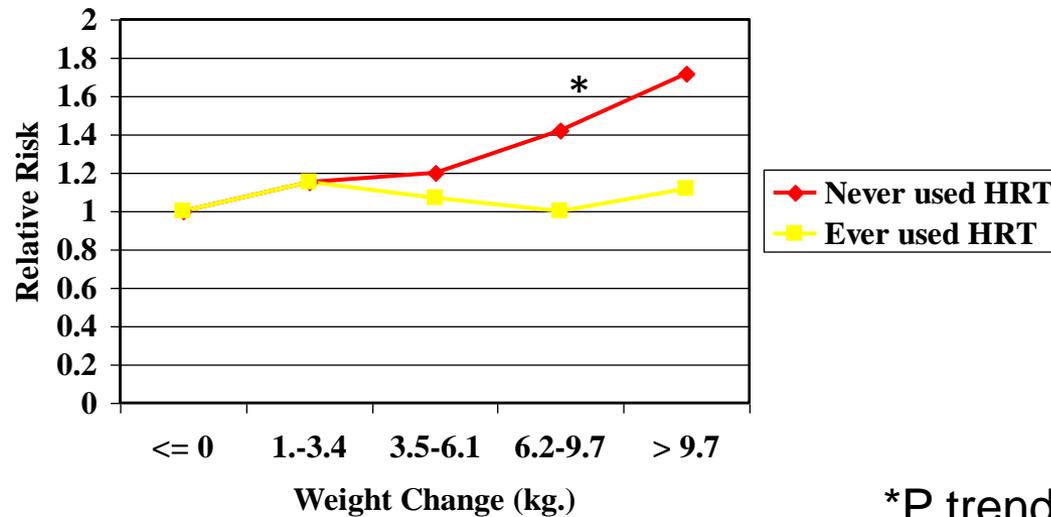
Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); ER, estrogen receptor; HR, hazard ratio; PR, progesterin receptor; +, positive; -, negative.

<sup>a</sup> Analyses were adjusted for age, race/ethnicity, education, parity, age at first birth, bilateral oophorectomy, family history of breast cancer, estrogen-alone use and duration, estrogen and progesterone use and duration, smoking status, diabetes mellitus, alcohol consumption, and stratified by baseline age group, HT trial randomization

group, dietary trial randomization group, hysterectomy status, Calcium/Vitamin D Randomized Trial randomization group (time-dependent) and extended follow-up (time-dependent).

<sup>b</sup> Corresponds to a trend test for the main effect of BMI on invasive breast cancer or other breast cancer end points, or a test of heterogeneity for trends between BMI and invasive breast cancer subtypes.

# Risk of Breast Cancer by Change in BMI between Age 18 and Study Entry: WHI

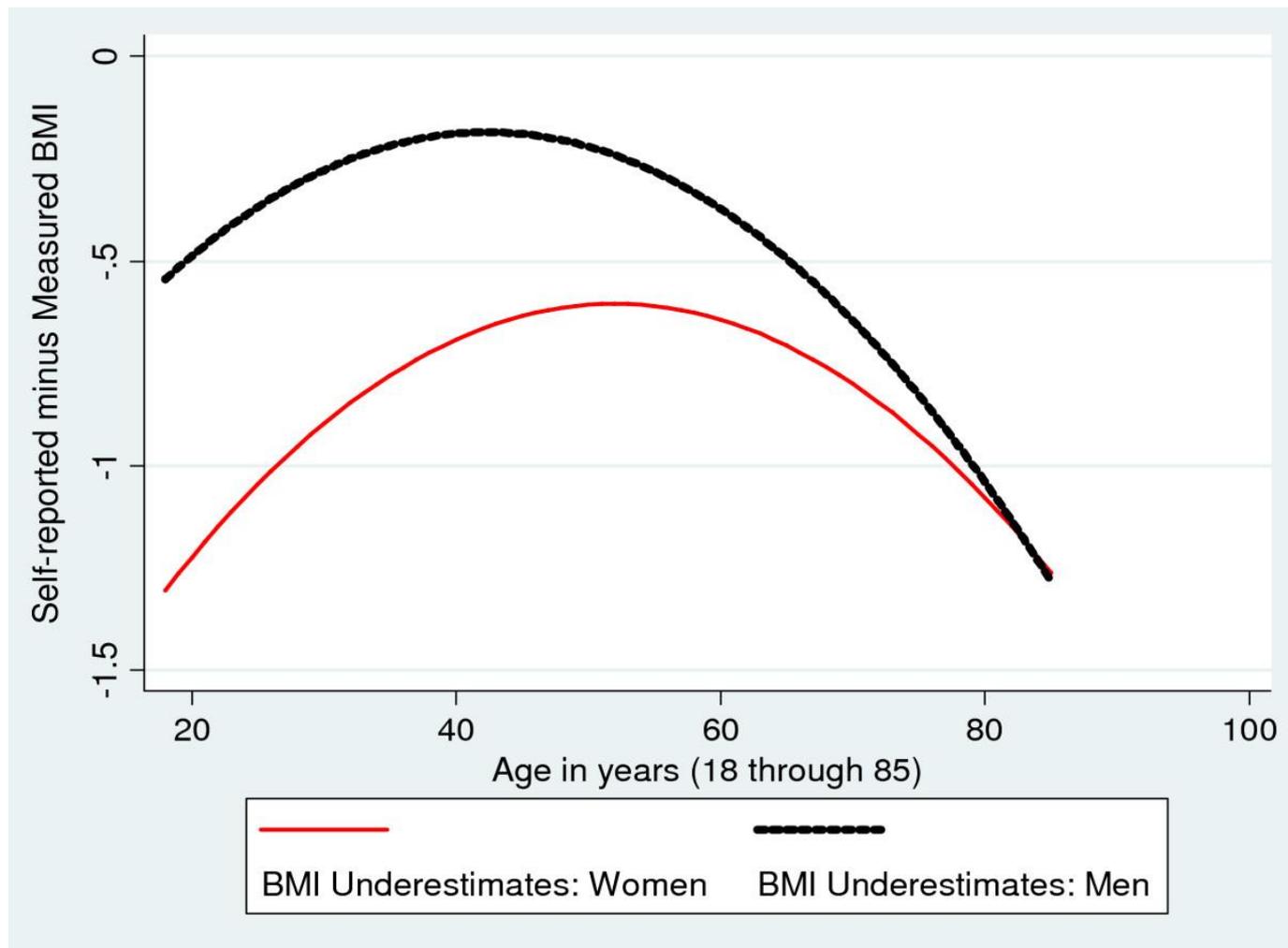


\*P trend = .002

# Measurement Issues

- Self-report vs. measured
- Method of measurement
  - Clothed vs. unclothed
  - Site of circumference measures
  - Fasting status
- Within-person variability

# Underestimation of Self-reported Height & Weight U.S. NHANES & NHIS



# U.S. NHANES: Recalled vs. Measured Weight Change in Men & Women

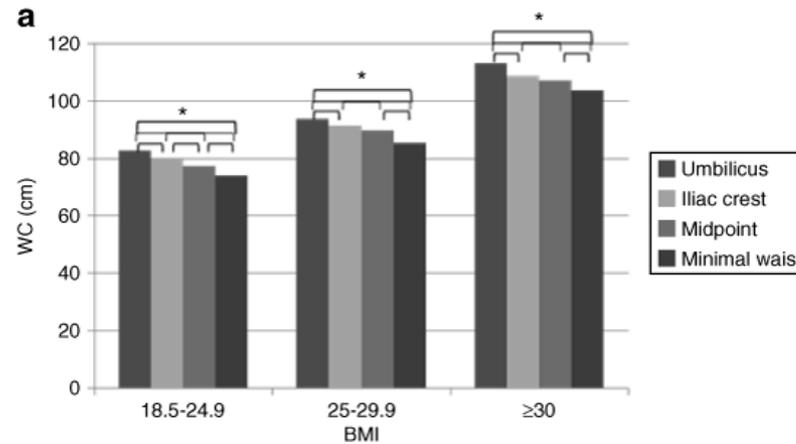
Recalled Weight Change (Pounds)	Measured Weight Change (Pounds)					Number of Subjects
	Lost >15	Lost 5-15	Stable ( $\pm 5$ )	Gained 5-15	Gained >15	
<b>Men</b>						
Lost >15	42 (10)*	23	20	9	6	81
Lost 5-15	14	39 (15)*	31	14	2	64
Stable ( $\pm 5$ )	5	18	40 (28)*	28	9	252
Gained 5-15	5	5	25	38 (24)*	27	148
Gained >15	3	5	14	20	58 (23)*	157
<b>Women</b>						
Lost >15	32 (11)*	23	17	19	9	190
Lost 5-15	23	26 (12)*	29	15	7	99
Stable ( $\pm 5$ )	8	12	40 (25)*	32	8	388
Gained 5-15	2	9	22	39 (28)*	28	238
Gained >15	3	4	13	23	57 (24)*	314

\* Expected proportion of agreement by chance in parentheses. Overall kappa = 0.27.

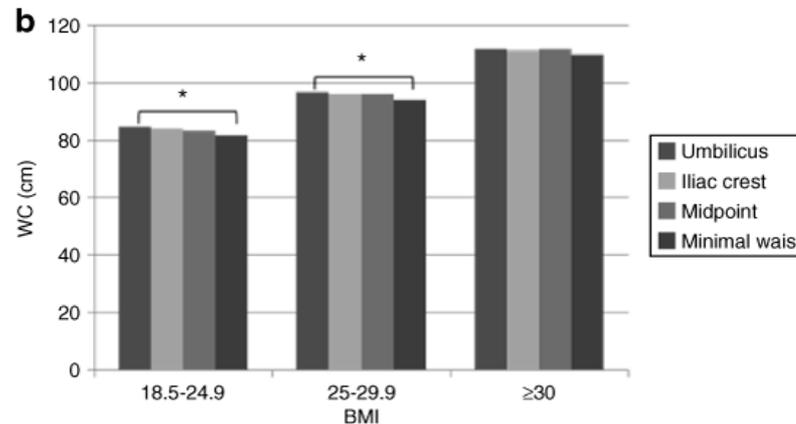
# Variability in Waist Circumference Measurements According to Anatomic Measurement Site

(223 men and 319 women, 20–67 years, Canadian)

Women



Men



# How Waist Circumference is Measured Affects Abdominal Obesity Prevalence

(N= 223 men & 319 women, 20–67 years, Canadian)

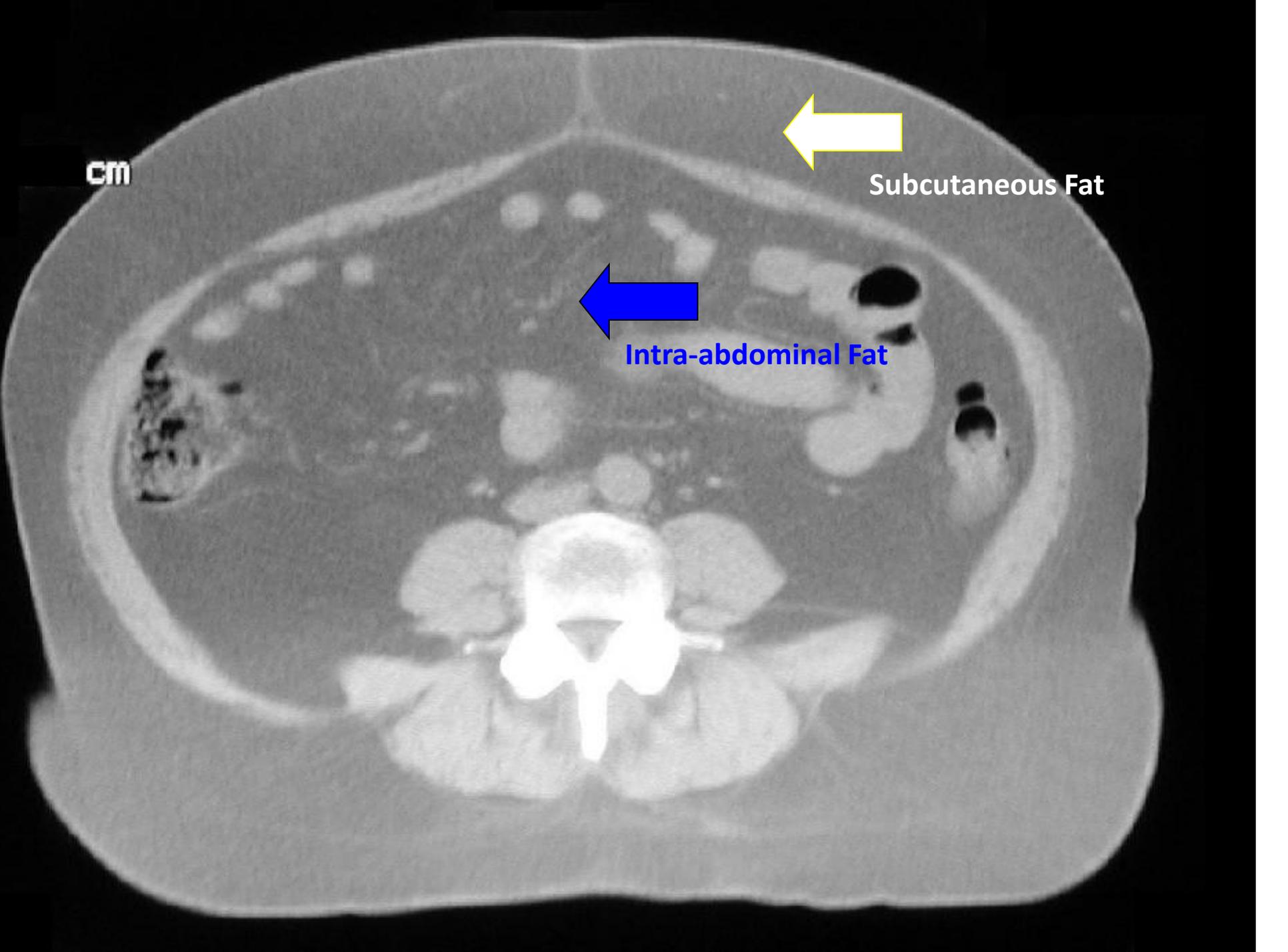
Measurement site	Men		Women	
	Mean (s.d.)	>102 cm/ 40 in (%)	Mean	>88 cm/ 35 in (%)
Umbilicus	98.3 (12.6)	34.1	91.9 (13.4) <sup>a,b,c</sup>	55.2
Iliac crest	97.8 (12.8)	31.8	89.1 (12.8) <sup>c,d</sup>	47.0
Midpoint	97.5 (13.2)	32.7	87.0 (13.1) <sup>c,d</sup>	41.1
Minimal waist	95.7 (12.5)	23.3	83.3 (12.9) <sup>a,b,d</sup>	30.7
Any WC site	—	35	—	57.1

Any WC site refers to the proportion of individuals with WC >102/88 cm at any one or more of the measured anatomical sites.

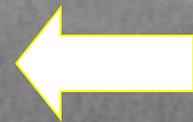
Superscript letters represent significant differences ( $P < 0.008$ ) between sites: <sup>a</sup>the superior border of the iliac crest; <sup>b</sup>midpoint between the superior border of the iliac crest and the lowest rib; <sup>c</sup>the minimal waist; <sup>d</sup>the umbilicus.

# What Do We Really Want to Know?

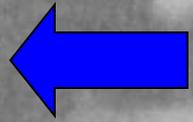
- Adipose tissue
  - Amount
  - Distribution
  - Secreted proteins/lipids
- Growth trajectory
- Lean mass, muscle, bone
- Genetics
- Diet & lifestyle correlates



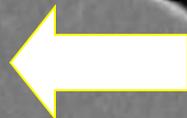
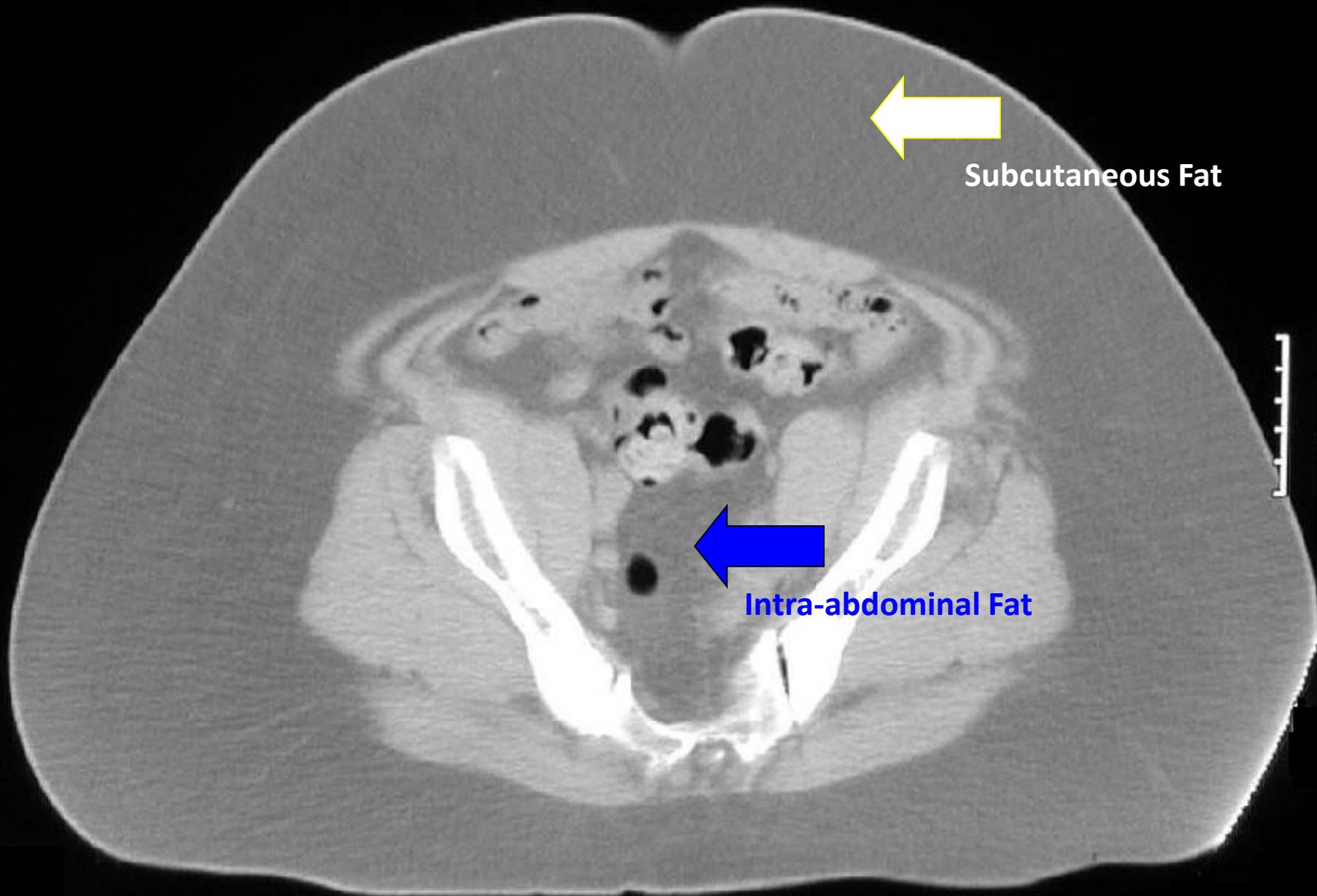
cm



Subcutaneous Fat



Intra-abdominal Fat



Subcutaneous Fat



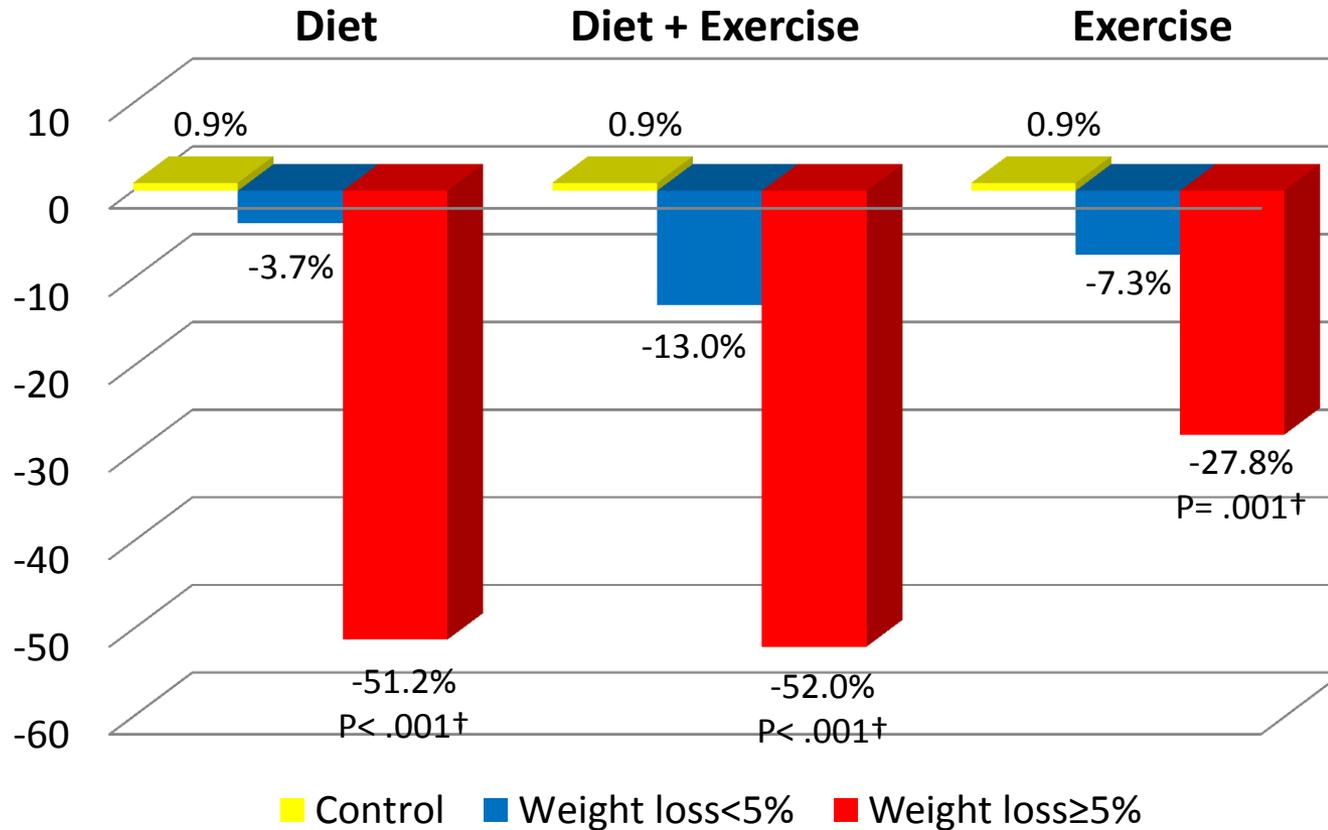
Intra-abdominal Fat

# Spearman Correlations of Serum Estrogens with Adipose Measures

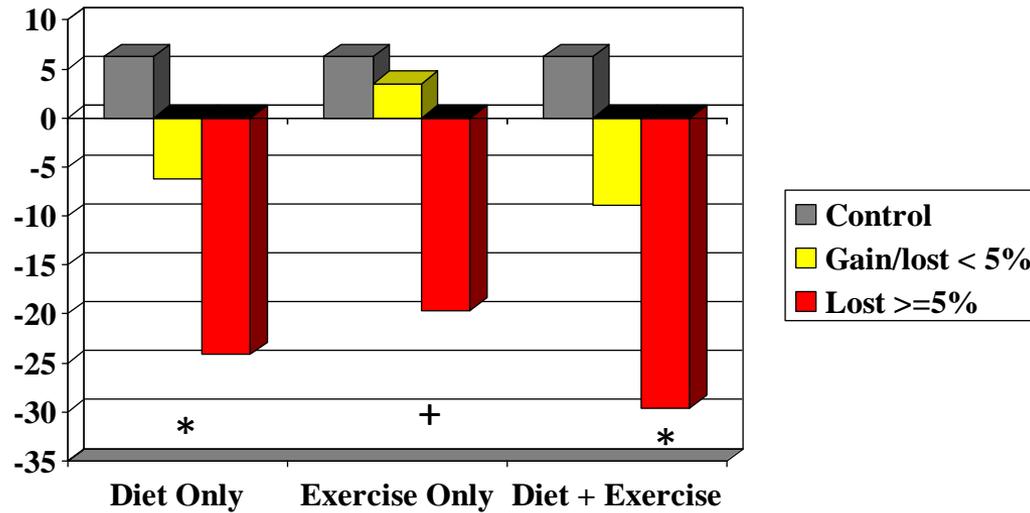
	BMI	Weight	% body fat (DXA)	Intra-abd fat (CT)	Subcut abd fat (CT)	Total abd fat (CT)
Estrone	0.419 ( $<.0001$ )	0.387 ( $<.0001$ )	0.349 ( $<.0001$ )	0.163 (0.03)	0.357 ( $<.0001$ )	0.360 ( $<.0001$ )
Estradiol	0.387 ( $<.0001$ )	0.383 ( $<.0001$ )	0.275 (0.0003)	0.060 (0.43)	-0.107 (0.158)	0.298 ( $<.0001$ )
SHBG	-0.363 ( $<.0001$ )	-0.365 ( $<.0001$ )	-0.150 (0.04)	-0.376 ( $<.0001$ )	-0.196 (0.01)	-0.333 ( $<.0001$ )
Free estradiol	0.456 ( $<.0001$ )	0.460 ( $<.0001$ )	0.297 ( $<.0001$ )	0.183 (0.01)	0.365 ( $<.0001$ )	0.373 ( $<.0001$ )

PATH Study, randomized trial, N=173, postmenopausal women aged 50-75 years, BMI  $\geq 25$  kg/m<sup>2</sup>

# 1-Year Weight Loss & Exercise Effects on C-reactive Protein (N=438 postmenopausal women BMI $\geq$ 25)



# % Free Estradiol Change by Weight Change

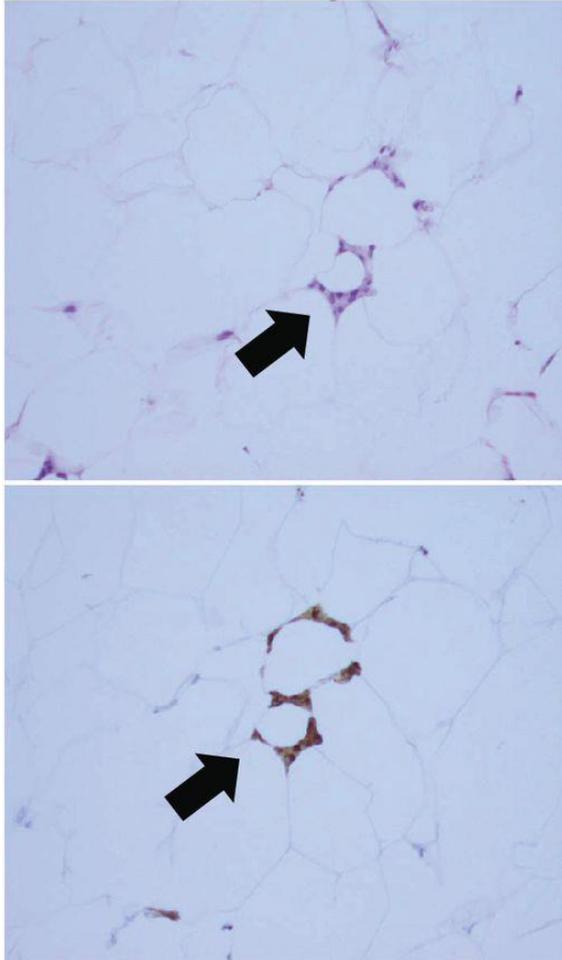


\*Ptrend<0.0001 vs. CO

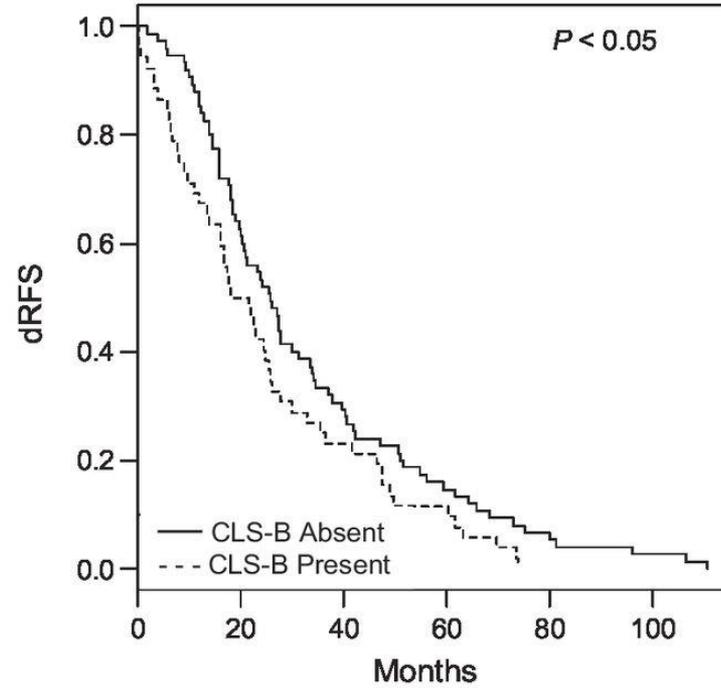
+ Ptrend<0.001 vs. CO

# White Adipose Tissue Inflammation and Breast Cancer Recurrence

**A**



**B**



Neil M. Iyengar et al. Clin Cancer Res 2016;22:2283-2289

# Measure Benefits & Drawbacks

	Benefit	Drawback
BMI	<ul style="list-style-type: none"> <li>Portable</li> <li>Little training needed</li> <li>Inexpensive</li> <li>Good reliability</li> <li>Self-report valid for associations</li> <li>Dose-response associations seen for multiple cancers</li> <li>Works for large pop studies</li> <li>WHO classifications</li> </ul>	<ul style="list-style-type: none"> <li>Self-report underestimates</li> <li>Doesn't measure fat distribution</li> <li>Doesn't differentiate fat vs. lean mass</li> <li>Race/ethnic/age variation</li> <li>Physical fitness effects</li> </ul>
Waist measure	<ul style="list-style-type: none"> <li>Portable</li> <li>Inexpensive</li> <li>Measures abdominal area, could be more relevant to some cancers</li> <li>Good reliability</li> </ul>	<ul style="list-style-type: none"> <li>Self-report?</li> <li>Does not differentiate visceral vs subcutaneous fat</li> <li>Validity/reliability depends on site measured</li> </ul>
Waist-to-hip	<ul style="list-style-type: none"> <li>Estimates body fat distribution</li> </ul>	<ul style="list-style-type: none"> <li>May not add to waist circumference information</li> </ul>
Weight change, duration overweight/obesity	<ul style="list-style-type: none"> <li>Estimates long-term exposure</li> </ul>	<ul style="list-style-type: none"> <li>Poor correlation self- vs. measured weight change</li> <li>Intentionality of weight loss difficult to prove</li> </ul>

# Summary

- BMI is a good measure for observational studies of associations between adiposity and cancer risk
- Waist circumference reasonable measure but unclear advantages vs. BMI for observational data
- Self-report valid for single-measure association studies
- Measured BMI & weight more accurate for change data
- Other data needed to supplement observational study data (human experiments, imaging studies, clinical/biological)