
Biological Determinants of Gestational Weight Gain (GWG)

Janet C. King, Ph.D.
Children's Hospital Oakland Research Institute,
and
University of California at Berkeley and Davis

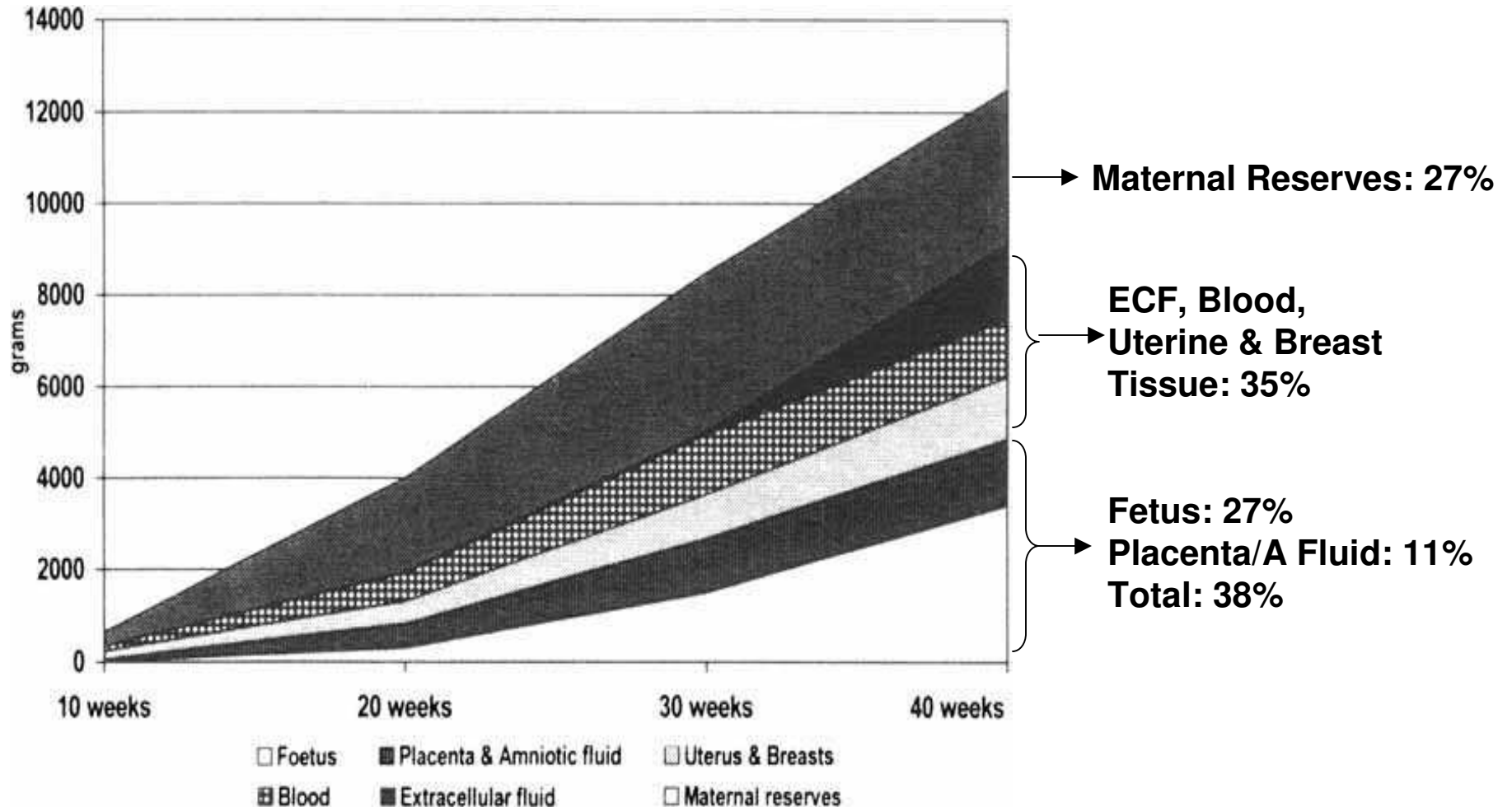
Emerging Themes

- n **Interaction** exists among biological factors influencing GWG, i.e., pre-pregnancy body weight, age, parity, and stature.
- n Impact of biological influences on GWG **varies widely** among individual women.

What is Gestational Weight Gain?

Components of Gestational Gain

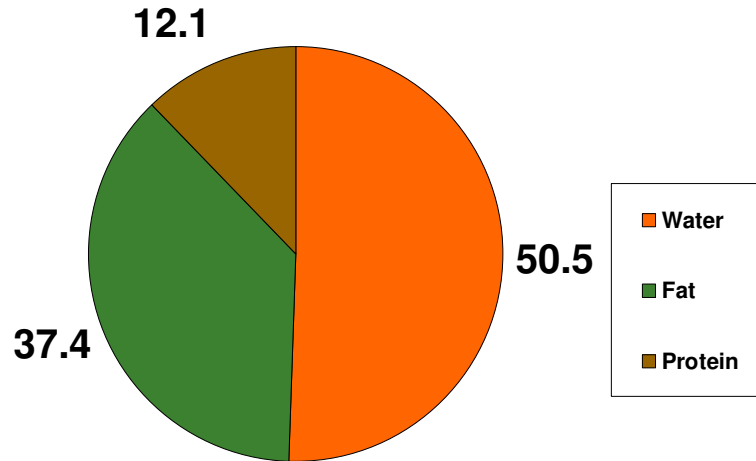
Hytten and Leitch. 1980



Roughly, pregnancy components = 70%; maternal stores = 30%.

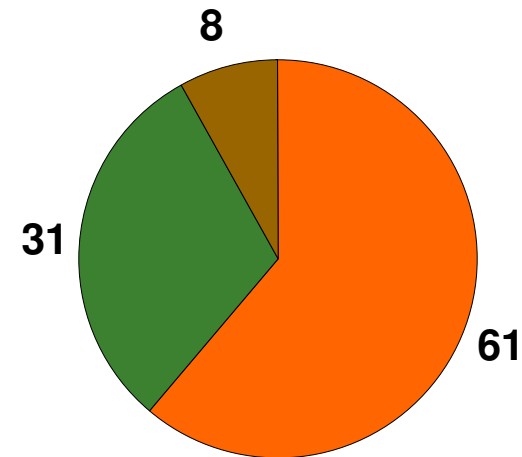
Proximate Composition of Weight Gain

Calculated

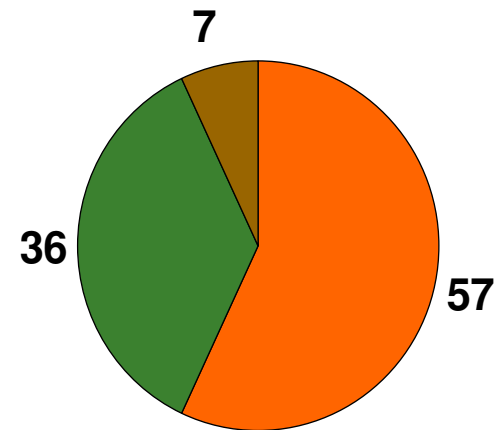


Hytten & Leitch. 1980

Measured



Kopp and King, 1999



Butte et al, 2003

For a 12 kg total gain:

•Water: 64%

•Fat: 31%

•Protein: 5%

Bull WHO. 1995

Outline:

- n **Pre-pregnancy BMI: Total, rates, and pattern of gain**
- n **Age**
- n **Parity**
- n **Stature**

- n **Fat Gain**

Biological Determinants of GWG: Pre-pregnancy BMI

**1990 IOM Report concluded that pre-pregnancy
BMI is a primary determinant of GWG.**

Recommendations referenced to BMI.

Mean GWG by BMI Group (1980)

National Natality Survey)

BMI Group	Sample #	GWG, kg
Low <19.8	1027	13.8
Normal 19.8-26	2393	13.8
High 26.1-29	246	12.4
Very High >29	280	8.4

Target Range:

Kg

Low BMI: 12.5-18
 Normal BMI: 11.5-16
 High BMI: 7-11.5
 Very High: >6.0

GWG of Women with Good Outcomes

<u>BMI</u>	<u>Mean, kg</u>
<19.2	14.6
19.2-25.6	15.3
25.61-28.9	15.4
>28.9	13.2

} > Recommendation

Abrams and Parker. Obstet Gynec. 1990

IOM. Nutrition During Pregnancy. 1990.

Distribution of Weight Gain Outside the IOM

Range Differs by Pre-pregnancy BMI, Wells et al.,

Mat Child Health J. 2006

**6625 Colorado Women participating in PRAMS
between 2000-2002**

**Odds ratio of gaining above or below the IOM
relative to normal weight women.**

Pre-pregnancy BMI	> IOM	< IOM
< 19.8	0.5	1.4
26-29	2.6	0.4
>29	18.6	6.6

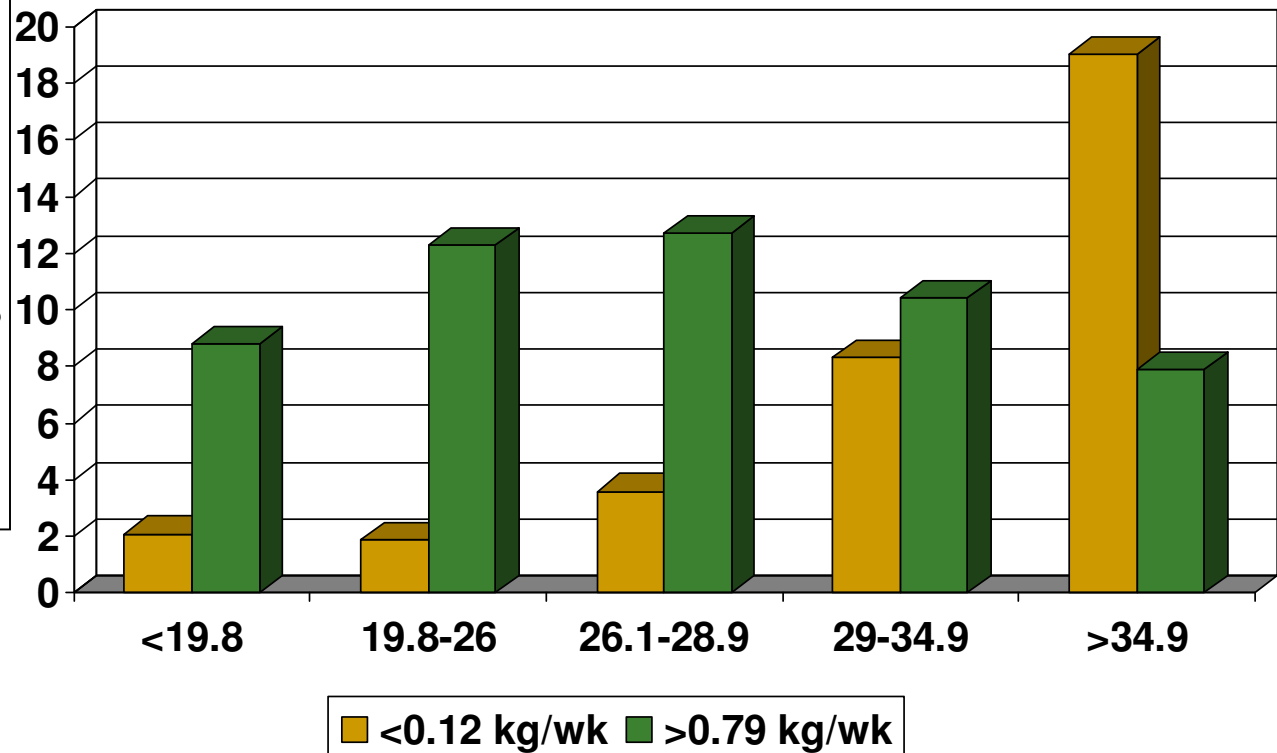
Pre-Pregnancy BMI and Rate of Total GWG

Percent of Women With Low or High Rates of GWG in the second and third trimester.

113,019 women in PRAMS Study. (Dietz et al., Epid. 2006)

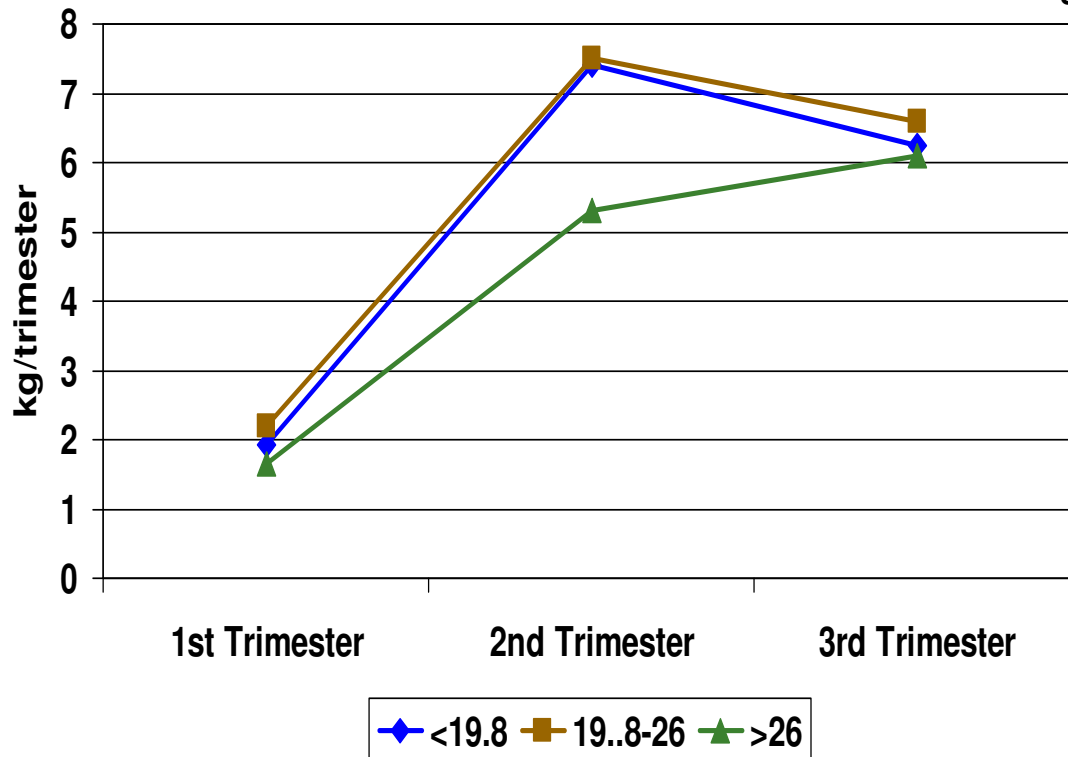
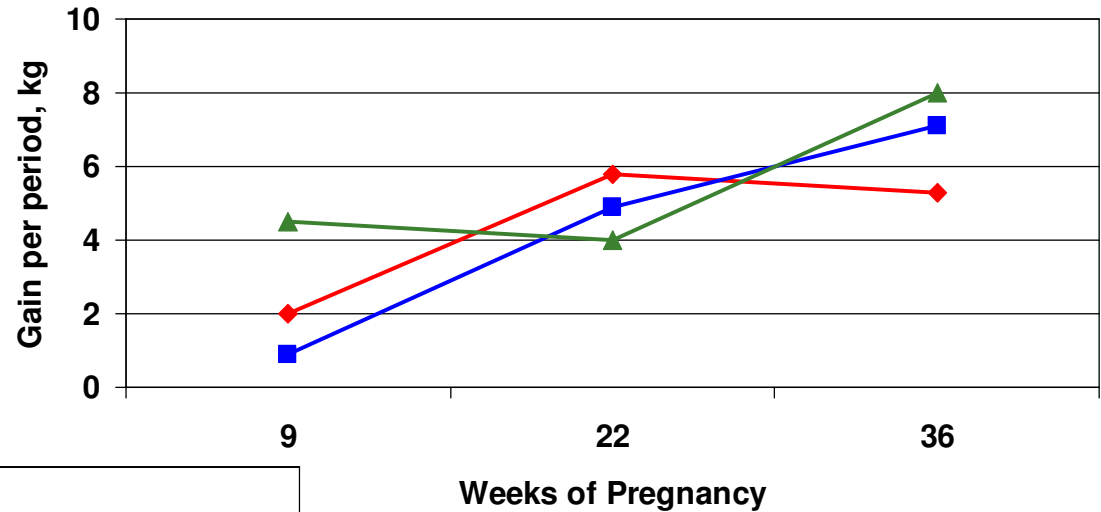
IOM recommended rate of gain:

- 0.4 kg/wk in 2nd and 3rd trimesters
- slightly lower in OW or obese
- higher (0.5 kg/wk) in UW



Pattern of Gain by Pre-pregnancy BMI

Trimester rates of gain by 7002 women with good outcomes. Carmichael et al., AJPH. 1997



Weeks of Pregnancy

◆ <19.8 ■ 19.8-26 ▲ >26

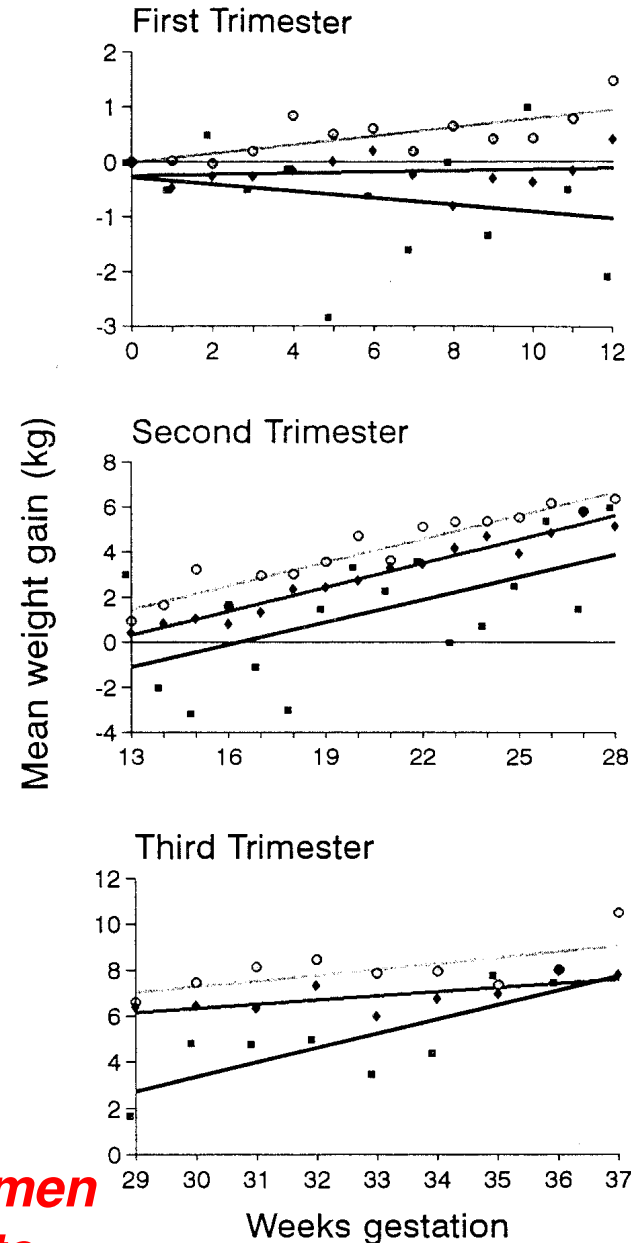
63 women measured **prior to conception**, and at 9, 22, and 36 weeks gestation. (Butte et al., AJOG. 2003)

Mean rates of gain > 0.4 kg/wk in all BMI groups except obese women in 2nd trimester.

Pre-pregnancy BMI and Weight Gain by Trimester in 1367 Filipino Women (Siega-Riz and Adair. AJCN. 1993)

In first trimester:
 OW lost weight
 In second trimester:
 Rate of gain equal among groups
 In third trimester:
 OW > UN or NW

○ = <18.5
 § = >25
 ◆ = 18.5-25



Early weight gain tends to be lower in women with high BMIs when fat stores accumulate.
Highest rates of gain occur in the 2nd trimester in UW and AW.

Pre-pregnancy BMI and GWG: Summary

1990

Average gain of OW/obese < normal weight.

No evidence low BMI women gain less.

No information on pattern of gain.

Update

Prevalence of high rates of gain similar by BMI group.

Prevalence of low rates of gain increase with pre-pregnancy BMI.

Average rate of gain tends to be >0.4 kg/wk.

Rate of weight gain is the highest in the 2nd trimester except in overweight women

Biological Determinants of GWG: Age

Age and Gestational Weight Gain

3 studies:

1419 teens (<18 years at registration) in Camden, NJ (Hediger et al., AJCN. 1990)

192 teens (14-17 years) in Arizona, (Johnston et al, JACN. 1991)

141 low-income, black teens in New York (Stevens-Simon et al., Pediatrics. 1993)

GWG: teens compared to adults:

NJ: Higher among teens

AZ: Did not differ

GWG of very young compared to older teens:

NJ: Higher among very young

Birth weight/GWG relationship:

NJ, AZ, NY: Differs from adults—lower B Wt/kg GWG in teens

NJ, AZ: Higher gain did not improve BWt

464 Brazilian young women with adolescent pregnancies between 1997 and 2001 (Gigante et al., JN. 2005)

□ Each pregnancy reduced height by 0.46 cm

□ Each pregnancy increased body weight by 2.25 kg

□ Each pregnancy increased BMI by 0.81 units

Age and GWG: Summary

1990

No consistent affect of age on GWG.

Two studies suggested that the GWG of very young adolescents (<2 years after menarche) is lower than that of older adolescents.

Update

Teen gain > adults

Very young > older teens

B Wt/GWG relationship differs from that of adults

Adolescent pregnancy may stunt growth and increase adult BMI.

No data on weight gains in older women (>40 yrs).

Biological Determinants of GWG: Parity

Parity and Maternal Weight

523 Multiparous women with pregnancies in UK during 1992/93 (Harris, HE et al., Annals of Human Biology.1997)

- q **High parity independently predicted:**
 - n **Decreased GWG**
 - n **Increased BMI later in life due to weight retention with each pregnancy**

2952 USA nonpregnant white or black women (Wolfe et al., Int J Obesity. 1997)

- q **Interaction between parity-associated weight gain over 10 years and ethnicity.**
 - n **Compared to heavy women at baseline, women with *low* baseline weights had the highest parity-associated weight retention, but Black women retained twice as much weight as White women.**

Parity and GWG: Summary

1990

Primiparous women of all age groups gain more weight (~1 kg).

After controlling for parity, differences in weight gain by age were small.

Update

GWG declines with increasing parity.

Interaction among pre-pregnancy BMI, parity, ethnicity, and temporal changes in body weight.

Biological Determinants of GWG: Stature

Stature and Gestational Weight Gain

4791 Hispanic women in Los Angeles in 1983-1986 (Siega-Riz and Hobel. JADA. 1997)

- Short underweight or normal-weight women had a 51% increased risk of poor weight gain.

2297 Brazilian women (20-45 years) in 1996 National Survey (Sichieri et al., Br J Med Biol Sci. 2003)

- Compared to tall women, childbearing increased non-pregnant BMI among short, urban women ($p < 0.04$), but not among short, rural women.
- Difference due to pre-pregnancy BMI?

Stature and GWG: Summary

1990

Short women (<157 cm/62 inches) gain about 1 kg less than taller women.

No evidence short women have a higher risk of low weight gain.

Update

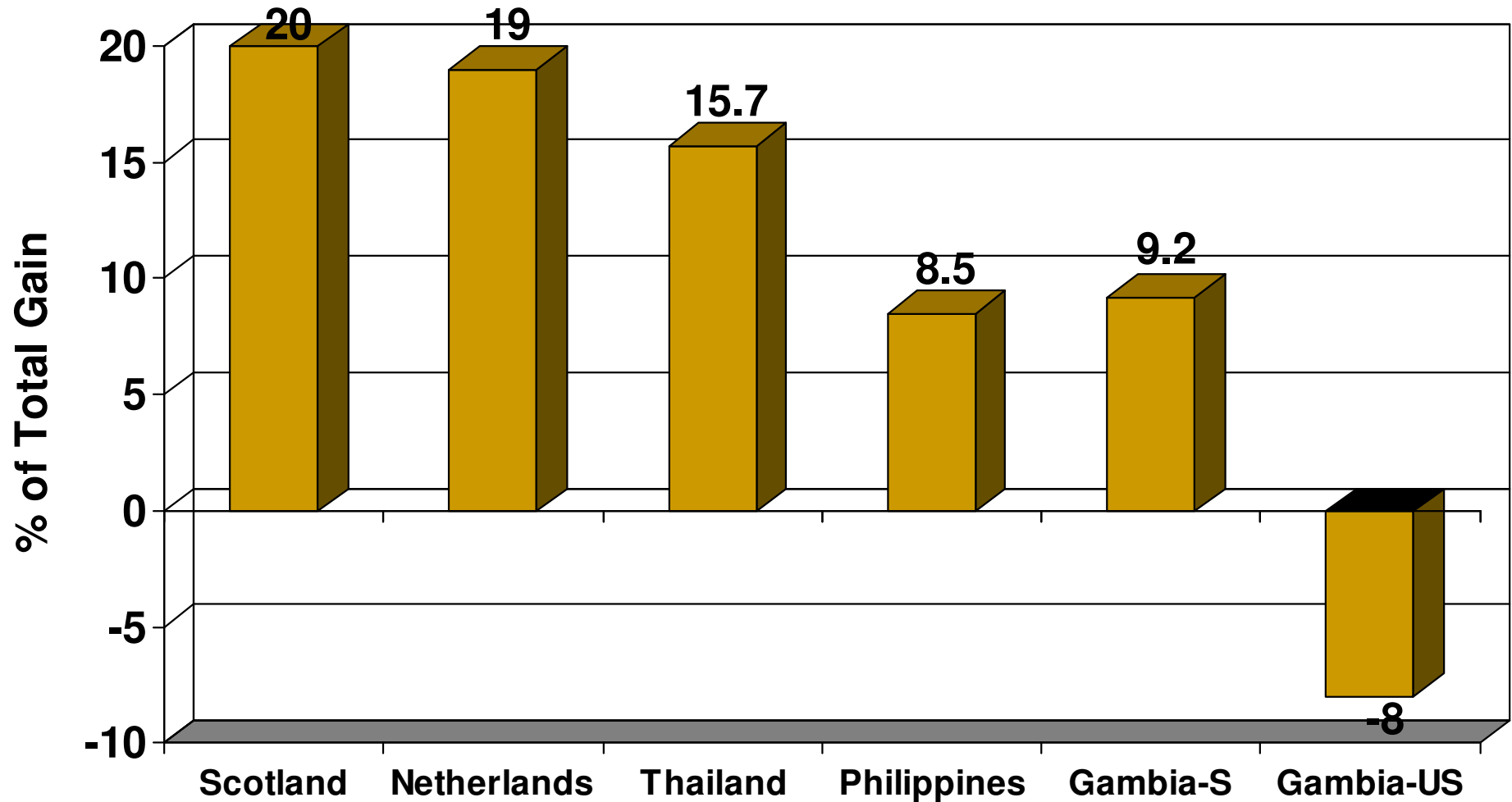
There appears to be an interaction among stature, pre-pregnancy BMI, and GWG.

‣ **Need data from OW women**

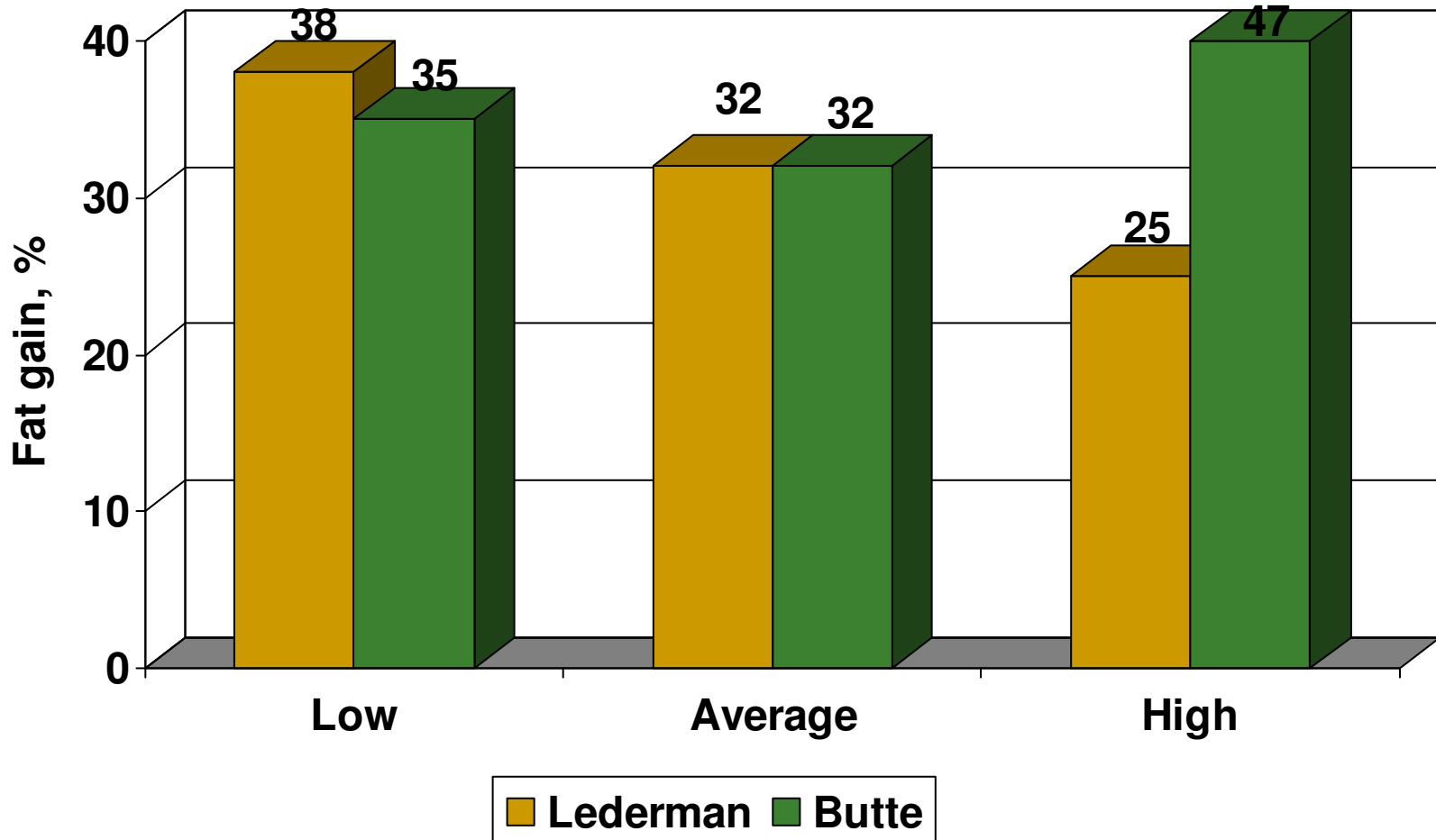
Is Fat Gain Associated with Higher Total GWG?

If so, what biological factors predict fat gain?

Gestational Fat Gain Varies Widely Among Women World-Wide: 5-Nation Study



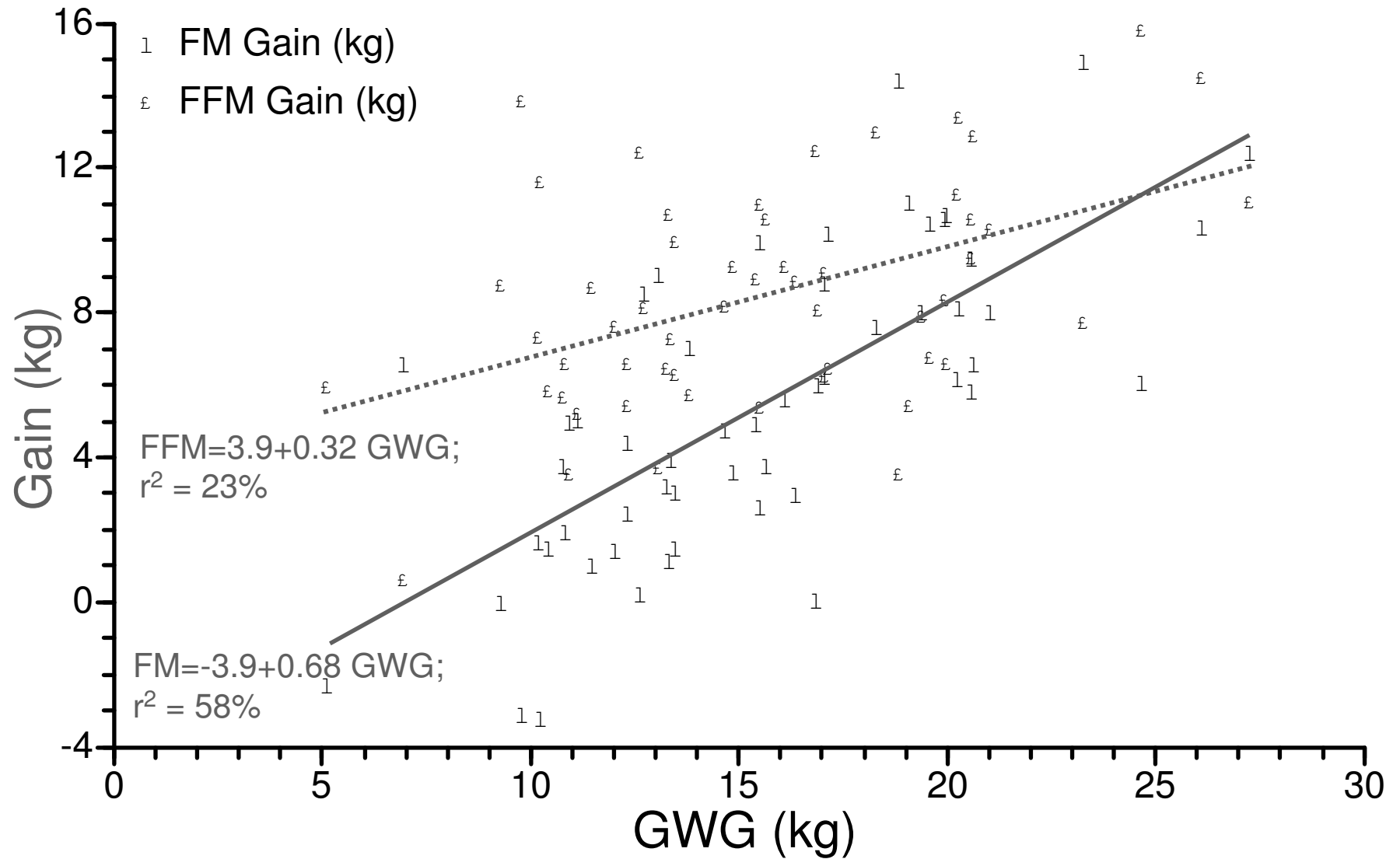
Measured mean gains in body fat among US women according to BMI status



Lederman et al., 1997. n=200

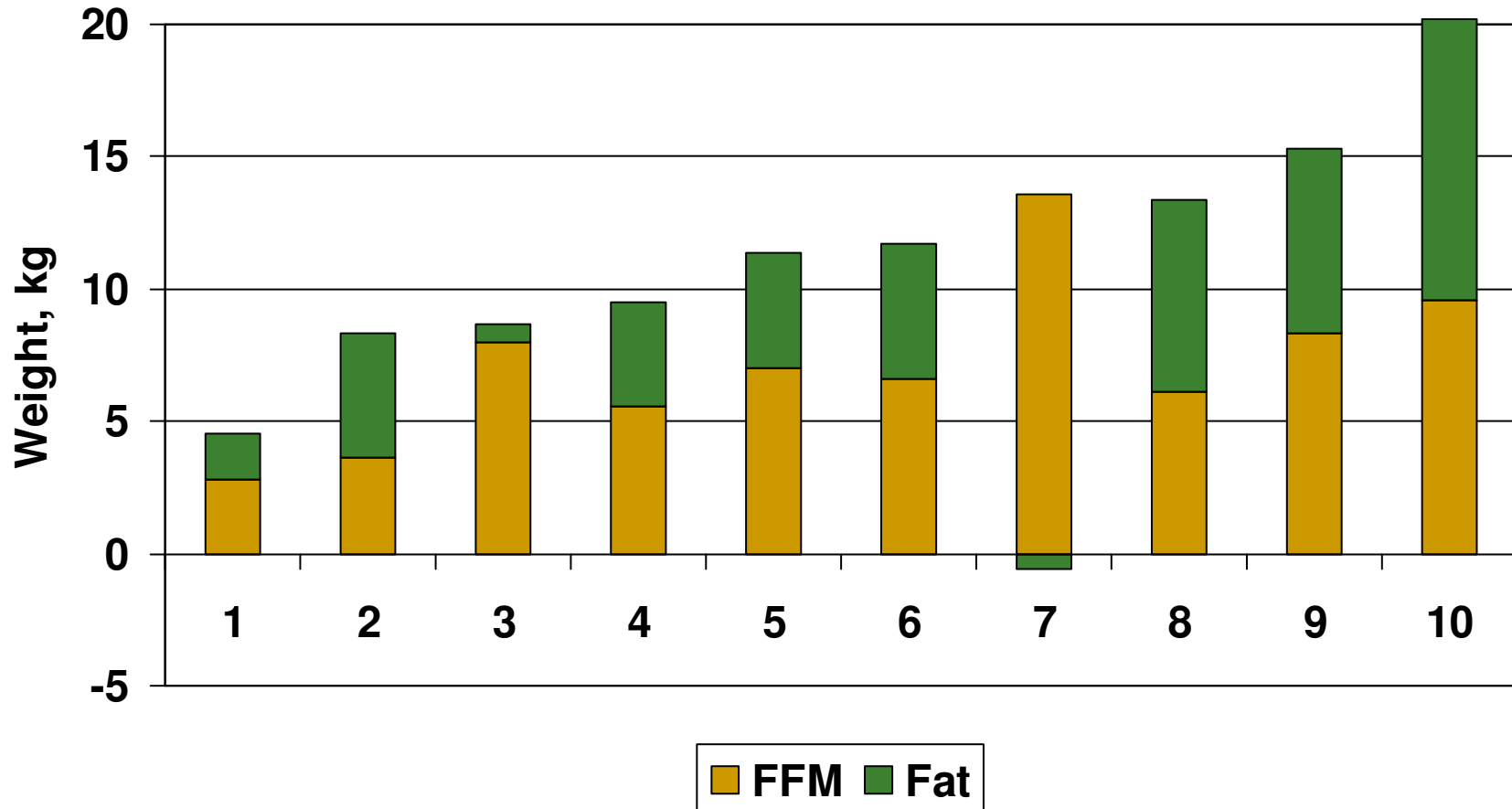
Butte et al., 2003. n=63

High GWG associated with higher fat gains



From: Butte, NF. personal communication.

Fat Gain Among Similar Women Varies Widely



Kopp-Hoolihan and King. AJCN. 1999

Correlation between GWG and Fat Gain. $R=0.705$, $p<0.01$

Biological Determinants of Fat Gain

Genetics

Insulin

Leptin

Genetics and Fat Gain

Women homozygous for the T allele of the G-protein β_3 subunit gained significantly more weight (17.4 kg) than other genotypes (14.8 or 15.3 kg). Homozygous for T allele—more resistant to lipolysis. (Dishy et al., Pharmacogenetics. 2003)

Women with GDM who have a polymorphism of the PPAR γ 2 gene gained significantly more weight (17.9 vs 12.2 kg) during pregnancy. Influences fatty acid oxidation. (Tok et al., Europ J Obstet Gynecol 2006).

Non-obese women in the highest quartile of fasting insulin at booking had a 2-fold increased risk of excessive weight gain (0.44 vs 0.37 kg/wk) and a 3.6-fold increased risk of excess weight postpartum (8.1 vs ~5 kg). Insulin promotes fat storage in early pregnancy. (Scholl and Chen. Maternal Child Hlth J. 2002).

Leptin Associated with Higher Postpartum

Weight Retention (i.e. fat gain) Stein et al, AJCN. 1998

103 women 13-29 years, Camden,
NJ

Average BMI

Mean GWG: 14.2 ± 0.72 kg

Wt retention@6 months: 4.5 kg

Weight retention—surrogate for
fat gain.

Higher initial log leptin
associated with higher
weight retention at 6 months

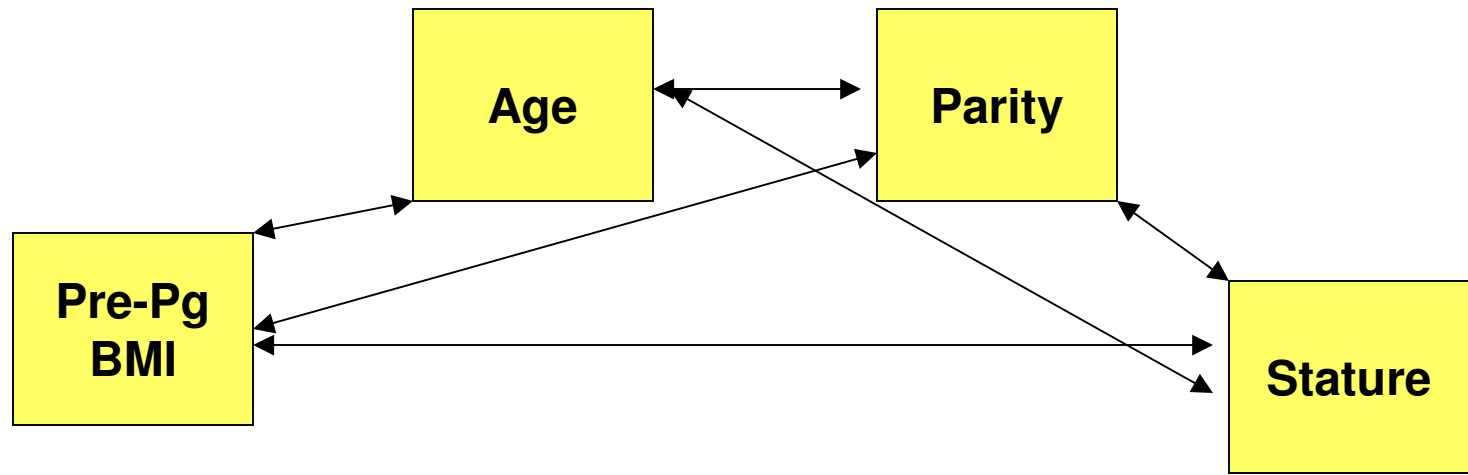
Predicted retained weight
postpartum increased 7.3
kg/unit log leptin at entry
($p < 0.05$)

Conclusion:

Leptin resistance, or a decreased tissue leptin signal,
may increase gestational fat gain.

Fat Gain and GWG: Summary

- n **High fat gains are associated with higher total weight gains and weight retention.**
- n **Genetic polymorphisms in genes regulating energy or lipid metabolism may predispose some women to higher fat gains.**
- n **Higher levels of insulin (and, possibly leptin) in early pregnancy may increase early fat deposition.**



Regulation of Energy/Fat Metabolism



Research Needed to Improve Management of GWG Clinically

What insufficient or excessive *rates* of gain are associated with poor pregnancy outcomes?

- q **Can extremes in rates of gain be predicted by maternal biological and social factors at conception?**
- q **If so, what are those factors and do their effects on GWG differ in early and late pregnancy?**

1. Abrams B, Parker JD. 1990. Maternal weight gain in women with good pregnancy outcome. *Obstet Gynecol* 76: 1-7
2. Butte NF, Ellis KJ, Wong WW, Hopkinson JM, O'Brian Smith E. 2003. Composition of gestational weight gain impacts maternal fat retention and infant birth weight. *Am J Obstet Gynecol* 189: 1423-32
3. Carmichael S, Abrams B, Selvin S. 1997. The pattern of maternal weight gain in women with good pregnancy outcomes. *Am J Public Health* 87: 1984-8
4. Dietz PM, Callaghan WM, Cogswell ME, Morrow B, Ferre C, Schieve LA. 2006. Combined effects of prepregnancy body mass index and weight gain during pregnancy on the risk of preterm delivery. *Epidemiology* 17: 170-7
5. Dishy V, Gupta S, Landau R, Hong-Guang X, Kim RB, et al. 2003. G-protein b3 subunits 825 C/T polymorphism is associated with weight gain during pregnancy. *Pharmacogenetics* 13: 241-2
6. Gigante DP, Rasmussen KM, Victora CG. 2005. Pregnancy increases BMI in adolescents of a population-based birth cohort. *J Nutr* 135: 74-80
7. Harris HE, Ellison GTH, Holliday M. 1997. Is there an independent association between parity and maternal weight gain? *Annals of Human Biology* 24: 507-91
8. Hediger ML, School TO, Ances IG, Belsky DH, Salmon RW. 1990. Rate and amount of weight gain during adolescent pregnancy: associations with maternal weight-for-height and birth weight. *Am J Clin Nutr* 52: 793-9
9. Hytten F, Chamberlain G. 1980. *Clinical Physiology in Obstetrics*. Oxford: Blackwell Scientific Publications
10. Institute of Medicine FaNB. 1990. *Nutrition during Pregnancy. Part I. Weight Gain. Part II. Nutrient Supplements*. Washington, D.C.: National Academy Press
11. Johnston CS, Christopher FS, Kandell LA. 1991. Pregnancy weight gain in adolescents and young adults. *J Am Coll Nutr* 10: 185-9
12. Kopp-Hoolihan LE, Van Loan MD, Wong WW, King JC. 1999. Fat mass deposition during pregnancy using a four-component model. *J Appl Physiol* 87: 196-202
13. Lang KE. 2006. *Maternal metabolic and pregnancy outcomes in obese and non-obese women*. University of California, Davis
14. Lederman SA, Paxton A, Heymsfield SB, Wang J, Thornton J, Pierson RN. 1997. Body fat and water changes during pregnancy in women with different body weight and weight gain. *Obstet Gynecol* 90: 483-8
15. Scholl TO, Chen X. 2002. Insulin and the "thrifty" woman: the influence of insulin during pregnancy on gestational weight gain and postpartum weight retention. *Matern Child Health J* 6: 255-61
16. Sichieri R, Silva CA, Moura AS. 2003. Combined effect of short stature and socioeconomic status on body mass index and weight gain during reproductive age in Brazilian women. *Brazilian Journal of Medical and Biological Research* 36: 1319-25
17. Siega-Riz AM, Adair LS. 1993. Biological determinants of pregnancy weight gain in a Filipino population. *Am J Clin Nutr* 57: 365-72
18. Siega-Riz AM, Hobel CJ. 1997. Predictors of poor maternal weight gain from baseline anthropometric, psychosocial, and demographic information in a Hispanic population. *J Am Dietet Assoc* 97: 1264-8
19. Stein TP, Scholl TO, Schluter MD, Schroeder CM. 1998. Plasma leptin influences gestational weight gain and postpartum weight retention. *Am J Clin Nutr* 68: 1236-40
20. Tok E, Ertunc D, Bilgin O, Erdal E, Kaplanoglu M, Dilek S. 2006. PPAR-gamma2 Pro12Ala polymorphism is associated with weight gain in women with gestational diabetes mellitus. *Eur J Obstet Gynecol Reprod Biol* e-pub
21. Wells C, Schwalberg R, Noonan G, Gabor V. 2006. Factors influencing inadequate and excessive weight gain in pregnancy: Colorado, 2000-2002. *Matern Child Health J* 10: 55-62
22. WHO. 1995. Maternal anthropometry and pregnancy outcomes--A WHO Collaborative Study. *Bull World Health Org* 73: 1S-69S
23. Wolfe WS, Sobal J, Olson CM, Frongillo EA, Jr., Williamson DF. 1997. Parity-associated weight gain and its modification by sociodemographic and behavioral factors: a prospective analysis in US women. *Int J Obes* 21: 802-10