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Carbohydrates and Energy Requirements

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January 29, 2020
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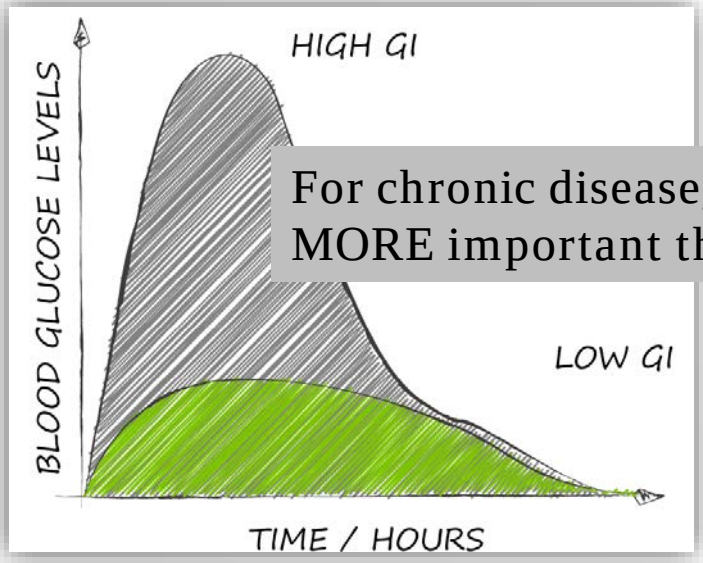
Characteristics of Carbohydrates

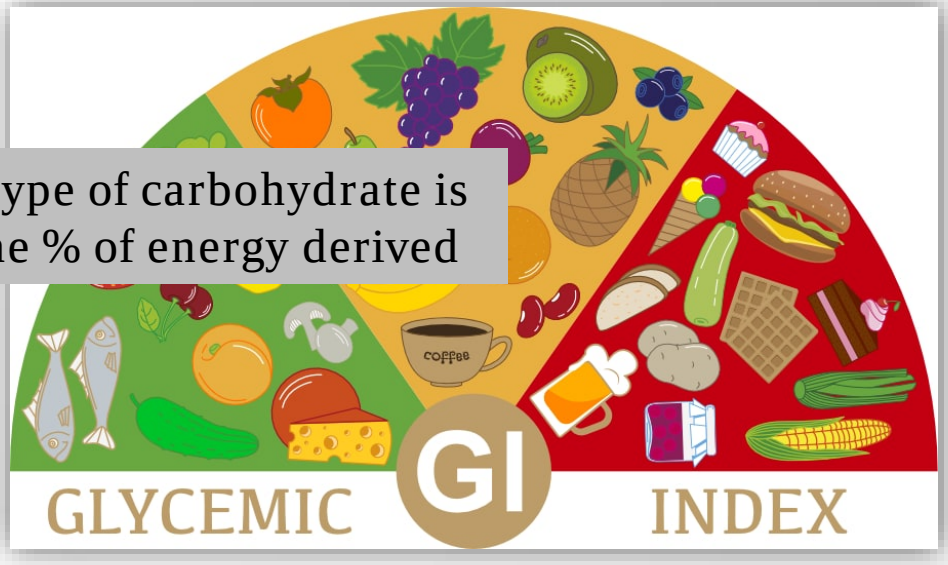
- Primary energy deriving nutrient in the human diet
- It's the only macronutrient without a minimal requirement
- Defined by their composition: carbon, hydrogen and oxygen $(CH_2O)n$, in the ratio 1:2:1 or saccharide (sugar) units
- Comprise of compounds which can be digested or metabolically transformed to glucose (or oxidation to pyruvate)
- Categorized according to degree of polymerization into monosaccharides, disaccharides, oligosaccharides and polysaccharides
- Carbohydrate polymer length determines rate of digestion/ absorption and the rise in postprandial blood glucose

Glycemic Index (GI)

Area under the curve for the increase in blood glucose after ingestion of a 50g portion of a carbohydrate food relative to a standard carbohydrate (50g glucose) over a 2-hour post-prandial period



For chronic disease, the type of carbohydrate is MORE important than the % of energy derived



Source: Ludwig et al. BMJ (2018); 361: k2340

Summary 1

Simple Carbohydrates		Complex Carbohydrates
SUGAR		STARCH
Refined Sugars	**Natural** Sugars	**Fiber**
Monosaccharides	Disaccharides	Polysaccharides
Sweet Low molecular weight Soluble in water		Non-sweet High molecular weight Insoluble in water
Glucose, Fructose	Lactose, Sucrose	





Estimated Average CHO Requirements for Women

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Assumptions:

- The average estimated requirements are based on the amount of carbohydrate needed for brain glucose utilization, without dependence on protein or fat
- ~ 8.64g/100g brain per day (female brain is approx. 1.29 kg)
- Daily brain carbohydrate requirement = 117 to 142 g per day

Non-pregnant: EAR = 100g/d

Pregnancy: EAR is increased considering fetal brain glucose utilization (brain is ~ 380g at term x 8.64g/100g ➔ ~32.5 g glucose. **EAR = 135g/d of carbohydrate**

Lactation: EAR is increased considering the lactose content of milk is ~74g/L (60g/d of carbohydrate). **EAR = 160g/d of carbohydrate**

Source: Institute of Medicine, Dietary Reference Intakes, Chapter 6. National Academy 2005

Dietary References Intakes (DRI)

DRI = EAR + 2 times coefficient of variation of brain glucose utilization (15%)

DRI for Carbohydrates in Women (Grams per Day)			
	Non-Pregnant	Pregnancy	Lactation
<18 years	130	175	210
19-60	130	175	210

Source: Institute of Medicine, Dietary Reference Intakes. National Academy 2005

Other Considerations – Added Sugar

- Are **sugars** and **syrups added** to foods or beverages when they are processed or prepared
- The 2015-2020 Dietary Guidelines Committee included limits for added sugars[1]
- <10% of energy intake[1] (for 2,000 kcal diet = approx. 200 kcal or 50g)
- Not specific to pregnant women but the Nat'l Academy of Nutrition & Dietetics suggests pregnant women reduce intake of added sugars [2]

Source: [1]2015-2020 Dietary Guidelines for Americans; [2]J Acad Nutr Diet (2014); 114:1099-1103.

Other Considerations - Fiber

- Two types:
  - *Dietary Fiber* - soluble (fruits, vegetables, legumes) and insoluble (wholegrains, nuts).
  - Functional Fiber – isolated non-digestible carbohydrates (cooked potato, rice)
- Induce various health benefits: delayed gastric emptying (favorable postprandial glucose), improve insulin sensitivity, satiation, dietary fat malabsorption (beneficial for cholesterol), laxation.
- DRI derived from benefit to CHD, cancer (colon, breast), weight management
- Pregnant women DRI for Total Fiber (dietary fiber + functional fiber) = 28g per day (14g / 1,000 kcal)

Source: [1]J Acad Nutr Diet (2014); 114:1099-1103, 2Institute of Medicine, [2]Dietary Reference Intakes, Chapter 6. National Academy 2005

Carbohydrate Intakes in Pregnant Women

DRI CHO = 175 g per day

UK

RDI %E	55-75%
g/ day	254±28g

Europe

RDI %E	55-75%
g/ day	268±42g

Japan

RDI %E	55-75%
g/ day	250±11g

N. America

RDI %E	45-65%
g/ day	285±31g

Aus/NZ

RDI %E	45-65%
g/ day	271±42g

Mean CHO Intake = 269.1 ± 37.0 g/day

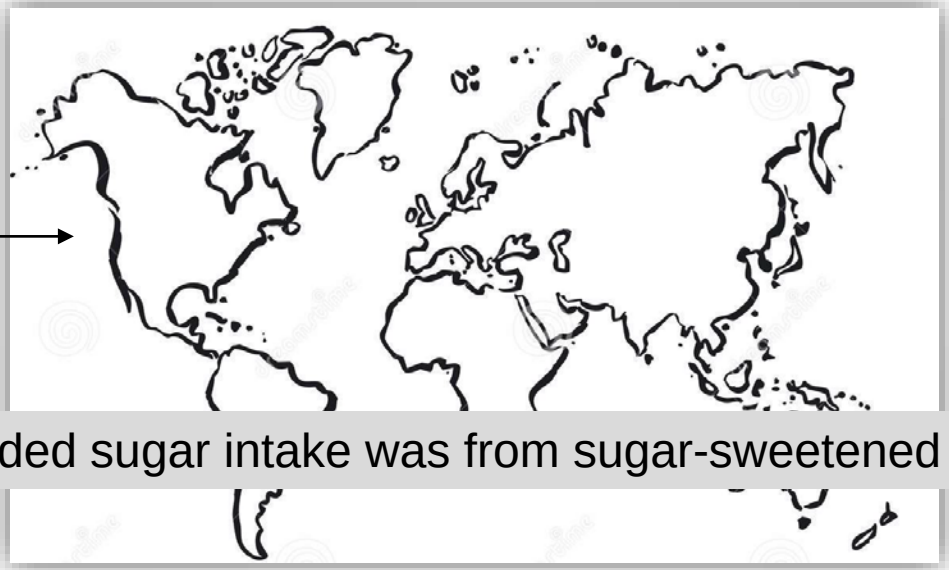
Mean CHO Intake = 46.6 - 49.6% Energy

Source: Adapted from Blumfield et al. 2012 Nutr Rev; 70(6): 322-336

Added Sugar Intake in Pregnant Women

2015-2020 DGA Goal = <10% Energy

N. America[1]	
%Energy	14.8%
g/ day	85.1g



Developed Countries[2]	
g/ day	50.3±9.2

39% of added sugar intake was from sugar-sweetened beverages[1]

Source: [1]Cioffi et al. JAND 2018; 118(5):886-895 , [2]Blumfield et al. 2012 Nutr Rev; 70(6): 322-336

Fiber Intake in Pregnant Women

DRI Fiber = 28 g/day

UK

RDI	>25g/day
g/ day	17.4±3.3

Europe

RDI	>25g/day
g/ day	19.4±5.3

Japan

RDI	21g/day
g/ day	15.1±6.2

N. America

RDI	28g/day
g/ day	18.8±3.6

Aus/NZ

RDI	28g/day
g/ day	21.9±1.1

Mean Fiber Intake = 18.7 ± 4.4 g/day

Source: Adapted from Blumfield et al. 2012 Nutr Rev; 70(6): 322-336

CHO Intake & Pregnancy Outcomes

GDM

- Increased risk: low carbohydrate dietary pattern prepregnancy (RR 1.36, 1.13-1.64), sweets and seafood dietary pattern (RR 1.38, 1.02-1.86)
- Reduced risk: DASH diet pattern (RR 0.66, 0.53-0.82), prudent dietary pattern (RR 0.54, 0.30-0.98), mediterranean diet pattern (OR 0.618), fiber intake

T2DM

- Reduced risk in women with GDM with DASH diet (RR 0.54, 0.39-0.73)

Preeclampsia

- Increased risk: increased sweet drinks/snacks (OR 1.21, 1.03-1.42)
- Decreased risk: high intake of vegetable/plant foods/oils (OR 0.72, 0.62-0.85), Mediterranean diet (RR 0.58, 0.42-0.81)

[1]Bao et al. AJCN (2014); 99:1378-1384, [2]Blumfield et al. 2012 Nutr Rev; 70(6): 322-336

CHO Intakes & Pregnancy Outcomes

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Preterm Birth

- Reduced risk: Mediterranean diet pattern (OR 0.61, 0.35-1.05)[1], prudent dietary pattern (OR 0.88, 0.80-0.97)[2]
- Increased risk: western diet (RR 1.30, 1.13-1.49)[1], high fat/sugar/takeout pattern (RR 0.31, 0.13-0.72)[2]

Small Gestational Age

- Increased risk: western diet, wheat products (OR 5.2, 1.1-24.4)
- Decreased risk: Mediterranean diet
- No effect

Low Birth Weight

- Increased risk: western diet or No effect

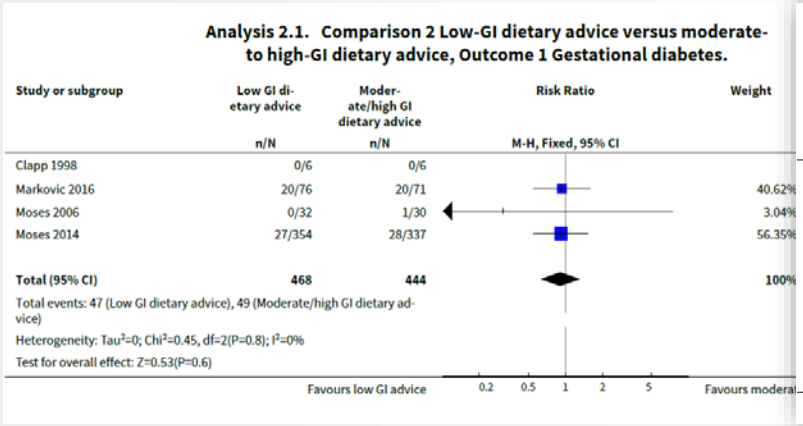
[1]Bao et al. AJCN (2014); 99:1378-1384, [2]Blumfield et al. 2012 Nutr Rev; 70(6): 322-336

Effects of Low GI Diets – RCTs

Tieu et al. Cochrane 2017 (4 RCTs; 3 USA, 1 Australia)

No significant effect

- GDM; 4 trials, n=912 (RR 0.91, 0.63-1.31)
- LGA; 3 trials, n=777 (RR 0.60, 0.19-1.86)
- Or other outcomes (eg. cesarean birth, hypertensive disorders, T2DM)
- **Quality of evidence: low to very low**



Analysis 2.1. Comparison 2 Low-GI dietary advice versus moderate-to high-GI dietary advice, Outcome 1 Gestational diabetes.

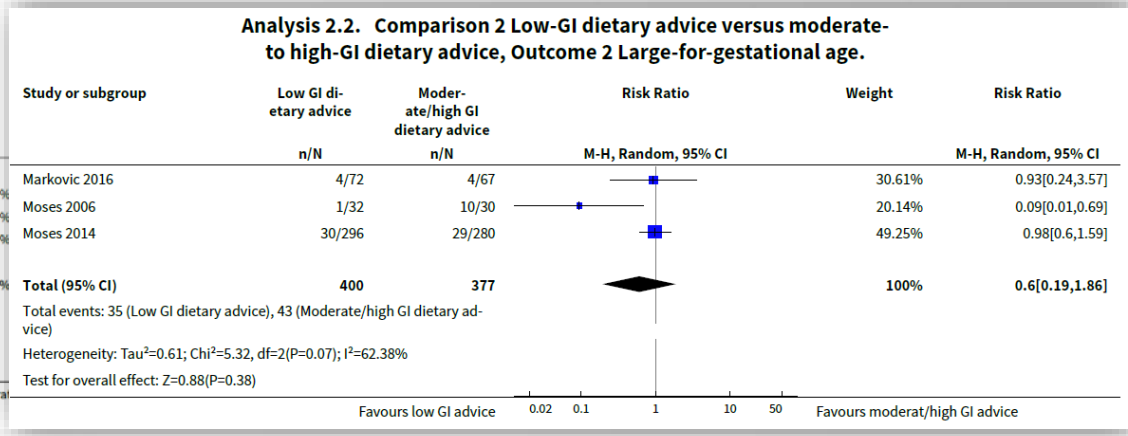
Study or subgroup	Low GI dietary advice n/N	Moderate/high GI dietary advice n/N	Risk Ratio M-H, Fixed, 95% CI	Weight
Clapp 1998	0/6	0/6		
Markovic 2016	20/76	20/71		40.62%
Moses 2006	0/32	1/30		3.04%
Moses 2014	27/354	28/337		56.35%
Total (95% CI)	**468**	**444**		**100%**

Total events: 47 (Low GI dietary advice), 49 (Moderate/high GI dietary advice)

Heterogeneity: $Tau^2=0$; $Chi^2=0.45$, df=2(P=0.8); $I^2=0\%$

Test for overall effect: Z=0.53(P=0.6)

Favours low GI advice | 0.2 | 0.5 | 1 | 2 | 5 | Favours moderat



Analysis 2.2. Comparison 2 Low-GI dietary advice versus moderate-to high-GI dietary advice, Outcome 2 Large-for-gestational age.

Study or subgroup	Low GI dietary advice n/N	Moderate/high GI dietary advice n/N	Risk Ratio M-H, Random, 95% CI	Weight	Risk Ratio M-H, Random, 95% CI
Markovic 2016	4/72	4/67		30.61%	0.93[0.24,3.57]
Moses 2006	1/32	10/30		20.14%	0.09[0.01,0.69]
Moses 2014	30/296	29/280		49.25%	0.98[0.6,1.59]
Total (95% CI)	**400**	**377**		**100%**	**0.6[0.19,1.86]**

Total events: 35 (Low GI dietary advice), 43 (Moderate/high GI dietary advice)

Heterogeneity: $Tau^2=0.61$; $Chi^2=5.32$, df=2(P=0.07); $I^2=62.38\%$

Test for overall effect: Z=0.88(P=0.38)

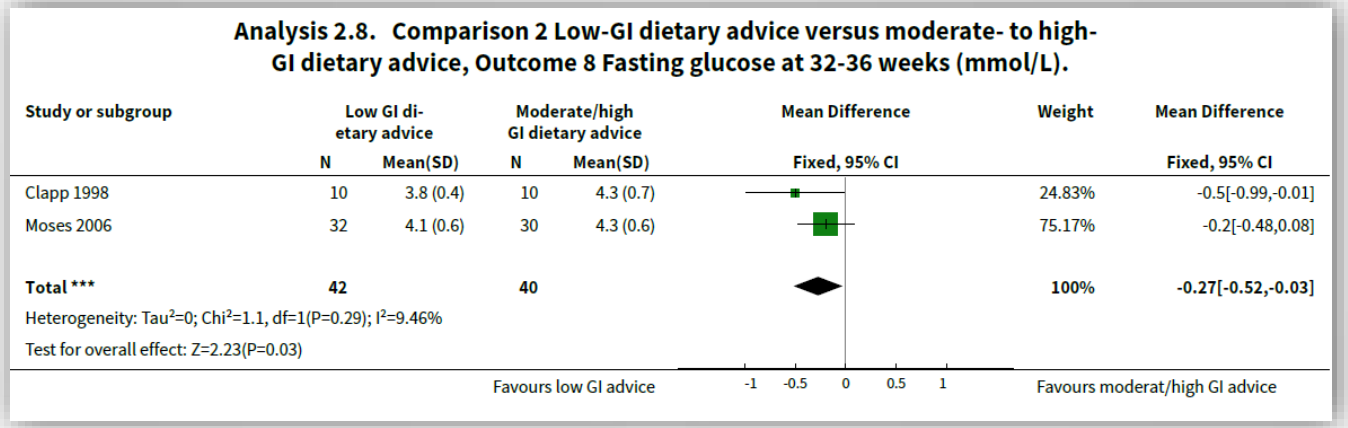
Favours low GI advice | 0.02 | 0.1 | 1 | 10 | 50 | Favours moderat/high GI advice

Effects of Low GI Diets – RCTs

Tieu et al. Cochrane 2017 (4 RCTs; 3 USA, 1 Australia)

Benefits:

- Hernandez et al: Pilot RCT, n=12, LCD (40%) vs HGI(60%) –↓ fasting glucose, ↓ insulin resistance



Analysis 2.8. Comparison 2 Low-GI dietary advice versus moderate- to high-GI dietary advice, Outcome 8 Fasting glucose at 32-36 weeks (mmol/L).

Study or subgroup	Low GI dietary advice N	Low GI dietary advice Mean(SD)	Moderate/high GI dietary advice N	Moderate/high GI dietary advice Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Clapp 1998	10	3.8 (0.4)	10	4.3 (0.7)		24.83%	-0.5[-0.99,-0.01]
Moses 2006	32	4.1 (0.6)	30	4.3 (0.6)		75.17%	-0.2[-0.48,0.08]
Total ***	**42**		**40**			**100%**	**-0.27[-0.52,-0.03]**

Heterogeneity: $Tau^2=0$; $Chi^2=1.1$, df=1(P=0.29); $I^2=9.46\%$

Test for overall effect: Z=2.23(P=0.03)

Favours low GI advice -1 -0.5 0 0.5 1 Favours moderat/high GI advice

Hernandez et al. Diab Care 2016;39:39-42

Effects of Low CHO Diets – RCTs on GDM

Yamamoto et al Diab Care 2018[1]

18 RCTs, 1,150 women

- Improved fasting/postprandial glucose
- Lower need for medication
- Decreased birth weight and macrosomia

[1]*Yamamoto et al Diab Care 2018; 41: 1346-1361*

Summary 2

- Fairly universal adoption of carbohydrate DRIs in High-Income countries worldwide
- Studies indicate women are exceeding daily CHO DRI (>175g/day)
- ~40% of added sugars are SSB and total fiber intake is below recommendations for pregnant women.
- Teasing out the benefits or harms of CHO intake in pregnancy is challenging
  - Non-uniformity in levels of CHO (%Energy) tested in RCT
  - Non-uniformity in quality of CHO (or GI of the diet)
  - One RCT modifying fiber
- A chief focus of trials has been on the impact on gestational diabetes and fetal growth
  - Randomized controlled trials are limited
  - Quality of evidence is low, more trials are needed

Energy Requirements

Reflects the energy needed to support optimal development of maternal tissues, and fetal growth and development.

- Influenced by pregravid body size (size of energy depots), physical activity, physiological demands of each trimester

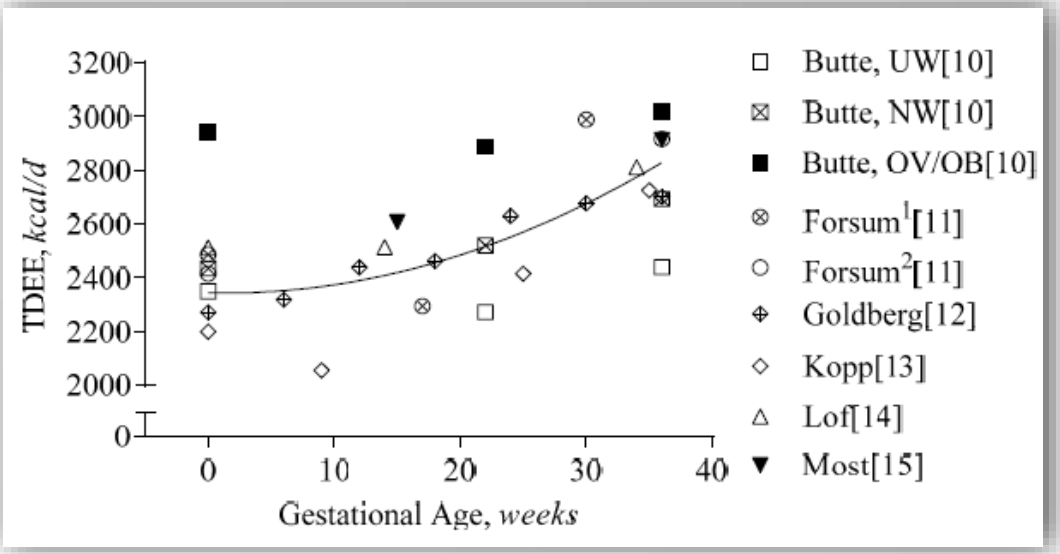
Table 1. Subject Characteristics of Cohorts in Energy Requirement Studies of Pregnancy.

First Author	Measurement Time Points	Cohort Size	Ethnicity	Age	BMI	Excess GWG
	Weeks Gestation	N	White, AA, Other			
Butte, UW [10]	0, 22, 36	17	15, 0, 2	31 ± 4	18.9 ± 0.8	18%
Butte, NW [10]	0, 22, 36	34	24, 4, 5	30 ± 3	22.1 ± 1.5	35%
Butte, OV/OB [10]	0, 22, 36	12	9, 2, 1	31 ± 5	28.8 ± 2.6	100%
Forsum[1] [11]	0, 17, 30	22		29 ± 4	22.3 ± 3.1	
Forsum[2] [11]	0, 36	19		28 ± 4	22.1 ± 3.4	
Goldberg [12]	0, 6, 12, 18, 24, 30, 36	12	12, 0, 0	29 ± 3	23.0 ± 3.3	
Kopp [13]	0, 9, 25, 35	10		29 ± 5	23.1 ± 2.1	10%
Lof [14]	0, 14, 34	23		30 ± 4	24.2 ± 4.8	
Most [15]	15, 36	54	28, 22, 4	28 ± 5	35.8 ± 5.0	67%

Source: Most et al. 2019 Nutrients; 11:1812

Changes in Total Energy Expenditure

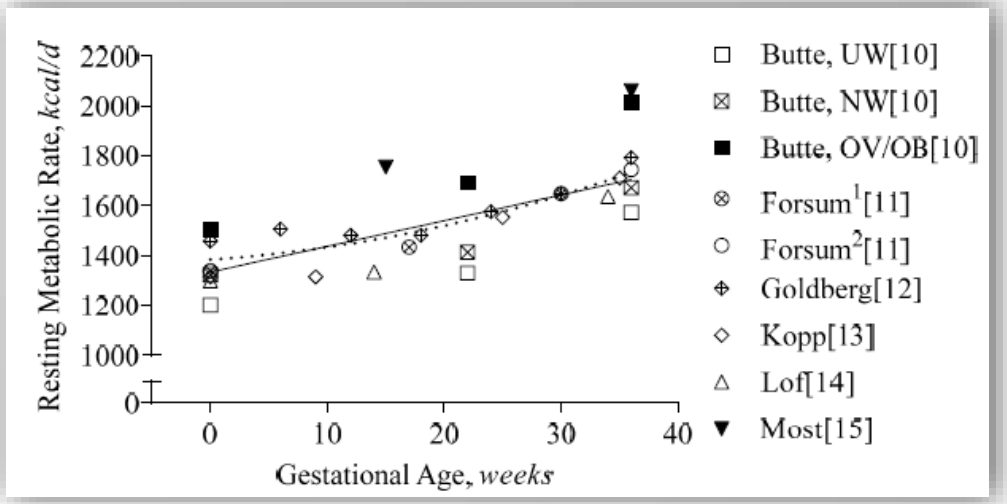
- Total daily energy expenditure (measured by doubly labeled water) increases ~420 kcal/d across gestation from 13-36wks.
  - TDEE does not increase in the first trimester
  - TDEE increase in trimester 2 and 3 are linearly related to weight gain
  - Increase in TDEE NOT attributed to gestational weight gain ~75kcal/d



Source: Most et al. 2019 Nutrients; 11:1812

Changes in Basal Metabolic Rate

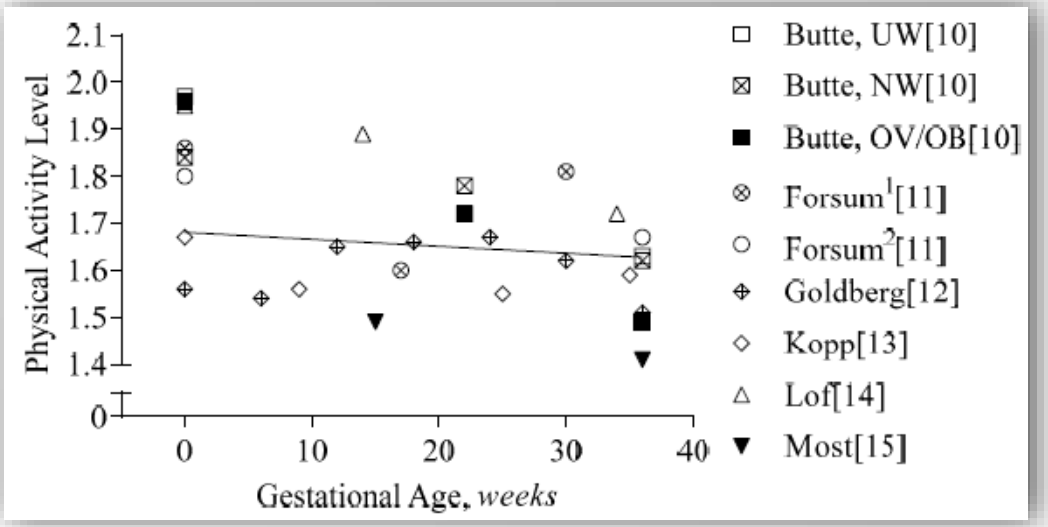
- Increases in the first trimester 60kcal/d total or ~20 kcal/d mass-adjusted
- Increases in trimester 2 and 3 by ~390kcal/d (17kcal/d per week)
- Approximately 50% (170 kcal/d) is explained by weight gain



Source: Most et al. 2019 Nutrients; 11:1812

Changes in Physical Activity

- Well-documented decline in physical activity across pregnancy
- ~-60 kcal/d



Source: Most et al. 2019 Nutrients; 11:1812

Energy Intake Requirements – DRI 2005

$EER_{pregnant}$ = $EER_{nonpregnant}$ + additional energy expended during pregnancy + energy deposition

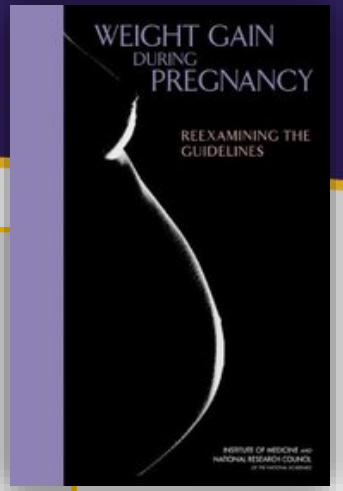
EERnonpregnant = 354 – 6.91 x age(y) + 9.36 x wt(kg) + 726 x height(m) + PA

Where: PA is 1.00 for PAL <1.4, 1.12 for 1.4≤PAL≤1.59, 1.27 for 1.6≤PAL≤1.89, 1.45 for 1.9 ≤ PAL ≤2.5

1st trimester = adult woman EER + 0 + 0
2nd trimester = adult EER + 160 kcal (8 kcal/wk x 20 wk) + 180 kcal (+340 kcal/d)
3rd trimester = adult EER + 272 kcal (8 kcal/wk x 34 wk) + 180 kcal (+452 kcal/d)

Source: Institute of Medicine, Dietary Reference Intakes, Chapter 5. National Academy 2005

Energy Intake Requirements – 2009 IOM[1]



First trimester, when weight gain is minimal, **no extra calories usually are needed**.
Second trimester, you need an **extra 340 calories a day**, and
Third trimester, **about 450 extra calories a day**.

Keep in mind that these amounts are for women who were a normal weight before pregnancy. If you are overweight or obese, you may need fewer extra calories.

Women with Obesity[2]: Recommended gestational weight gain (5-9kg) requires -125±52 kcal/d (~4%) less in trimester 2 and 3. Energy needs are meet from mobilization of adipose tissue energy stores.

Source: [1]Institute of Medicine, Weight Gain During Pregnancy Report. 2009, [2]Most et al JCI, 130:4682-4690, 2019

Summary 3

- Pregnancy is an energy costly process.
- Older energy requirement estimates do not consider gestational weight gain. Many women in those studies had excess weight gain.
- Energy requirement estimates are different for women based on pregravid body size.
- New studies of pregnant women with obesity suggest they do not need to increase caloric intake.
- Simpler energy intake requirement equations are needed for use by prenatal care providers and patients

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