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ENERGY DENSITY OF FAT AND FAT-FREE MASS

Energy substrates

- Biochemicals that can be oxidized to produce higher energy phosphate bonds

- Carbohydrates
- Lipids
- Proteins
- Minor amounts of other biochemicals

Energy density of macronutrients

4-9-4 energy rule

- Pro 4 kcal/g
- FAT 9 kcal/g
- CHOH 4 kcal/g
- Atwater factors

Dietary Energy Units

- Gross energy

  Energy released when combusted to CO_2, H_2O and N_2
- Digestible energy

  Energy absorbed

  Gross energy – fecal energy losses
- Metabolizable energy

  Energy available to the body

  Digestible energy – urinary energy losses

  Gross energy – (fecal + urinary losses)

Atwater factors (dietary)

- Gross energy — kcal/g
  - Protein — 5.65
  - Fat — 9.40
  - Carbohydrate — 4.10
- Digestible energy
  - Protein — 5.2
  - Fat — 9.0
  - Carbohydrate — 4.0
- Metabolizable energy
  - Protein — 4
  - Fat — 9
  - Carbohydrate — 4

Body composition

- Fat mass
  - Triglyceride
- Fat-free mass
  - Water
  - Protein
  - Mineral
  - Glycogen

Energy composition

- Fat mass
  - **TRIGLYCERIDE**
- Fat-free mass
  - Water
  - **PROTEIN**
  - Mineral
  - **GLYCOGEN**

Energy density of FAT MASS

Animal fat

gross energy 9.45 kcal/g

no fecal or urinary loss

energy density 9.45 kcal/g

Energy density of FAT MASS

Exception

- Loss of ketone bodies
  - β–hydroxybutric acid 4.96 kcal/g
  - Acetoacetic acid 4.15 kcal/g
  - Acetone 7.37 kcal/g
- Starvation (limited data)
  - Losses 10-20 g/d (3-5% of E_{lipid})
  - +100 g dietary CHOH <1 g/d

Energy density FAT-FREE MASS

- Glycogen
  - = Starch
  - Gross energy 4.12 kcal/g
  - No urinary loss
- Protein
  - Gross energy 5.65 kcal/g
  - Urinary loss controversy
  - Metabolizable

Urinary loss associated with protein oxidation

- Traditional Atwater approach
  - Assume all urinary energy loss from incomplete protein oxidation.
  - Atwater urine analyses
    - 7.9 kcal/g urinary N
    - 1.25 kcal/g protein
- 1 meat diet experiment
    - 7.7 kcal/g urinary N
    - 1.23 kcal/g
- De novo calculation
  - Urinary N urea, ammonia, creatinine 90:5:5
  - 5.8 kcal/g urinary N
  - 0.93 kcal/g

Energy density FAT-FREE MASS

- Glycogen
  - = Starch
  - Gross energy 4.12 kcal/g
  - No urinary loss
- Protein
  - Gross energy 5.65 kcal/g
  - Urinary loss 0.93 to 1.23 kcal/g
  - Metabolizable 4.72 to 4.42

Energy density FAT-FREE MASS

Exceptions

- Uncontrolled diabetes
  - Glycosuria
  - Up to 150 g/d
- Starvation
  - N excreted mostly as ammonia
  - Less urinary energy loss from protein oxidation
  - Linked to ketone loss preserve acid/base balance
  - ≈ compensates for energy lost as ketones

Composition of FAT-FREE MASS

Water	73%
Protein	21%
Osseous mineral	5%
Non-osseous mineral	0.7%
Glycogen	0.7%

Multiple sources because there is not a constant value

Energy density of FAT-FREE MASS

Protein 0.21 * (4.65-1.2)

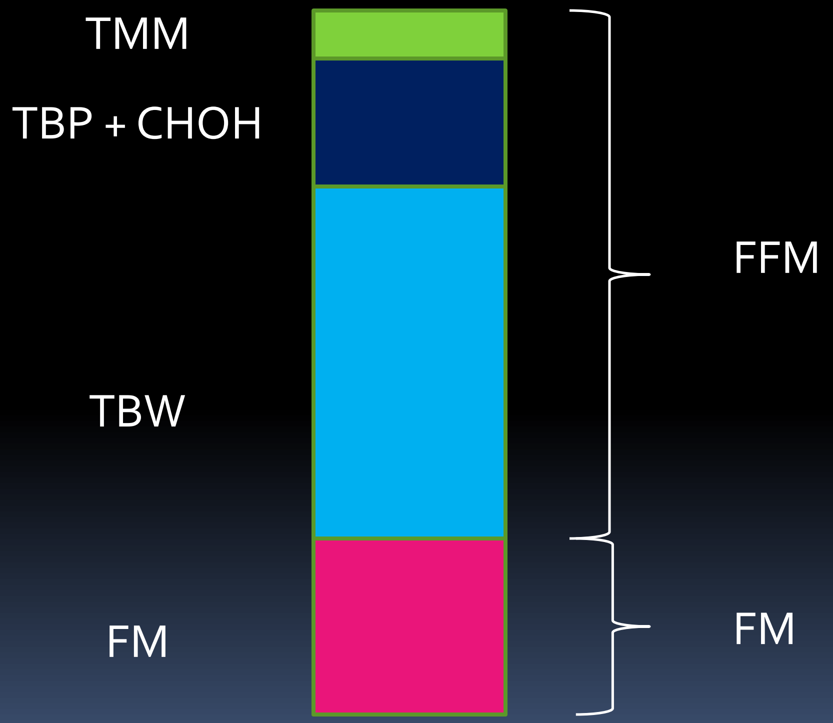
Glycogen 0.007*4.12

FFM: 0.96 kcal/g

Adjust for no bone loss

FFM: 1.0 kcal/g

But do these proportions hold true for the composition of change in weight?



Human Experimental Data

Weight loss

4C body composition analysis

- TBW – D dilution/1.04
- TMM – DXA ash*1.27
- Body density by water or air displacement

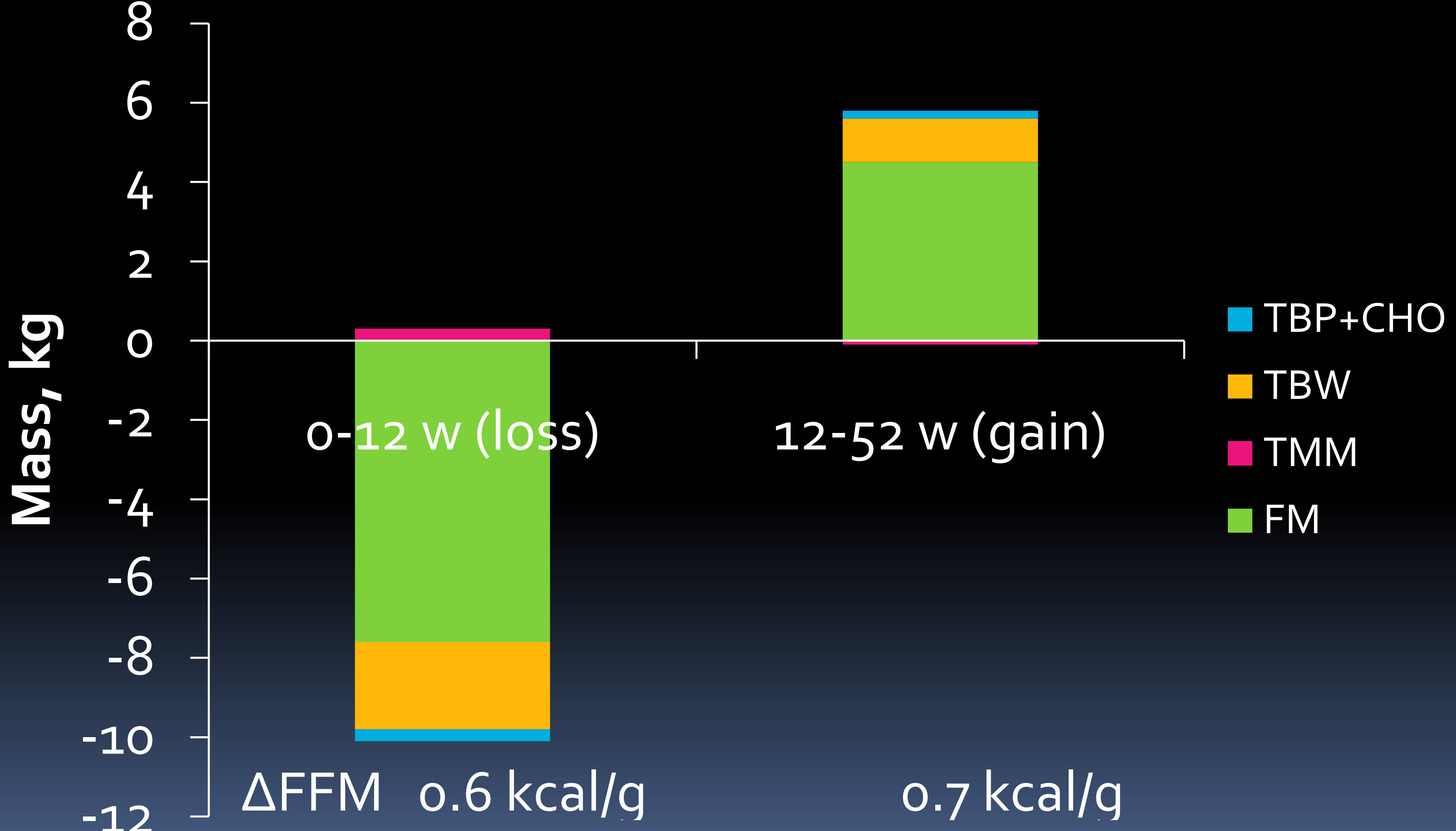
Minimal assumptions

- Total body water
- Total mineral mass
- Protein (+ CHOH) mass
- Fat mass

Jebb et al Intl J Obesity 31, 756, 2006

- 48 adult women
  - 24-65 y
  - BMI > 25 kg/m^2
  - 12 w wt loss + 40 follow-up

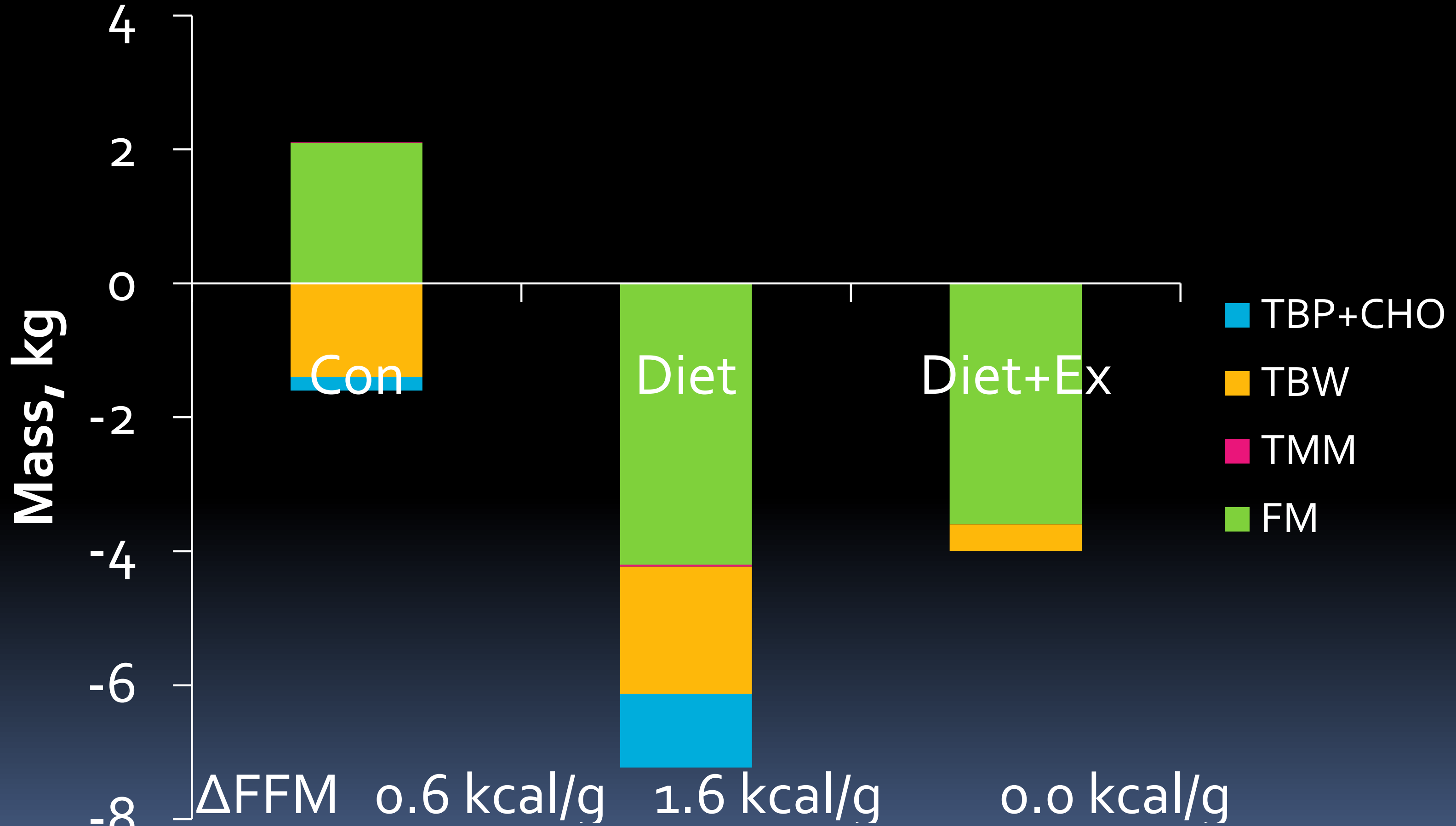
Jebb et al Intl J Obesity 31, 756, 2006



Evans et al. Am J Clin Nutr 70:5, 1999

- Women n= 9 in each of three groups
- 21-40 y
- 58-132 kg
- 27-44 kg/m^2
- Tx 10wk
  - Control
  - -1000 kcal/d balanced diet
  - Diet + 350 kcal/d moderate Ex

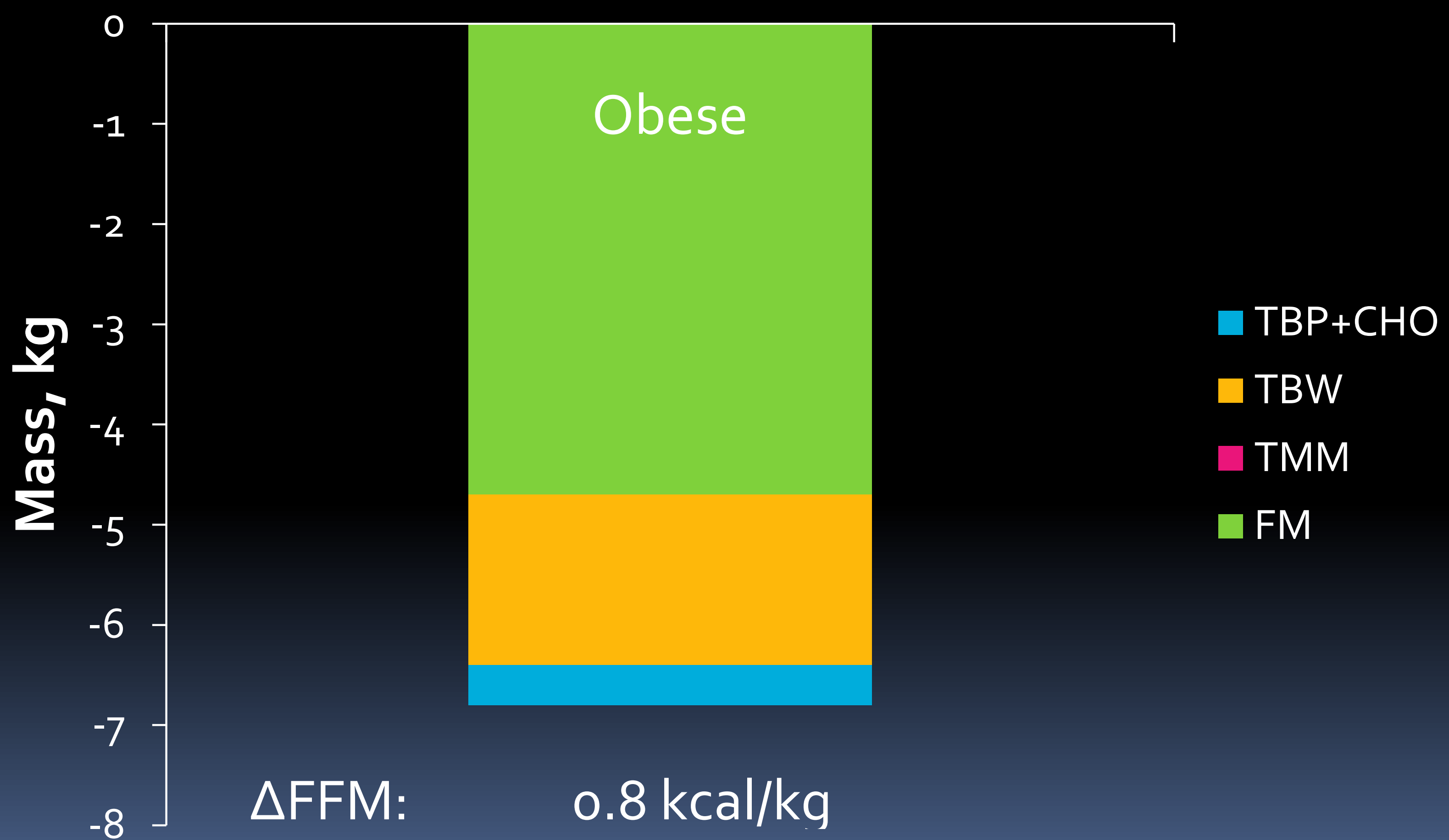
Evans et al. Am J Clin Nutr 70:5, 1999



Mahon et al. J Nutr Hlth Aging 11:203, 2007

- Women, n=27 postmenopausal
- 59 $\pm$ 8 y
- 77 $\pm$ 10 kg
- 29 + 3 kg/m^2
- Tx
  - 9 wk
  - 1200 kcal/d balanced diet

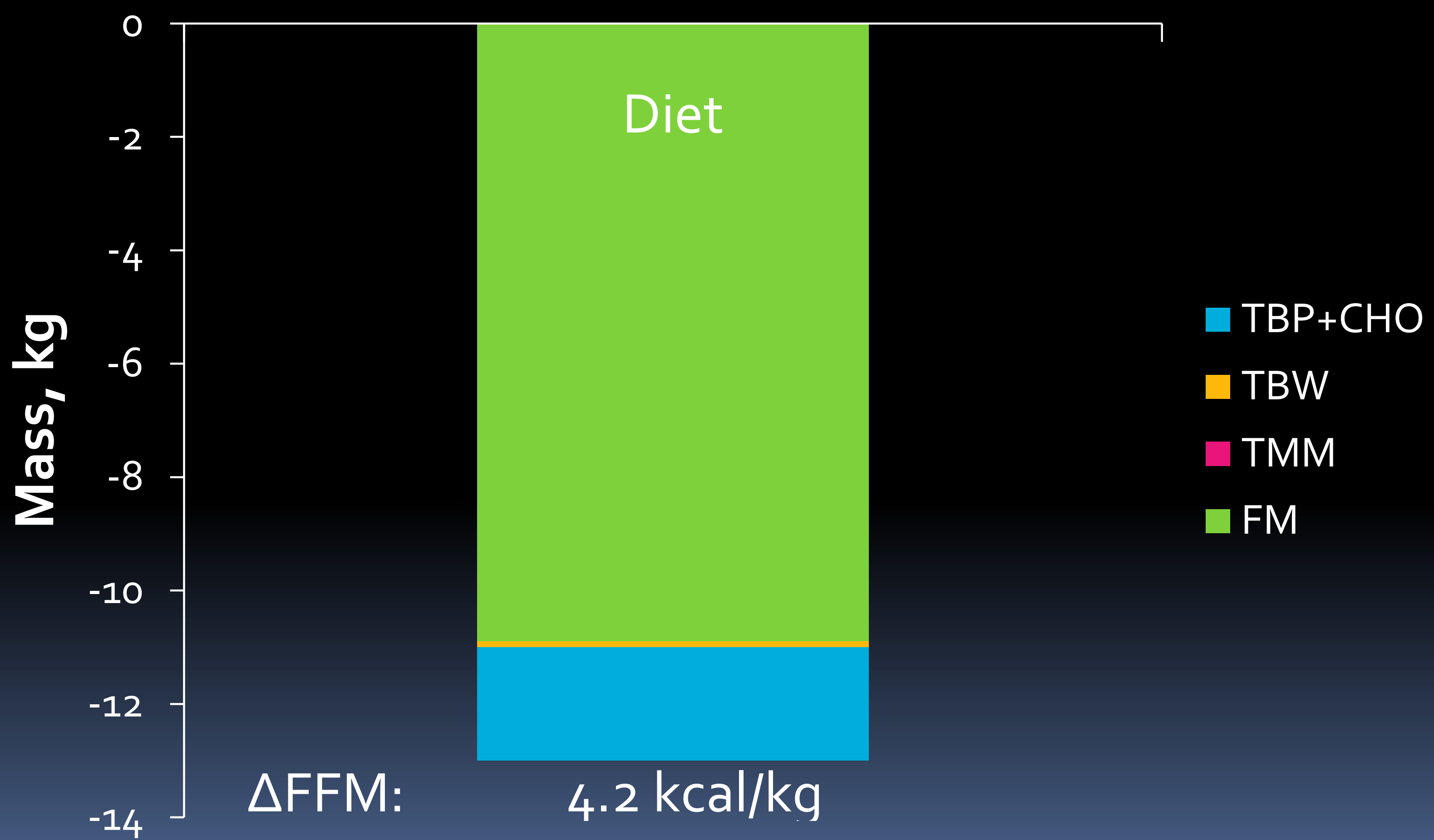
Mahon et al. J Nutr Hlth Aging 11:203, 2007



Fogelholm et al. Metabolism. 46:968, 1997

- Women, n-32
- 30-45 y
- 94 $\pm$ 11 kg
- 35 $\pm$ 4 kg/m^2
- Tx
  - 12 wk
  - 600 kcal/d (1100 kcal/d final body comp)

Fogelholm et al. Metabolism. 46:968, 1997



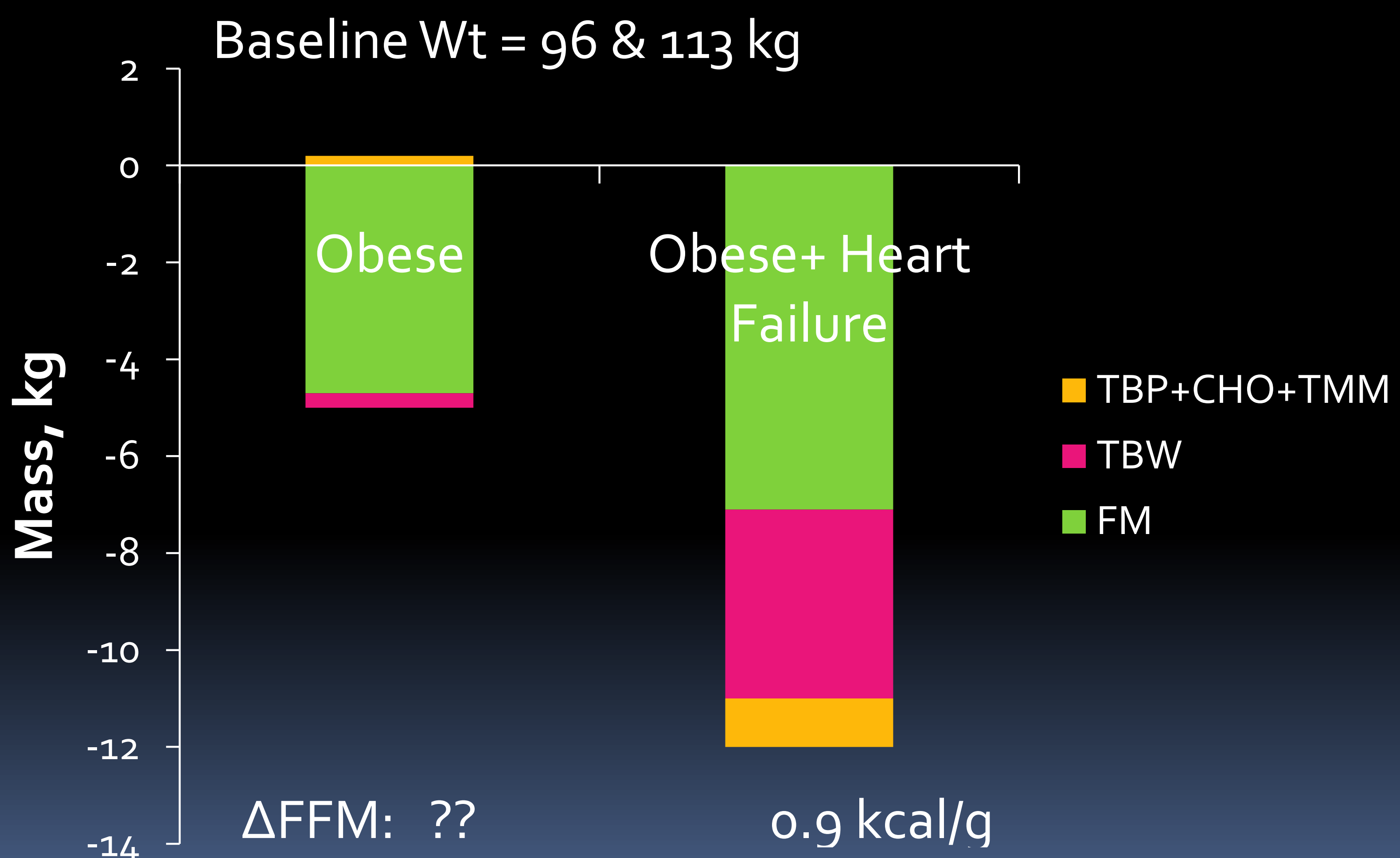
Myint et al, Obesity, 18:391, 2010

Otherwise healthy

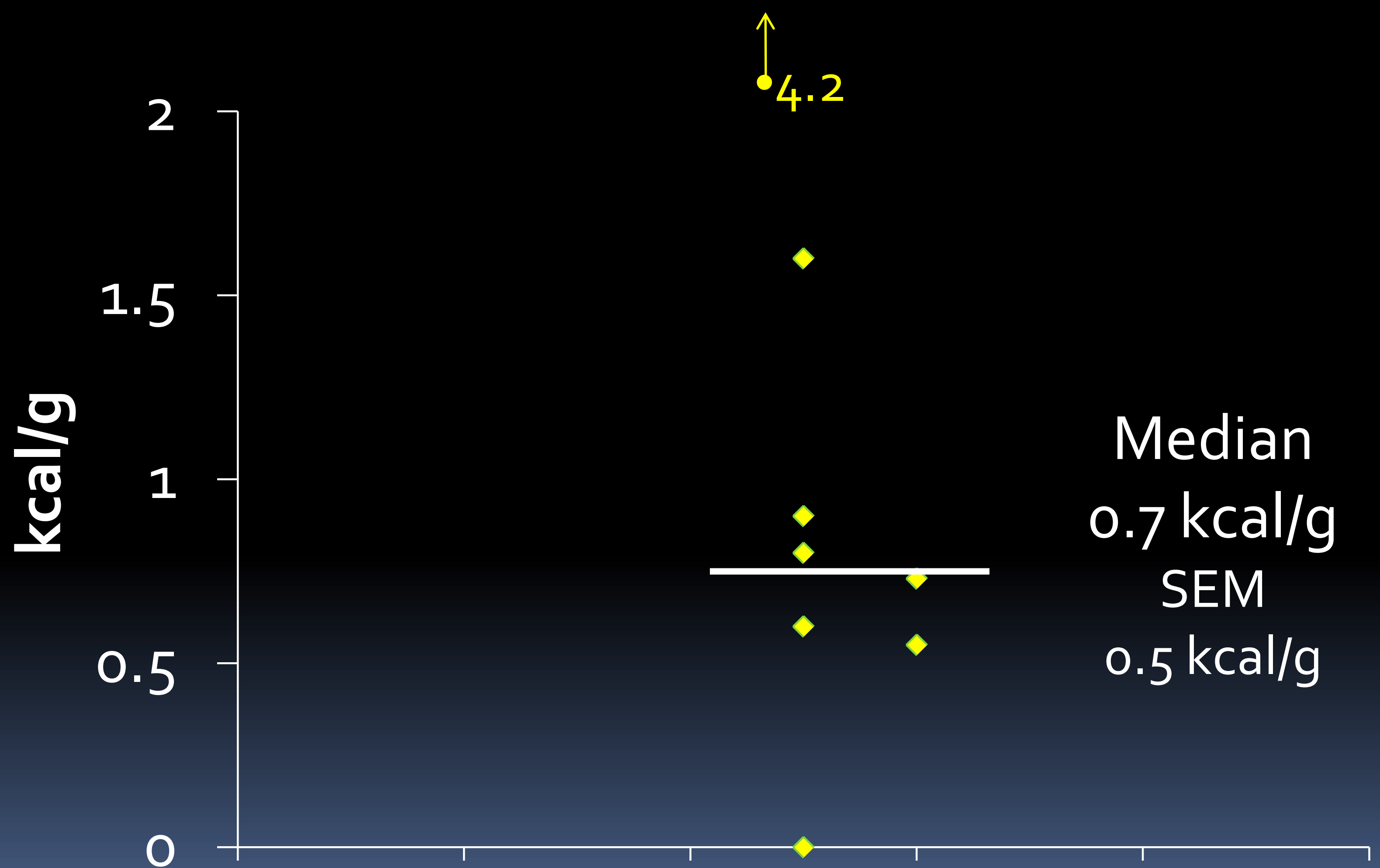
- M:F 4:7
- 42 ±14 y
- 31 ± 1 kg/m²
- Tx
  - 8 wks
  - 600 kcal/d deficit

- Heart failure (excess TBW)
- M:F 3:8
- 54 ±10 y
- 38 ± 5 kg/m²
- Tx
  - 6 wks
  - 600 kcal/d deficit

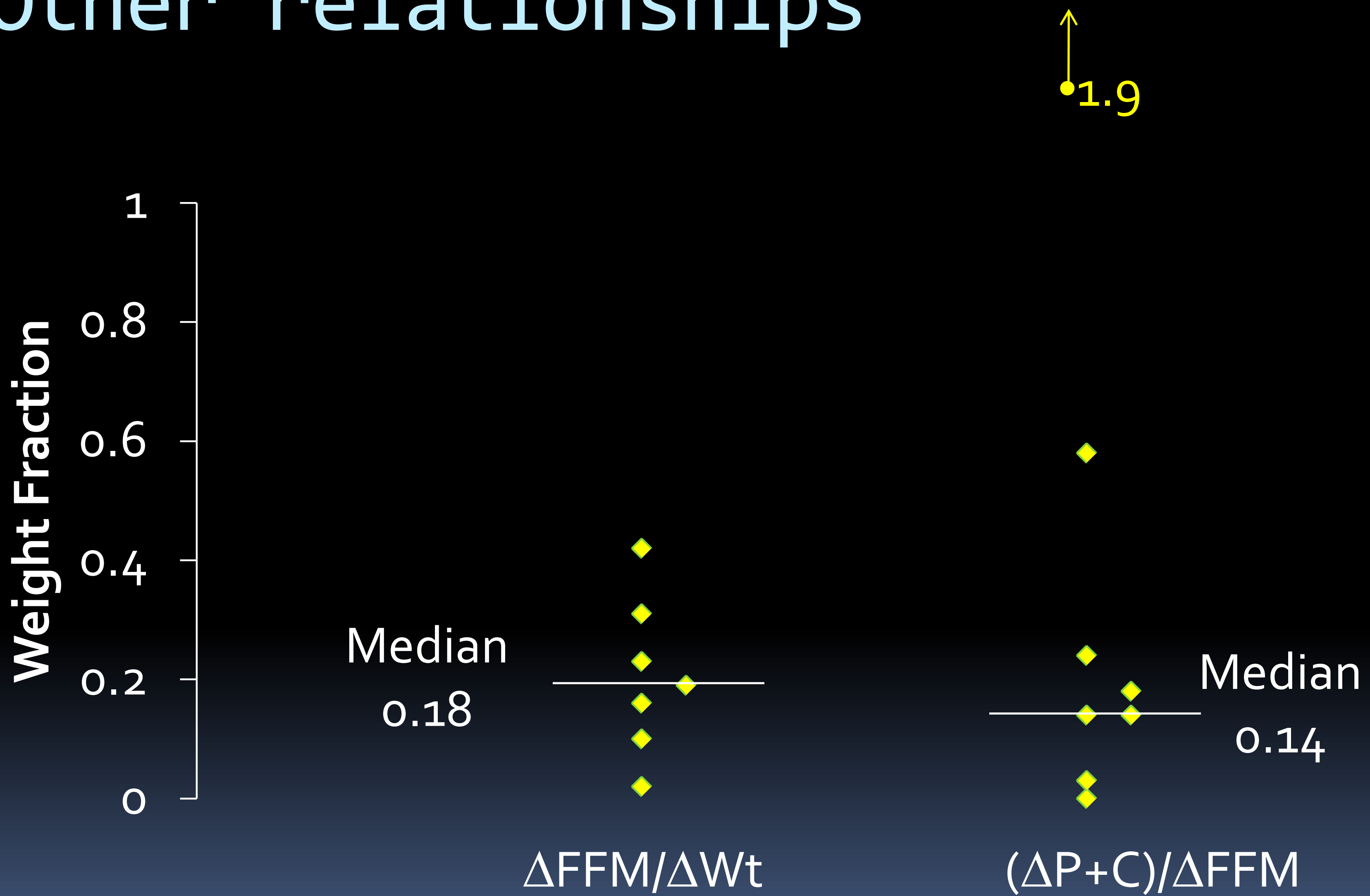
Myint et al, Obesity, 18:391, 2010



Energy Density ΔFAT-FREE MASS



Other relationships



Why so variable?

Problem of propagation of error
and small changes

M/Db = Mtbw/Dtbw + Mtmm/Dtmm
+Mpro/Dpro + Mfm/Dfm

Why so variable?

Problem of propagation of error
and small changes

M/Db = Mtbw/Dtbw + Mtmm/Dtmm
+ Mpro/Dpro + Mfm/Dfm

And Mpro = M – Mtbw – Mtmm - Mfm

Why so variable?

Problem of propagation of error

and small changes

- ΔTBW sd = 0.4kg
- Pro + CHOH
  - Δ 0.4kg/10 kg wt loss,
  - sd = 0.4+kg

  - If n = 100, then SEM = 0.04kg

4C approach cannot detect differences in energy density of ΔFFM without a large n, but the median is meaningful.

Conclusions

- Energy density of FM
  - 9.45 kcal/kg
  - High level of confidence
- Energy density of FFM
  - 1.0 kcal/g
  - High level of confidence in theory
  - Modest level of confidence in practice