

# Energy expenditure in response to energy intake and physical activity

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## Objectives

Does a change in intake affect activity?

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## Background

Energy balance can be maintained by adapting intake to expenditure and vice versa

Key variables are food intake and physical activity

## Model

Total = basal + diet + activity expenditure  
 $TEE = BEE + DEE + AEE$

$DEE = 0.1 EI$  (energy intake)

1 kg weight change = 75% FM + 25% FFM

## Overeating and physical activity

Reference	Subjects	Overfeeding	PAL <sub>baseline</sub> <sup>1)</sup>	PAL <sub>overfeeding</sub>
Roberts et al (1990)	7 males, normal weight	3 weeks + 4.2 MJ	1.85±0.01	1.89±0.04 <sup>1)</sup>
Diaz et al (1992)	9 males, normal/overweight	6 weeks, 150% baseline	1.8±0.2	1.8±0.3 <sup>1)</sup>
Pasquet (1992)	9 males, normal weight	9 weeks, 200% baseline	1.87±0.12	1.45±0.09*
Levine et al (1999)	4 females, 12 males, normal weight	8 weeks + 4.2 MJ/d	1.67±0.21 <sup>2)</sup>	1.90±0.28*
Joosen et al (2005)	7 females, normal weight	2 weeks, 150% baseline	1.78±0.19	1.77±0.21 <sup>1)</sup>
Siervo et al (2008)	6 males, normal weight	9 weeks, 120-160% baseline	1.60	1.65 <sup>1)</sup>

\* Significantly different from baseline (p<0.001).

<sup>1)</sup> Physical activity level, doubly labeled water assessed energy expenditure as a multiple of resting energy expenditure.

<sup>2)</sup> Energy intake as a multiple of resting energy expenditure.

No effect when overfeeding is lower than twice maintenance requirement

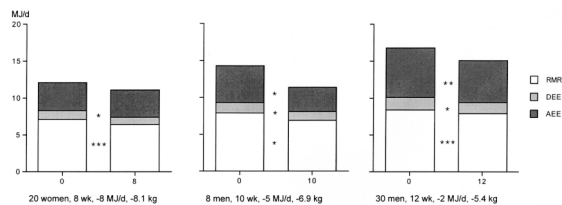
Westerterp. Nutr Rev 2010;68:148-54

## Discussion

Overeating increases total energy expenditure with ~10 % due to:

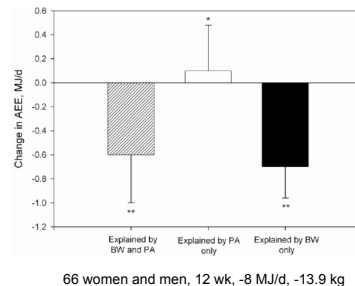
- Increased diet induced energy expenditure
- Storage cost of excess nutrients

## Undereating and physical activity



Kempen et al. Am J Clin Nutr 1995;62:722-9  
 Velthuis-te Wierik et al. Int J Obes 1995;19:318-22  
 Westerterp-Plantenga et al. Am J Clin Nutr 2001;74:426-34

## Undereating and physical activity



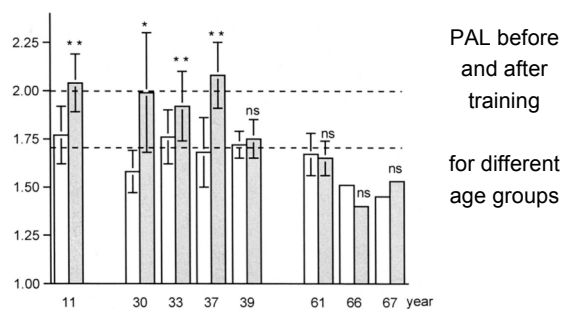
66 women and men, 12 wk, -8 MJ/d, -13.9 kg  
 Subjects can hardly offset the weight loss induced decrease in AEE  
 Bonomi et al. submitted

## Discussion

Undereating decreases total energy expenditure with ~20 % due to:

- Decreased basal energy expenditure
- Decreased diet induced energy expenditure
- A reduction of activity energy expenditure

## Exercise training and activity level



Westerterp & Plasqui Curr Opin Clin Nutr Metab Care 2004;7:607-13

## Exercise training and body weight

Reference	Subjects	Training mode	Δ Expenditure (MJ/d)	Δ Body weight (kg)
Bingham et al (1989)	2 females, 3 males, normal weight	jogging for 9 weeks	+ 2.8*	- 0.9 <sup>ns</sup>
Blaak et al (1992)	10 boys, obese	cycling for 4 weeks	+ 1.3*	+ 0.5 <sup>ns</sup>
Westerterp et al (1992)	5 females, 8 males, normal weight	jogging for 40 weeks	+ 2.3***	- 0.9 <sup>ns</sup>
Van Etten et al (1997)	12 males, normal weight	weight training for 12 weeks	+ 0.8**	- 1.1*

\* P<0.05, \*\*P<0.01, \*\*\*P<0.001, for significant differences with baseline; <sup>ns</sup>, not statistically significant

Exercise induces increased energy intake

Westerterp. Nutr Rev 2010;68:148-54

## Discussion

Exercise training increases energy expenditure, especially in younger subjects with ad libitum intake

Exercise training hardly affects body weight, through a compensatory increase of intake

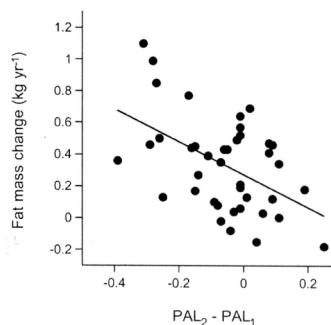
## Reduced physical activity

	Baseline	Follow-up
Age (y)	27±5	39±8***
Body mass index (kg/m <sup>2</sup> )	22.8±2.0	24.3±2.6**
Resting energy expenditure (REE, MJ/d)	6.76±0.98	6.84±1.00
Total energy expenditure (TEE, MJ/d)	12.19±1.82	11.95±1.77
Activity energy expenditure (0.9TEE-REE, MJ/d) <sup>1)</sup>	4.21±1.05	3.92±1.19*
Physical activity level (TEE/REE)	1.81±0.16	1.75±0.11**

<sup>1)</sup> Calculation based on a fixed 10% of TEE for diet induced energy expenditure.  
\* P<0.05; \*\* P<0.01; \*\*\* P<0.001 for difference with baseline (n=40).

Westerterp and Plasqui PLoS ONE 2009;4:e4745

## Reduced physical activity



Westerterp and Plasqui  
PLoS ONE 2009;4:e4745

## Discussion

A change to a more sedentary routine does not induce an equivalent reduction of energy intake

Physically active subjects have an increased risk of fattening

## Discussion

The asymmetric activity response has important consequences for the regulation of energy balance

There is similar evidence for resting metabolic rate

## Conclusions

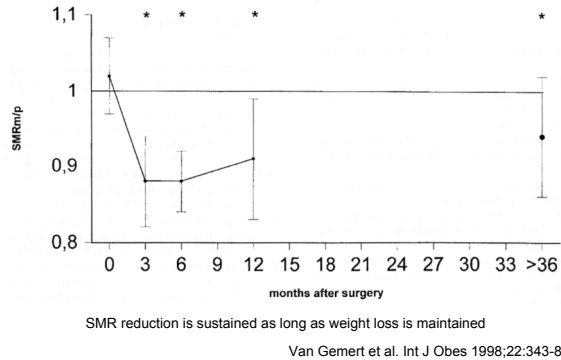
- Overeating does not affect physical activity
- Undereating decreases habitual physical activity
- Exercise induced energy expenditure is compensated by increased intake
- A more sedentary lifestyle does not induce an equivalent reduction of intake

## Resting metabolic rate

Overeating and undereating induce changes in diet induced energy expenditure, being on average 10% of intake

Additionally, basal metabolic rate is affected by undereating

## Measured versus predicted SMR



## Discussion

Eating less induces a reduction of REE

Eating more does not induce an increase in REE

The asymmetric response has consequences for the regulation of energy balance

## Simulation

From energy equilibrium in reference man:

Increasing intake 750 kJ/d induces a weight increase of 1 kg in 40 days

Decreasing intake 750 kJ/d induces a weight decrease of 1 kg in 55 days

## Discussion

It takes 40 days to gain 1 kg and more than 55 days to lose that kg again with a 750 kJ/d intake manipulation as eating less reduces REE and AEE

## Conclusions

It is easier to gain than to lose weight

Preventing weight gain by eating less is most effective