Perspective on the Influence of Physical Activity on Energy Balance

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ILSI at ICN 2013
Energy Balance and Active Living
What is a perspective?

The Energy Expenditure and Food Intake of Individual Men

BY O. G. EDHOLM AND J. G. FLETCHER
Division of Human Physiology, National Institute for Medical Research, London
and Elsie M. Widdowson and R. A. McCance
Medical Research Council Department of Experimental Medicine, University
of Cambridge
(Received 5 February 1955)

What are the effects on food intake of being in an active or sedentary state?

the major activities of mankind. In the surveys so far carried out the time spent sitting has varied from $8\frac{1}{4}$ to $10\frac{3}{4}$ h/day and the time lying down has been of the same order (Table 10). It looks as though man should be regarded now, if not in the past, as predominantly a sedentary rather than an upright animal.
Energy Intake

Energy Expenditure

HOMEOSTASIS and HEDONICS
Health warning: exercise makes you fat

Re-programming body fat is the key to weight loss, not working out, says Richard Gray

Fast is a massive problem. Nearly 60% of the country's adult population is now overweight, while one in five children are obese by the time they start school that their health is destined to be at risk. All told, weight problems are estimated to cost the economy £16 billion a year - on top of the fact that ambulances have to be fitted with reinforced heavy-lifting equipment to get patients into the vehicles and that a growing number of soldiers are too fat to fight.

Yet something strange is going on. While obesity levels have grown year on year, so have levels of physical activity. More people in Britain do the recommended amount of exercise - at least 30 minutes of moderate-intensity activity at least five times a week - than did 12 years ago. Use of personal trainers and gym sessions soared over the past five years, the amount spent on the latter has grown by 56% per year, to more than £1.37 billion. Is it possible that all that exercise is doing nothing to make us thinner?

Exercise is, of course, one way to burn fat, but so that it produces less bad effects, it could get rid of some of the metabolic consequences of obesity, says Prof Tom Kuhn, head of obesity research at Imperial College London. The problem, however, is that exercise is time-consuming and leaves us feeling tired. It also bacteria in the intestine. And that is the main reason why we get fat. The bacteria in the intestine produce energy from fatty acids, and this energy is then used to make us feel full.

Scientists now believe that activating brown fat stores in obese patients - and even increasing their levels of brown fat - could help them to keep their weight down. In particular, Prof Kuhn has discovered that a growth factor called BMP7 can be used to turn stem cells into brown fat. When this was transplanted into mice, the tissue formed discrete islands of brown fat. The team now plans to use the approach on fat from humans.

"If we treat fat that has been removed by liposuction to correct it into brown fat, we could then put it back into patients," says Prof Kuhn. "If you combine this with improved diet and exercise, the effect could be dramatic."

Other groups are also looking at alternative methods to increase the amount of brown fat in obese patients by manipulating cells. Researchers in Australia have found more brown fat mixed in with our muscles - and in experiments with sheep, they have found a hormone that increases muscle temperatures by two and half degrees during and immediately after exercise, on brown fat stores are attenuated.

Prof lain Clarke, from the Department of Physiology at Monash University in Melbourne, Australia, believes that while brown fat may be responsible for some of the weight gain in human beings, the muscle cells themselves may also provide a way of burning off extra calories. His group has found they are able to manipulate...
Perspective

• The media is fascinated by prediction. Prediction is difficult – particularly when it is about the future!

• Regarding obesity and energy balance, we have difficulty predicting the past. No consensus whether obesity caused by too much EI or too little EE!

• We are therefore trying to gain understanding in an environment of great uncertainty.

• We have ample information – too much!; we lack knowledge.

• The gap between what we know and what we think we know is increasing (Silver, 2012)
Systematic reviews

• Cochrane review:.. ‘exercise has a positive effect on body weight and cardiovascular risk factors in people with overweight and obesity, particularly when combined with a diet (Shaw et al, 2006)

• …for people starting an exercise programme, this leads to ‘a negative energy balance and a remarkably consistent loss of body fat in relation to the net cost of exercise training’ (Elder and Roberts, 2007).

Summary statements not spectacular, but they are positive
INTERACTION BETWEEN PHYSICAL ACTIVITY, APPETITE and BODY WEIGHT
INTERACTION BETWEEN AMOUNT OF PHYSICAL ACTIVITY and BODY WEIGHT

(Jakicic, 2008)

Figure 3. Percentage weight loss by physical activity categories (minutes per week) (n=170).

Figure 4. Percentage weight loss by physical activity categories (kilocalories per week) (n=170).
Extended perspective

Fast food and sedentary lifestyle: a combination that leads to obesity\textsuperscript{1,2}

David R Jacobs Jr

The late Henry L Taylor favored a model that linked energy intake to energy expenditure in a J-shaped curve (personal communication, late 1970s). The first part of his concept was that energy intake is in exact homeostasis with energy expenditure under conditions of high energy expenditure. The second part was that there is a failure of homeostasis in a sedentary lifestyle because of its accompanying low energy expenditure. He postulated that body signals go awry in sedentary lifestyles; when a person does no physical work, the body will not recognize that it is being overfed. Sedentary persons may lose the innate ability to compensate for inactivity by reducing their eating. Neither Bes-
DRAWS ATTENTION TO THE IMPLICATIONS FOR FOOD INTAKE OF BEING IN AN ACTIVE OR SEDENTARY STATE
## REACTIV Programme: Comparing active and sedentary people

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<th>Mean</th>
<th>SD</th>
<th>P</th>
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<td><strong>Age</strong></td>
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<tr>
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<td>21.1</td>
<td>1.6</td>
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<td>23.3</td>
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<th><strong>Weight (kg)</strong></th>
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<tr>
<td>Active (A)</td>
<td>77.6</td>
<td>8.0</td>
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<td>Sedentary (SED)</td>
<td>73.6</td>
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<th><strong>BMI (kg/m²)</strong></th>
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<td>Active (A)</td>
<td>22.8</td>
<td>2.4</td>
<td>0.871</td>
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<td>Sedentary (SED)</td>
<td>22.9</td>
<td>2.3</td>
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<tr>
<th><strong>%FM</strong></th>
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<td>Active (A)</td>
<td>8.6</td>
<td>3.9</td>
<td>0.004</td>
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<td>Active (A)</td>
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<td>3.0</td>
<td>0.008</td>
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<td>Sedentary (SED)</td>
<td>13.6</td>
<td>7.9</td>
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<th><strong>FFM (kg)</strong></th>
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<tr>
<td>Active (A)</td>
<td>71.0</td>
<td>8.7</td>
<td>&lt;0.0001</td>
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<td>Sedentary (SED)</td>
<td>59.9</td>
<td>3.4</td>
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<th><strong>RMR (kcal)</strong></th>
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<td>Active (A)</td>
<td>2050.1</td>
<td>264.9</td>
<td>0.009</td>
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<tr>
<td>Sedentary (SED)</td>
<td>1764.9</td>
<td>219.2</td>
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What happens when people change state?

• Initially Sedentary (EE) and become Active (EE) – what happens to EI?

• Initially Active (EE) and become Sedentary (EE) – what happens to EI?
Acute (single day) studies

• El not responsive to enforced inactivity (over 2 days)

• Little or no compensation

• Need to be active to avoid positive energy balance on HF diet
Beyond acute studies: extended period of raised daily activity (DLW to measure daily EE)

- 6 men and 6 women
- Days 1 – 2 maintenance
- Days 3 to 16 – activity requirements
- Nex (no additional activity)
- Mex (28.6 kJ/kg/day) approx 2.0 MJ/day
- Hex (57.1 kJ/kg/day) approx 4.0 MJ/day
## RESULTS

<table>
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<tr>
<th></th>
<th>EE (MJ/day)</th>
<th>EI (MJ/day)</th>
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<tr>
<td><strong>MEN</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>nex</td>
<td>12.2</td>
<td>10.6</td>
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<tr>
<td>mex</td>
<td>14.0</td>
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<tr>
<td>hex</td>
<td>16.7</td>
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<tr>
<td><strong>WOMEN</strong></td>
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<tr>
<td>nex</td>
<td>9.2</td>
<td>8.3</td>
</tr>
<tr>
<td>mex</td>
<td>11.6</td>
<td>8.6</td>
</tr>
<tr>
<td>hex</td>
<td>13.7</td>
<td>9.9</td>
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OUTCOME

• Prolonging the period of raised activity induces changes in food intake
• 30% increase in EI for increased EE
• Men – 29%, women – 31%

• Large Individual differences emerging:
  • Compensators – 56% of EE by EI
  • Non-compensators – 0%
Strength of the systems approach lies in its capacity to integrate variables that otherwise would be isolated from each other.
12 week aerobic exercise program

• 5 exercise sessions per week
  – ~ 500 kcal per session
  – 70% HR max
  – Overweight/obese Ss: mean BMI 31.7
• PA Supervised and measured
• Food intake measured objectively in intensive Probe Days

• Evaluate relationship between variables in the sedentary state (week 0) and after a period increased energy expenditure (week 12)
Study Procedure

12 week aerobic exercise

- Probe Day 1: High Fat Exposure
- Probe Day 2: Low Fat Exposure
- Probe Day 3: Low Fat Exposure
- Probe Day 4: High Fat Exposure
- Probe Day 5: High Fat Exposure
- Probe Day 6: Low Fat Exposure

Subjects:
- Main group: Overwt & obese
- 12 wk exercise

Multilevel analysis
- Total within-day energy intake (probe days)
- Appetite sensations
- Hedonics: food liking and implicit wanting
- Eating behaviour traits
- GI biomarkers (wk0 & 12)
- Resting metabolism and substrate oxidation
- Body composition (FM and FFM)
# RESULTS: Body Composition

<table>
<thead>
<tr>
<th>Variable</th>
<th>Week 0</th>
<th>Week 12</th>
<th>Change</th>
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<tbody>
<tr>
<td><strong>Body Mass (kg)</strong></td>
<td>90.9 ± 12.1</td>
<td>87.6 ± 12.4</td>
<td>-3.3 *</td>
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<tr>
<td><strong>Absolute Fat Mass (kg)</strong></td>
<td>31.9 ± 9.4</td>
<td>28.6 ± 9.8.</td>
<td>-3.3 *</td>
</tr>
<tr>
<td><strong>Fat Mass (%)</strong></td>
<td>34.8 ± 7.8</td>
<td>31.9 ± 8.4</td>
<td>-2.1 *</td>
</tr>
<tr>
<td><strong>Waist Circumference (cm)</strong></td>
<td>101.5 12.4</td>
<td>96.5 11.8</td>
<td>-5.0 *</td>
</tr>
<tr>
<td><strong>Lean Mass (kg)</strong></td>
<td>59.2 ± 9.5</td>
<td>59.2 ± 10.7</td>
<td>0.0 ± 2.8</td>
</tr>
</tbody>
</table>

*Significant difference between week 0 & week 12 (P< 0.01)*
Individual Variation in BW & FM Following 12 Weeks of Exercise

Range

Body Mass (kg): -14.7 to +2.0 kg

Fat mass (kg): -10.3 to +2.6 kg

Change in BW & FM (kg)

(King et al IJO 2008; AJCN 2009)
• The average is an abstraction. Reality is variation.

• Blastland and Dilnot (2005) The Tiger that isn’t.
• Silver (2012) The Science of Prediction
• Blastland and Siegenhalter (2013) The Norm Chronicles
**Daily Energy Intake**

NR have a significant increase in EI (Wk0 – Wk12; p<0.005)
*Increased drive to eat measured by Hunger AUC
*Increase in satiety measured by Satiety Quotient (SQ)

HUNGER IS AN IMPORTANT SENSATION – A RISK FACTOR FOR EATING

HUNGER IS A BIOMARKER OF THE INTENTION OR WILLINGNESS TO EAT
NR have a significant increase in hunger ($P = 0.002$)

**AUC Hunger (AUC)**

Week 0

Week 12

Responders

Non Responders

NR have a significant increase in hunger ($P = 0.002$)
FIGURE 1—Changes in anthropometric variables from week 0 to week 12 for overweight and obese males and females (mean ± SEM).
Body composition and appetite: fat-free mass (but not fat mass or BMI) is positively associated with self-determined meal size and daily energy intake in humans

John E. Blundell¹*, Phillipa Caudwell¹, Catherine Gibbons¹, Mark Hopkins², Erik Naslund³, Neil A. King⁴ and Graham Finlayson¹
FFM Predicts Energy Intake Independent of Type of Food Consumed

Independent observations of FFM and energy intake demonstrated a significant positive relationship whether dietary fat content was high (>50% energy) or low (<25% energy)
FFM and not FM influenced within-day profile of hunger and fullness sensations

Figure shows sensations of Hunger (left) and Fullness (right) during the probe days as a function of Fat Free Mass.
Resting metabolic rate is associated with hunger, self-determined meal size, and daily energy intake and may represent a marker for appetite\textsuperscript{1-3}. 

Phillipa Caudwell, Graham Finlayson, Catherine Gibbons, Mark Hopkins, Neil King, Erik Näslund, and John E Blundell

\textbf{Interpretation: Resting Metabolic Rate is a Driver of Meal Size and Daily Energy Intake}
Body composition and energy expenditure predict *ad-libitum* food and macronutrient intake in humans

CM Weise, MG Hohenadel, J Krakoff and SB Votruba
Signals from adipose tissue

Influence from FFM and RMR

Signals from GI tract
BODY COMPOSITION
Tonic appetite signals

ENERGY BALANCE

ENERGY INTAKE

Tonic inhibition of energy intake

Fat-Free Mass

Fat Mass

Leptin and other adipokines

Resting Metabolic Rate

Energy demand and drive to eat

CKK, PYY, GLP-1

Gastrointestinal Tract
Episodic appetite signals

Exercise
Acute and long-term effects

Appetite stimulating hormones

Appetite inhibiting hormones

Ghrelin

Energy expenditure

Energy intake

Energy expenditure
Dual process of appetite control

- Changes in orexigenic drive and changes in satiety
- It is the combined strength of these processes that will determine the level of compensatory eating and weight loss.
How to think about this?

• In examining the effect of physical activity on body weight you cannot simply add up the number of kcal expended and perform a conversion to weight change.

• PA changes the components of physiological system that mediates appetite control.

• This contains the core of the explanation for adaptation

• ............and is one perspective on the influence of PA on Energy balance
Regulated zone

Non-regulated zone

Becoming sedentary does not downregulate food intake

Increasing physical activity improves satiety signalling.

Improves body composition

Blundell, 2011 Nut Bull
Changes in health markers are independent of changes in body weight.
CHARACTERISTICS OF WEIGHT GAINERS

Exercise makes you LEAN, not fat.
Rate and extent of compensatory changes in energy intake and expenditure in response to altered exercise and diet composition in humans

R. J. Stubbs, D. A. Hughes, A. M. Johnstone, S. Whybrow, G. W. Horgan, N. King, and J. Blundell

The effect of an incremental increase in exercise on appetite, eating behaviour, and energy balance in lean men and women feeding ad libitum

Stephen Whybrow, Darren A. Hughes, Patrick Ritz, Alexandra M. Johnstone, Graham W. Horgan, Neil King, John E. Blundell, and R. James Stubbs

Body composition and appetite: fat-free mass (but not fat mass or BMI) is positively associated with self-determined meal size and daily energy intake in humans

John E. Blundell, Phillipa Caudwell, Catherine Gibbons, Mark Hopkins, Erik Naslund, Neil A. King, and Graham Finlayson

Comparison of Postprandial Profiles of Ghrelin, Active GLP-1, and Total PYY to Meals Varying in Fat and Carbohydrate and Their Association With Hunger and the Phases of Satiety

Catherine Gibbons, Phillipa Caudwell, Graham Finlayson, Domir Per M. Hellström, Erik Näslund, and John E. Blundell

A decrease in physical activity affects appetite, energy, and nutrient balance in lean men feeding ad libitum

R James Stubbs, Darren A Hughes, Alexandra M Johnstone, Graham W Horgan, Neil King, and John E Blundell

Dual process action of exercise on appetite control: increase in orexigenic drive but improvement in meal-induced satiety

Neil A King, Phillipa P Caudwell, Mark Hopkins, James R Stubbs, Erik Naslund, and John E Blundell
BBSRC 2\textsuperscript{nd} cohort

![Diagram showing change in body composition (kg)]

- Change BM
- Change FM
BioPsychology: Energy Balance and Appetite Group
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Dr Phillipa Caudwell
Dr Catherine Gibbons
Mark Hopkins (Trinity College, Leeds)

Prof Erik Naslund (Karolinska)
Prof Neil King (QUT, Brisbane)
Dr James Stubbs (Slimming World)