Physics and physiology of obesity: higher rate of energy input than output. Comment on “The carbohydrate–insulin model: a physiological perspective on the obesity pandemic”


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Letter to the Editor, American Journal of Clinical Nutrition

Physics and physiology of obesity: higher rate of energy input than output. Comment on DS Ludwig et al.

David S. Ludwig and co-authors (1) provide a physiological perspective on the epidemic of obesity by comparing their carbohydrate-insulin model (CIM) with commonly held views based on what they call the energy balance model (EBM). They characterise EBM as the restatement of a principle of physics that fails to consider the biological mechanisms of weight gain. The CIM attributes increased body energy content to hormonal responses to high-carbohydrate diets that increase the deposition of fat.

Their account of both models is fundamentally flawed. First, physics does not state that body energy gain comes from an accumulation of the amount of energy intake exceeding the amount expended. Second, there are no clear physiological mechanisms by which increased fat deposition could drive weight gain.

Thermodynamics concerns the rates (MJ/day) of exchange of energy between the body and the environment, not an imbalance of amounts of energy (MJ) in and out. “Balance” is simply constancy at zero difference: it cannot be “positive” or “negative”. The implication of the law of conservation of energy (without interconversion of energy and mass) is that an object’s energy content must increase while the average rate of energy input persistently exceeds the average rate of energy output.

Further to the physics, neither CIM nor EBM as stated here allows for the adaptation of basal metabolic rate or thermic effect of assimilation by the minority change in fat-free mass during a change in body weight (2,3). A maintained change in rate of the ingestion of energy and/or of expenditure in physical activity or cooling results in a step change in weight.

Contrary to the longstanding assumption, there is not a cumulative effect on body weight of
the intake of greater amounts of energy than is spent in physical activity. Physiological, social
and behavioral research on obesity should focus on the causes and consequences of sustained
changes in rates of energy exchange, measured as intervals between occurrences of repeated
patterns of ingestion, physical activity and thermal behavior (4,5).

The evidence that lower carbohydrate, higher fat diets increase energy expenditure is
equivocal, according to Ludwig and colleagues elsewhere (6) and an earlier re-analysis (7). In
this review, they cite no further data on physiological mechanisms whereby carbohydrate-
insulin effects might fatten by lowering the rate of energy expenditure; they refer only to
other theoretical statements of CIM.

The evidence cited here that insulin levels or increased fat content of adipose tissue raise
energy intake is dubious at best. The blood glucose dip that can trigger requests for food is so
transient that it is likely an epiphenomenon of switching from glycogen deposition to
glycogenolysis or similar as absorption slows (cp. 8). Reports of hunger during abnormally
low cellular supply of glucose provide little basis for an epidemic of obesity. Other references
are to theoretical suggestions based on fragmentary data from experimental animals.

From a wider biological perspective, advocates of the CIM need to take account of the
evidence that most people for millennia have been living on high-carbohydrate diets –
namely, starch from cultivated grains in the last 8-12,000 years and from wild roots, tubers
and grasses for over 100,000 years (9). In contrast, the prevalence of obesity has reached
epidemic proportions in recent decades only. That timing is much closer to the switching to
deskwork from young adulthood and the wide distribution of portable foods, made safe by
drying or the incorporation of salt, fat and/or sugar as expected by eaters.

1. Ludwig DS, Aronne LJ, Astrup A, de Cabo R, Cantley LC, Friedman MI, Heymsfield SB,


5. Laguna-Camacho A, Booth DA. Measurement of weight change after change in frequency of a locally recognised habit. How much weight is lost while one higher-protein breakfast more is eaten per week? PsyArXiv 2021; osf.io/kcetd


Authors DAB and ELG declare that neither has a conflict of interest.

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