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Estimating my equilibrium energy intake during lockdown: very introspective study

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Additional material is published online only. To view please visit the journal online.

Cite this as: *BMJ* 2020;371:m4561
<http://dx.doi.org/10.1136/bmj.m4561>

Accepted: 12 November 2020

ABSTRACT

OBJECTIVE

To estimate the daily dietary energy intake for me to maintain a constant body weight. How hard can it be?

DESIGN

Very introspective study.

SETTING

At home. In lockdown. (Except every Tuesday afternoon and Saturday morning, when I went for a run.)

PARTICIPANTS

Me. n=1.

MAIN OUTCOME MEASURES

My weight, measured each day.

RESULTS

Sleeping, I shed about a kilogram each night (1.07 (SD 0.25) kg). Running 5 km, I shed about half a kilogram (0.57 (SD 0.15) kg). My daily equilibrium energy intake is about 10 000 kJ (10 286 (SD 201) kJ). Every kJ above (or below) 10 000 kJ adds (or subtracts) about 40 mg (35.4 (SD 3.2) mg).

CONCLUSIONS

Body weight data show persistent variability, even when the screws of control are tightened and tightened.

Introduction: naive and kicking

Trust me, I'm a physicist. Not a physician. Mass and energy are my stock in trade. My research question was simple enough: what energy input do I need to maintain my mass (hereafter referred to as weight)? The answer should be equally simple to look up. But, just as when you ask three economists a question and get four answers, there are more answers than questions when it comes to dietary intake. I might need as few as 7950 kJ or as many as 10 878 kJ per day.¹⁻⁶ But I want more precision than that; I'm a physicist. So, I turned to the tried-and-tested path of self-experimentation⁷ (while appreciating that it may be worse than worthless⁸).

Methods: a balancing act

My underlying assumption was energy balance. Food supplies energy. Activity uses energy. If more energy is supplied than is used, then body weight goes up, and vice versa. My goal was to find the sweet spot (mostly avoiding sweets) where energy in equals energy out. I knew there was more to it than that. I knew, for example, that I could gain 1 kg in an instant with very little effort and no calories by drinking a litre of water. But I assumed that, over time, surplus water would be expelled from my body, and my base state of hydration maintained, with no net weight gain due to water. I assumed that water found its own level.

Back to the food. To measure its energy content, a calorimeter would be ideal,⁹ but this was not practical. Instead, I found the energy density from the food packaging or, if unpackaged, from the web.⁶ I measured food portions to the nearest gram on kitchen scales. Multiplying the energy density by the mass gave the energy content. Several factors enhanced the regularity of my energy input. Firstly, undertaking the study during coronavirus disease 2019 (covid-19) isolation meant that unknown quantities of unknown foods—such as from working lunches, dinner parties, or restaurant meals^{9 10}—were eschewed rather than chewed. The identity of every food was known, the amount of every food was audited. Secondly, the proportion of different foods in my diet was largely the same every day. Each morning, for example, I ate cereal. Thus, even if the absolute energy content for the cereal was incorrect, that contribution remained consistent across the study. Thirdly, changing the energy intake was largely achieved by varying the amounts of the same foods, rather than by introducing new foods.

I did not explicitly measure my activity, but it was kept at much the same level from day to day. Again, lockdown promoted regularity. Each day was the same: get up, weigh myself, check emails, eat breakfast, Zoom, eat elevenses, Zoom, eat lunch, Zoom, time for a little nap, Zoom, eat dinner, and so to bed. The only exceptions were Tuesday evening and Saturday morning, when I ran 5 km. I weighed myself on bathroom scales. My reference weight was that measured in the morning, immediately after waking, undressing, and urinating.

In summary, the experimental design was to systematically control my energy intake (independent variable: food) and measure the response (dependent variable: body weight) while holding the energy out (activity) as constant as possible and ignoring everything else.

Of course, energy balance studies have been pursued for a long time and have been performed more rigorously, monitoring every ounce of solid and liquid

WHAT IS ALREADY KNOWN ON THIS TOPIC

People like me need to take in between 7000 and 11 000 kJ each day to maintain their body weight

WHAT THIS STUDY ADDS

Determining maintenance energy intake is challenging, even during lockdown, when there are no work lunches, no skipped meals, no dinner parties, no restaurants, and the same old same old routine day in day out

Step changes in dietary intake—even steep steps—are not reflected in step changes in body weight

A simple model accounts for the data and allows an estimation of the equilibrium energy intake even in the face of substantial fluctuations in body weight hour by hour and day by day

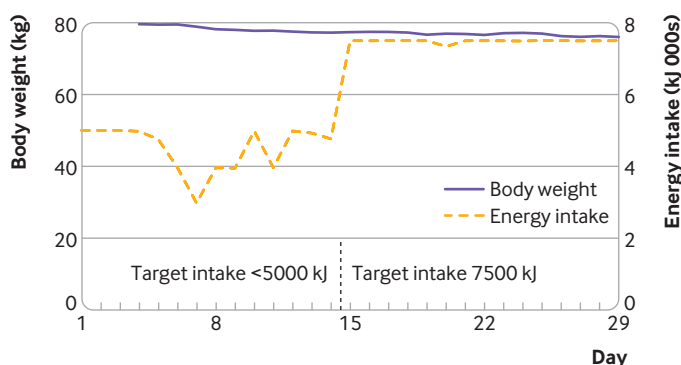


Fig 1 | Body weight and energy intake, beginning with a daily energy intake of under 5000 kJ for 14 days, then jumping to approximately 7500 kJ for 15 days. Note that a greater than 50% step increase in intake produces a negligible proportional change in weight

and gas taken in and expelled and every iota of work done. As reported as long ago as 1897, A W Smith, a physicist, was locked in a “respiration chamber” 7 feet long, 4 feet wide, and 6 1/3 feet high for 12 days.¹¹ Now that’s isolation.

Results

Step 1

The plan was this, metaphorically: take the foot off the accelerator (reduce energy intake), wait until the car slows down (weight is being lost), then gradually depress the accelerator (systematically increase energy intake) until a steady speed is reached (steady weight; equilibrium intake realised). Detailed data are provided in the figures and the supplementary table; in the text I provide a descriptive narrative. Step 1 was to eat less¹² to lose weight.¹³ To err on the safe side, I began below 5000 kJ per day. My weight dropped from 79.61 kg to 77.38 kg in 11 days. Surprising to me, my weight loss was not uniform from day to day. Even more surprising to me, on three of the 11 days, my weight increased rather than decreased. In retrospect, this was the first hint of the ominous ogre of weight variability, the role of which is to confound experiments, even when control is attempted.

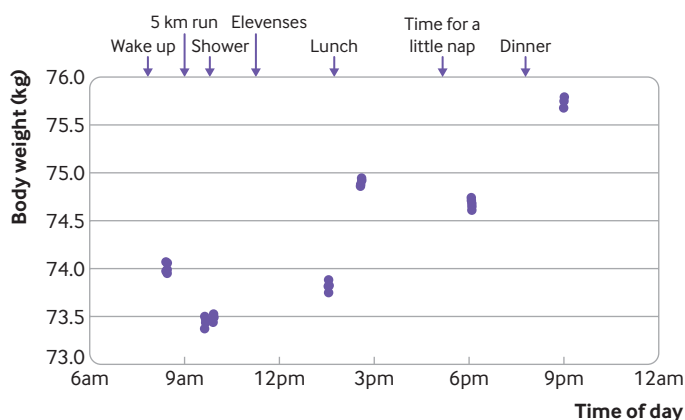


Fig 2 | Body weight measured across one day, with seven life events indicated. Five measurements were made on each occasion, demonstrating good scale reproducibility. Body weight fluctuated by more than 2 kg over the course of a single day

Step 2

Now it was time to increase energy intake, slow weight loss, and reach a steady weight. But how hard should I press on the accelerator? I didn’t want to overshoot and start gaining weight. I thought it would be safe to try 7500 kJ per day, less than any of the authorities suggested.¹⁻⁶ So, I did that for a few days. There was little change in my weight trajectory (fig 1). So, I tried it for a week. Still not much to see. So, I persisted for a second week. This was harder than I thought.

Surprisingly, a substantial proportional change in energy intake (an increase of >50%, from <5000 kJ to 7500 kJ) produced a negligible proportional change in weight (80 kg to 76 kg, 5% change). More surprising, the abrupt step in energy intake did not result in any discernible step change in weight. Sadly, it seemed that my steady state weight was not yet reached, my weight kept drifting down, so further steps would have to be taken.

Steps 3, 4, 5, and 6

On day 30, I made a small increase to 8000 kJ per day and stuck at that for two weeks. I must be getting close to equilibrium, I thought, and didn’t want to overshoot; but the weight data seemed to be trending down still. So, I made another baby step to 8500 kJ (close to the recommended intake of 8700 kJ). Still, my weight seemed to be dropping. Eight weeks on this project with no answer. Time to take a bigger step—I don’t have all year for this—up to 9500 kJ for two weeks. My weight might be going up or going down or staying the same. Who knows? Then a fortnight at 10 500 kJ. Same.

Step 7

I was getting desperate. I increased my intake to 11 500 kJ. Why weren’t the data clearly showing whether I was losing or gaining weight? I started weighing myself twice a day, morning and night, to see if this gave more systematic data. In desperation, I weighed myself 30 times one day, and even more the next.

On 6 June 2020 (day 88) I weighed myself five times in quick succession at seven time points throughout the day, 35 measurements in all (fig 2). The bathroom scale fluctuated a little, but it was not the main source of the variability—it looks like the life events were. Across this particular day, my weight varied by more than 2 kg. This revealed a challenge: large intra-day fluctuations not directly related to dietary intake. I had tried to factor this out by measuring at the same time and in the same state each day but had not appreciated how big the intra-day fluctuations were relative to the inter-day change I was hoping to measure.

Some activities occurred regularly on a weekly basis (running on Tuesday and Saturday, tuna bake on Sunday night), which is why I stayed on each energy step for a multiple of one week. (I had noticed a weekly pattern of lower weight on Wednesday and Sunday, following the runs.) So, I calculated moving averages over seven days and over the 14 days of each dietary step, but even with this refinement it was still not clear if my weight was going up.

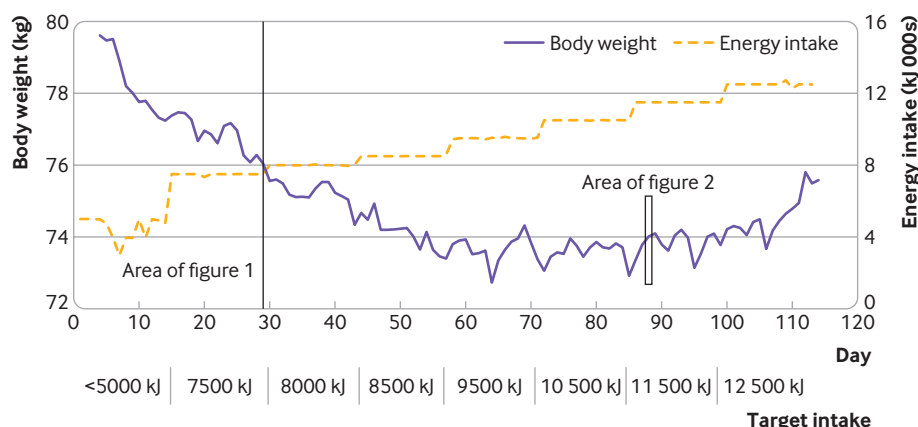


Fig 3 | Daily reference body weight measured first thing every morning over 16 weeks and daily energy intake over the same period

Eat. Run. Sleep. Repeat

These intra-day variations stimulated a closer look at some systematics. I found that my weight loss during a 5 km run averaged 0.57 (SD 0.15) kg. This equates to about a kilogram per hour and about a kilogram per 10 km. I found that the weight lost between going to sleep and waking up averaged 1.07 (SD 0.25) kg.

Day after day, day after day: baked beans

What more could I do? I had been on a fixed energy intake, but from a menu which varied (slightly) from day to day. I decided to remove even that variability. I decided to have exactly the same food every day. This was tough. The baked beans, in particular, proved hard to swallow, day in, day out. My admiration grew for physicist A W Smith who managed 120 g of baked beans a day for 12 days straight.¹¹ Yet my weight data looked no less variable, so I did not persist beyond seven days. Then, after a final fling at 12 500 kJ, I pulled the plug on the experiment, conceding defeat.

Discussion: retrospection

The daily data taken as a whole (fig 3) seem to show that weight was lost at a daily energy intake of 7500 kJ and gained at 12 500 kJ, suggesting an equilibrium

daily intake of $(10\,000 \pm 2500)$ kJ. Is that all that can be concluded after 114 days of self-imposed, self-disciplined self-experimentation?

Weight, there's more. This might be modelled mathematically¹⁴⁻¹⁶; being a physicist, that's what I would try. The simplest model I could conceive had two parameters: the daily equilibrium energy intake—the holy grail of this investigation—and the rate at which excessive energy intake adds weight. Weight and energy intake on one day then predict weight on the next day. Playing with these two parameters, the best fit to the data was for an equilibrium intake of 10 286 kJ per day, with 35.38 mg of body weight added per kJ in excess of this, and vice versa (fig 4). This intake, 10 286 kJ, is within the range of reference values,¹⁻⁶ within my estimate of $10\,000 \pm 2500$ kJ (fig 3), and about what my spouse thought before the whole thing began.

Bonus

As a bonus, I obtained the answer to a question I did not originally ask: by how much does my weight change if I take in more energy than required for weight maintenance? For me, the answer was about 35 mg/kJ and, inversely, 28 MJ/kg.¹⁷ So, an extra apple a day¹⁸ (148 kJ) will add about 5 g to my weight, or about 2 kg over a year.

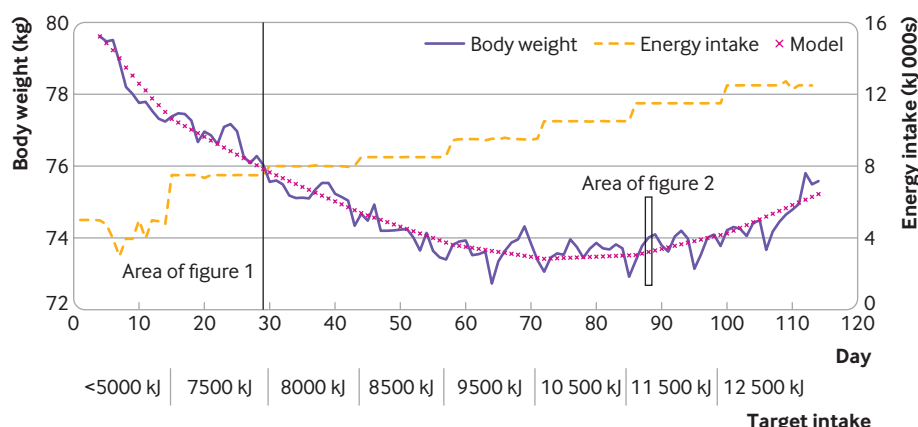


Fig 4 | Daily reference body weight measured first thing every morning over 16 weeks and daily energy intake over the same period with a model of 10 286 kJ equilibrium intake and ± 35.38 mg per kJ superimposed

Were I not to eat at all, my weight would reduce by the product of 10 286 kJ and 35.38 mg/kJ, namely 364 g per day or about 2.5 kg per week. At the start of the experiment I was about halfway between eating nothing at all and my equilibrium intake and so losing about 2.5 kg per fortnight (fig 1). This came as a surprise to me, as my gut feeling had been that my equilibrium intake would be below the recommended 8700 kJ per day.

Finale

The limitations are pretty much those of a previous study.¹⁹ Overall, I am happy with these outcomes, but would rather be 1.07 (SD 0.25) kg lighter. And so to bed.

The author thanks Sophie Cassidy for suggesting this publication outlet.

Contributors: RAL had the original idea, weighed the food, ate the food, weighed the body, ran, weighed the body, slept, weighed the body, analysed the data, made the model, interpreted the results, wrote the first draft, and wrote the nth draft. The author had full access to the data and can take responsibility for the integrity of the data and the accuracy of the data analysis. The corresponding author attests that all listed authors meet authorship criteria, and no others meeting the criteria have been omitted. The author acts as guarantor.

Funding: None.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: Not required.

Data sharing: Data are available from the author.

RAL affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained.

Provenance and peer review: Not commissioned; externally peer reviewed.

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Supplementary information: Daily data