Scientific Advisory Committee on Nutrition

For comment:

Agenda Item: 5

A method for linking changes in body weight to changes in energy balance; the dose response function

The Government have set a PSA target *to halt the year on year rise in obesity among children under 11 by 2010 in the context of a broader strategy to tackle obesity in the population as a whole.*

DH is estimating the impact of interventions and policies currently being undertaken and planned in order to achieve the target and need a method of quantifying the impact of different policies on the target. In particular, to estimate the effect of given changes in energy balance on bodyweight and the timescale over which these changes have their effect. For this purpose we have developed a "dose response function" together with a time trajectory.

> Members are requested are to comment on the "dose-response function" particularly on the methodology and its application.

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A method for linking changes in body weight to changes in energy balance; the dose response function

FAO/WHO/UN publication "Human energy requirements"[1] sets out the determinants of energy expenditure in children and adolescents. Energy expenditure depends on basal metabolic rate (BMR), physical activity level (PAL), and growth. BMR is the energy used at rest. It is partly constant and partly proportional to weight. PAL depends on the mix of activities of different intensity undertaken within a given period, their "physical activity ratio" (PAR), and the proportion of time spent in each. It is proportional to the BMR and in this way creates another link between body weight and energy output. In children and adolescents growth contributes about 1% on top of other energy requirements and can be neglected for most purposes.

There are lists of the PARs of different activities, e.g. in the COMA report on dietary reference values[2].

The relationship between energy output, weight and physical activity level can be expressed as follows:

$$K = (\alpha + \beta W)\,p$$

K – daily calorie expenditure kcal; W – weight kg; $(\alpha + \beta W)$ – BMR; p – PAL.

In steady state calorie output is equal to calorie intake. Following the Cutler, Glaeser, Shapiro paper[3], to calculate the effect of calories on weight we solve for W:

$$W = \frac{K - \alpha p}{p\beta}$$

In a typical boy 7-10, α = 504 calorie, β = 22.7, p = 1.56[4]. The average daily calorie intake (from NDNS) is 1785. These figures imply a weight of 28.2kg. The actual average in NDNS is 30 kg. However, the PAL of 1.56 relates to 1991, whereas NDNS relates to 2000. It is quite possible that PAL was lower in 2000. The PAL would only have to fall to 1.5 to deliver a weight of 30 kg.

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[1] ftp://ftp.fao.org/docrep/fao/007/y5686e/y5686e00.pdf

[2] Dietary reference values for food energy and nutrients in the United Kingdom. Report of the panel on dietary reference values of the Committee on Medical Aspects of Food Policy. Report on Health and Social Subjects 41. Department of Health. 1991.

[3] Cutler DM, Glaeser EL, Shapiro JM. Why have Americans become more obese? J Econ Perspectives 2003;17:93-118.

[4] 10 year old boy from COMA DRV table 2.4

As an illustration of the effect of a change in the energy balance, a 100 calorie reduction in intake, or a similar rise in expenditure, would lead to a 10% reduction in body weight in boys and girls in primary school, quite substantial. It is interesting to note that Cutler et al find that a "strikingly small" average daily increase in net energy intake of 150 calories is enough to explain the rise in obesity prevalence in the United States in the closing two decades of the twentieth century.

The effect on body weight of a small change in energy intake is inversely proportional to the increase in BMR per unit of weight and the level of physical activity PAL:

$$\frac{1}{p\beta}\Delta K$$

The effect on bodyweight of a small change in the level of physical activity is more complicated. It depends on the level of calorie intake, the increase in BMR per unit of weight, and the PAL before the change.

$$-\frac{K}{p^2\beta}\Delta p$$

Trajectory of change in body weight following calorie increase

1. The dose response function provides results in terms of steady state. It tells us that if daily intake of calories changes by x, weight will eventually change by y. It tells us nothing about the timescale over which these effects come in or their trajectory.

2. It is possible to say something about the trajectory but we need an additional piece of information. There is a result [somewhere] that 7500 cals in excess of normal requirements corresponds to an increase of one kg in bodyweight.

3. As an individual increases intake by a given amount each day, normal requirements in terms of BMR will gradually rise with the result that the extra calories available to add to weight diminish over time.

4. An example will illustrate. A boy of 11 has an energy requirement of

   (658 + 17.7*weight in kgs)*1.56,

   Where 1.56 is the PAL, the physical activity level. The typical body weight would be about 41 kg. So the total daily energy requirement would be about 2080.

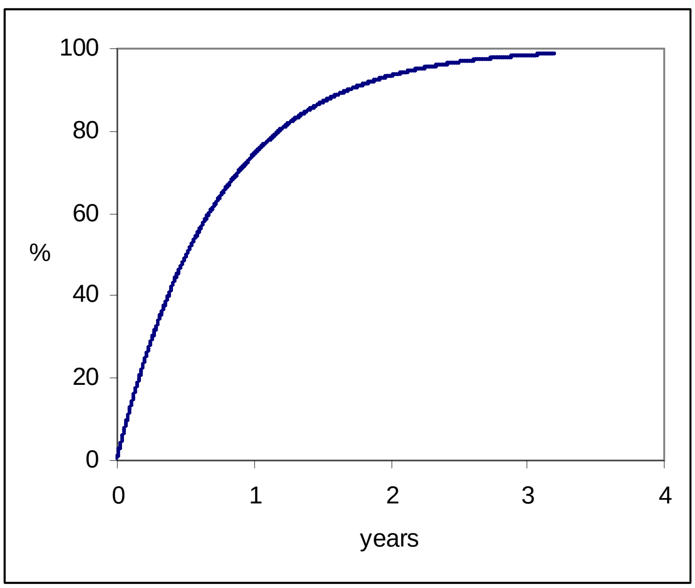
5. Suppose the daily calorie intake rises by 20 calories. Each excess calorie adds 1/7500 kg. So the first day's extra calories will add 0.002667 kgs to body weight. The second day, his weight has increased by that amount, so his requirement for energy rises, by 0.074 calories. But that means that of the 20 calories, only 19.926 are

available to increase weight further. By a succession of such steps, we can trace the trajectory of weight gain over time. The position after a year is as follows:

Time taken to reach eventual weight increase			
	additional calories	additional weight kg	additional requirement cals
day			
1	20	0.002667	0.073574
2	19.9	0.002657	0.073303
364	5.24	0.000700	0.019307
365	5.23	0.000697	0.019236
total	4020	0.54	14.8
eventual weight gain		0.724896	
proportion of weight gain within one year		74%	

6. Because body weight rises, the "normal requirement" for calories rises. As a result after a year only 5 of the extra 20 cals are still contributing to increasing weight. The weight gain after a year is about 0.54 kgs, 74% of the eventual gain of 0.72 kgs.

7. The chart below shows the trajectory. Virtually all of the effect has come through in three years.



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