https://doi.org/10.1017/S0007114598001251 Published online by Cambridge University Press

Invited commentary

Energy requirements assessed using the doubly-labelled water method

Energy requirements of animals and man were originally determined in intake–balance studies, measuring the energy intake to maintain energy balance. Nowadays energy requirements are preferably determined by measuring energy expenditure. During growth, energy expenditure is combined with a figure for energy deposition. The reasons for the switch from intake to expenditure measurements are twofold: energy intake measurements are difficult to perform unless all food is provided for and it is difficult to get evidence that intake really meets requirements, especially in large organisms where energy intake is relatively low compared with the energy stores of the body; and the measurement of body composition is relatively inaccurate compared with daily energy turnover. In a human subject we can, at best, measure the body energy stores ± 1 kg, equivalent to ± 38 MJ, compared with a daily energy turnover for an adult of 8–12 MJ. Energy expenditure measurements are easier to perform since the development and application of the doubly-labelled water technique. The estimation of energy requirements in free-living red deer in this issue (Haggarty *et al.* 1998) is a good example of this approach.

The doubly-labelled water technique for the measurement of energy expenditure was developed in the 1950s. In the late 1970s several groups started to use the technique in small animals, and in another 10 years it was used in human subjects. Validation studies in mammals, including man, and birds show algebraic errors around 1 % with a mean deviation of up to 6 % (Speakman, 1997), indicating its value for the assessment of energy requirements. The advantage is minimal interference with the subject and the consequent applicability in real-life conditions. A disadvantage is the technically difficult sample analysis. However, samples can be sent to a specialized laboratory to be analysed. Application in animals focused on energy budgets in free-living birds to understand energy constraints on successful breeding at different stages of the breeding cycle. Subsequently, research was extended to the relationship between energy requirements and food supply in other species, and conditions to understand constraints to habitat choice and survival. In animal husbandry the focus is on the efficiency of (outdoor) production conditions. In human nutrition the applications are manifold, from the energy requirements in preterm infants, growing children, lactating mothers and old people to special circumstances like disease and extremes of physical activity.

Fundamental issues like the existence of an energetic ceiling were triggered by the application of the doubly-labelled water method. ‘Why are sustained energy budgets of humans and other vertebrates limited to not more than about seven times resting metabolic rate? The answer to this question has potential applications to growth rates, foraging ecology, biogeography, plant metabolism, burn patients and sports medicine’ (Hammond & Diamond, 1997). The method has become a gold standard for the validation of techniques, not only to measure food intake but also for the assessment of physical activity. Techniques like heart-rate monitoring and ambulatory accelerometry are potentially promising for the assessment of patterns of physical activity, while doubly-labelled water results in an overall estimate. Eventually the technique should allow us to get hard evidence for debates like whether the human obesity epidemic is caused by gluttony or sloth (Prentice & Jebb, 1995). Are we really eating less, knowing that we tend to under-report food intake the more we are told we should not eat too much, or are we getting below an optimal level of physical activity for the maintenance of energy balance?

Haggarty *et al.* (1998) concluded from the data on energy expenditure in free-living red deer that energy requirements were 20 % higher than recommended intake for animals kept outdoors, and one-third higher than the value for animals kept indoors. Interestingly, the data for free-living red deer are in the range of energy expenditure in man. Fig. 1 shows energy expenditure measured using doubly-labelled water for the red deer and for man. Human data are from our laboratory, excluding the following characteristics: age < 20 and > 50 years, an intervention

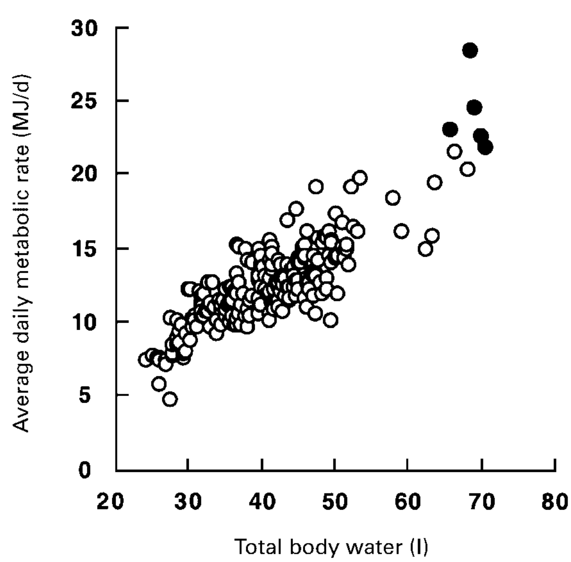

Fig. 1. Average daily metabolic rate as a function of total body water in 226 human subjects (○; Westerterp (In the Press)) and five free-living red deer (●; Haggarty *et al.* (1998)).

in energy intake, an intervention in physical activity including athletic performance, pregnancy, lactation and disease (Westerterp, 1998). Energy expenditure is plotted against total body water, available for both species, as a measure for metabolic active body mass. When a free-living mammal close to the body size of man has a comparable level of energy turnover, i.e. a comparable level of physical activity, it might indicate that we are not as inactive as often suggested. As such, the data bring us a step further in the mentioned debate on gluttony or sloth.

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References

Haggarty P, Robinson JJ, Ashton J, Milne E, Adam CL, Kyle CE, Christie SL & Midwood AJ (1998) Estimation of energy expenditure in free-living red deer (*Cervus elaphus*) with the doubly-labelled water method. *British Journal of Nutrition* **80**, 263–272.

Hammond KA & Diamond J (1997) Maximal sustained energy budgets in humans and animals. *Nature* **386**, 457–462.

Prentice AM & Jebb SA (1995) Obesity in Britain: gluttony or sloth? *British Medical Journal* **311**, 437–439.

Speakman JR (1997) *Doubly Labelled Water, Theory and Practice.* London: Chapman & Hall.

Westerterp KR (1998) Physical activity and obesity. *International Journal of Obesity* (In the Press).