ENERGY BALANCE AND THE NATURE OF GROWTH IN LOW BIRTHWEIGHT INFANTS

R. K. Whyte, J. C. Sinclair, and H. S. Bayley

Department of Pediatrics, McMaster University, Hamilton and the Department of Nutrition, University of Guelph, Guelph, Ontario, Canada

Human milk, either from milk banks or as milk expressed by the baby’s own mother, is often considered the feed of first preference for low birthweight infants. Infant formulas ("preterm formulas") are now available which have been designed to address the theoretical nutritional needs of growing low birthweight infants, and unlike previous formulas there is a deliberate departure in their design from the composition of human milk. A number of studies have shown that infants fed with banked human milk gain weight more slowly than do the infants fed with a "regular" 2.8 mJ/L (20 kcal/oz) commercial formula (1,2,3,4) and that the advantage in weight gain is even more striking when infants fed with 3.5 mJ/L (24 kcal/oz) formulas are compared to those fed with banked human milk (4,5,6). It has been demonstrated that in many of these studies the methods used for collecting human milk for banking resulted in a banked milk of exceptionally low nutrient content (5,6), and feedings with mother's own expressed breast milk gave rates of weight gain comparable to those of infants fed with regular formula (3). Nevertheless, low birthweight infants fed with high-energy, protein and mineral containing "preterm" formulas appear to experience much greater weight gains than do infants fed with their own mother's expressed breast milk.

It has been recognized for some time that a rapid gain in weight cannot be assumed to be indicative of rapid growth of appropriate composition. In some of the earlier studies of different protein levels in infant feeding (1,4) high rates of weight gain were associated with high protein intakes: later these high rates of weight gain were attributed to excessive gains of salt and water (8,9). Comparisons of gains in body weight are best qualified with measurements of associated changes in body composition.

Body composition is best measured by direct mass measurements of body components thought to be constantly related to the size of various compartments of the composition of the body, an example being the measurement of whole body potassium by external whole body ⁴₀ K counting (10). None of these direct techniques are accurate enough for measurements of very small infants. Dilutional techniques are becoming more available for use in low birthweight infants now that stable isotope techniques (11,12) are replacing radio-isotope dilution techniques (13), but volumes of distribution do not always measure the expected compartmental volumes, and true verification data for many of these
techniques is lacking. Balance techniques, which are only applicable for the measurement of the composition of growth, have been used extensively in studies of low birthweight infants. The technique involves a number of assumptions described below; like all balance techniques there is a tendency towards overestimation of nutrient retentions (14).

The basis of the technique and its inherent assumptions are these. The rate of energy storage is determined by measuring rates of energy intake, excretion and expenditure, and subtracting the latter two values from the former. Nitrogen balance is established by subtracting excretion from intake. Atwater's values for the heats of combustion of protein, carbohydrate and fat (respectively 24, 16 and 39 kJ/g) are assumed, as is the value of 6.25 g of protein for every gram of stored nitrogen (15). The contribution of carbohydrate storage to the rate of energy storage in the growing fetus is very small (0.02% of the total energy stored by the fetus (16)), and so it can be ignored in the calculations. From these assumptions the following equations are derived:

\[ \text{% Protein} = \frac{g \text{ N ret} \times 6.25 \times 100}{g \text{ weight gain}} \]
\[ \text{% Fat} = \frac{(\text{Energy stored} - (g \text{ N ret} \times 0.147)) \times 100}{g \text{ weight gain} \times 39} \]
\[ \text{% Water & minerals} = 100 - \text{% Protein} - \text{% Fat} \]

Where 'g N ret' is the daily rate of nitrogen retention in mg/d and where daily energy storage and weight gain are expressed as kJ/d and g/d respectively.

Protein growth is at least partly representative of growth of the lean body mass, and is associated with the growth of the body cell mass and with intracellular water. Lipid growth is distributed between central nervous tissue (1%), the structural fats of the body organs (19%), and as storage fat in adipose tissue (80%) (17). Presumably most of the variation in the accumulation of body salt and water is accommodated in the extravascular space.

From estimates of the fetal rate of weight gain and its composition (18) it can be calculated that at 34 weeks gestation the rate of energy accretion is about 8 kJ of energy and about 22 mg of nitrogen per gram of weight gain, which therefore consists of about 17% fat, 14% protein and 69% minerals and water. The term infant in the first six weeks of life has a much higher energy accretion (19), consisting of some 20 kJ of energy and 18 mg of nitrogen per gram of weight gain, which therefore consists of 42% fat, 11% protein and 52% minerals and water.

We conducted a study of the energy balance of growing low birthweight infants of gestational ages ranging from 27 to 34 weeks (20). Nine infants were fed with their own mother's expressed breast milk, and nineteen were fed with a 2.8 mJ/L (20 kcal/oz) formula (figure 1). Both groups received similar gross intakes of nitrogen and energy (mean values 423 mg/(kg.d) and 529 kJ/(kg.d) respectively. We showed that energy digestibility and metabolizability was similar between the two feeds (89% and 86% of gross intake respectively). Although metabolizable energy intake was almost exactly the same for the two groups, the rate of energy expenditure was significantly lower in the human milk fed infants. As a result, the rate of energy storage was slightly greater in the human milk fed infants. 'As rates of weight gain were similar, the rate of energy...